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(54) **Internal combustion engine control methods and control devices therefor**

(57) Embodiments of the present invention may include an internal combustion engine (1) equipped with a blow-by gas circulating means and a control means (40). An intake pipe (31A) is connected to the engine (1), and blow-by gas piping (12) for circulating blow-by gas to the engine (1) is connected to the intake pipe (31A). An internal combustion engine (1) control method includes an environmental condition determination step and a forcible blow-by gas temperature rising step. In the environmental condition determination step, the control means (40) determines whether or not the engine (1) is in an environmental condition in which ice can be generated at a joining portion between the blow-by gas piping (12) and the intake pipe (31A) based at least on a temperature of intake air taken-in through the intake pipe (31A). When it is determined that the engine (1) is in an environmental condition in which ice is generated, the control means (40) changes the operational condition of the engine (1) such that a temperature of the blow-by gas increases in the forcible blow-by gas temperature rising step.

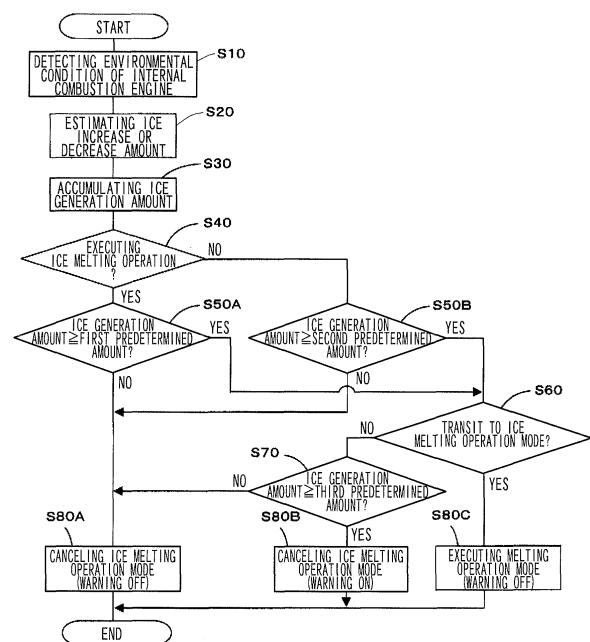


FIG. 2

## Description

**[0001]** This application claims priority to Japanese patent application serial number 2012-253021, the contents of which are incorporated herein by reference.

**[0002]** Embodiments of the present invention relate to control methods and controllers for an internal combustion engine equipped with a blow-by gas circulating mechanism. Blow-by gas is an air/fuel mixture leaking into a crankcase through a gap between a piston and a cylinder in an engine or the like. The circulating mechanism has, for example, piping for returning the blow-by gas from the crankcase into an intake pipe.

**[0003]** In an internal combustion engine, pressure in a combustion chamber increases during combustion stroke. As a result, a minute amount of half-combusted gas may leak from the combustion chamber into the crankcase through the gap between a piston and a cylinder. The internal combustion engine may be provided with a blow-by gas circulating device. The circulating device returns the half-combusted gas (blow-by gas) from the crankcase into an intake pipe without releasing the half-combusted gas into the atmosphere. As a result, the blow-by gas is mixed with fresh intake air, and then may be combusted in the internal combustion engine.

**[0004]** The blow-by gas is a half-combusted gas, so that it contains H<sub>2</sub>O (in the form of steam) at a temperature higher than that of the atmospheric air. The fresh intake air is at a lower temperature than the blow-by gas. In particular, the intake air is at low temperature in winter, etc., when the temperature of the atmospheric air is equal to or lower than the freezing point. At a joint portion where the intake air and the blow-by gas are mixed with each other, there is the possibility of the generation of ice or frost due to condensation. When ice or frost accumulates, it may cause adhesion between peripheral apparatuses or the flowing of ice or frost particles downstream. This may cause the malfunctioning of the throttle valve, turbo compressor, the internal combustion engine main body, etc.

**[0005]** Japanese Laid-Open Patent Publication No. 2010-285937 discloses a blow-by gas processing device for an internal combustion engine. When it is determined that there is a high possibility of ice condensation from water in the blow-by gas piping, the blow-by gas processing device circulates low pressure EGR gas from the piping of a low-pressure gas EGR (exhaust gas re-circulation device). The piping of the low-pressure gas EGR connects to the blow-by gas piping. The EGR gas heats the portion in the vicinity of a connection portion between the blow-by gas piping and the low-pressure EGR piping. Thereby, the ice generated in the vicinity of the connection portion is melted.

**[0006]** Japanese Laid-Open Patent Publication No. 2009-24514 discloses a PCV valve controller. In the PCV valve controller, a PCV valve provided for the opening/closing of blow-by gas piping is equipped with an electric heater. Electricity is supplied to the electric heater to

melt the ice generated in the vicinity of the PCV valve. The electricity is supplied until a target quantity of heat is attained, and without having to produce excess electricity.

**[0007]** In the related-art technique disclosed in Japanese Laid-Open Patent Publication No. 2010-285937, the ice is melted by using the EGR gas which is at a higher temperature than the blow-by gas. However, in some operational conditions, it is desirable for the internal combustion engine not to circulate the EGR gas. Thus, the above-mentioned technique is not always to be utilized. In the above-mentioned technique, it is indispensable for the blow-by gas piping and the low-pressure EGR piping to join each other on the front side of the intake passage. Thus, in some cases, there is no space available for an installation of the technique in an engine room, in which a plurality of apparatuses and piping are packed.

**[0008]** The related-art technique disclosed in Japanese Laid-Open Patent Publication No. 2009-24514 involves the PCV valve and the electric heater. The PCV valve is of a rather high cost and large size. To melt the ice generated at the joining portion, it is necessary to arrange the large PCV valve in the vicinity of the joining portion. Thus, in some cases, there is no space available for the installation of such technique in an engine room.

**[0009]** Therefore, there is need in the art for a control method and a controller for an internal combustion engine in which it is easy to install in an engine room. The control method or controller is configured to prevent the accumulation of ice at a joining portion where fresh intake air and blow-by gas join each other. The control method or controller is configured to help to further simplify such a structure.

**[0010]** According to an aspect of the invention, an internal combustion engine is equipped with a blow-by gas circulating means (circulating mechanism) and a control means (controller). An intake pipe is connected to the internal combustion engine, and blow-by gas piping for circulating blow-by gas to the internal combustion engine is connected to the intake pipe. An internal combustion engine control method includes an environmental condition determination step and a forcible blow-by gas temperature rising step. In the environmental condition determination step, the control means determines whether or not the engine is in an environmental condition in which ice can be generated at a joining portion between the blow-by gas piping and the intake pipe based at least on the temperature of intake air taken-in through the intake pipe. When it is determined that the engine is in an environmental condition in which ice is generated, the control means changes the operational condition of the internal combustion engine such that a temperature of the blow-by gas increases in the forcible blow-by gas temperature rising step.

**[0011]** Normally, an intake air temperature detection means for detecting the temperature of the intake air of the internal combustion engine has already been provided.

ed. Thus, to achieve the present control method, there is typically no need to provide an intake air temperature detection means. In the case where no intake air temperature detection means has already been provided, a relatively small intake air temperature detection means can be easily mounted to the intake pipe.

**[0012]** In the present control method, it is only necessary to change the operational condition of the internal combustion engine such that the temperature of the blow-by gas increases. Thus, in the present control method, there is no need to provide EGR piping, a heater, etc. Thus, the member for achieving the present control method can be easily mounted in an engine room or the like, and is of a simple construction. According to the present control method, it is possible to prevent the accumulation of ice generated at the joining portion where the fresh intake air and the blow-by gas join each other.

**[0013]** According to another aspect of the invention, in the environmental condition determination step, the control means may estimate an ice increase or decrease amount at the joining portion based at least on the temperature of the intake air. The control means may estimate an ice generation amount through accumulation of the estimated ice increase or decrease amount. When it is determined that the estimated ice generation amount is equal to or greater than a predetermined amount, the control means may determine that the engine is in an environmental condition in which ice is generated. Thus, it is possible to determine more appropriately whether or not the engine is in an environmental condition in which ice is generated.

**[0014]** According to another aspect of the invention, in the environmental condition determination step, the control means may estimate the ice increase or decrease amount based on the temperature of the intake air and the temperature of the blow-by gas. Alternatively, it can be based on the temperature of the intake air, vehicle speed, and either a speed gear stage or speed-change stage.

**[0015]** Thus, it is possible to more appropriately estimate the ice increase or decrease amount at the joining portion. Normally, an intake air temperature detection means, a vehicle speed detection means, and a vehicle speed gear stage detection means are often already provided in the vehicle. Thus, any newly required detection means would be a blow-by gas temperature detection means. The temperature detection means is relatively small, and can be easily mounted to the blow-by gas piping. Thus, the member for achieving the present control method is of a simple construction and easy to mount in the engine room or the like.

**[0016]** In the environmental condition determination step, the control means may determine the state of a region when estimating the ice increase or decrease amount at the joining portion. A region is a frost generation region where frost is generated. A region is a water generation region where water droplets are generated. A region is a dry region where neither frost or water drop-

lets are generated. The regions are determined based on the condition of the temperature of the intake air and the temperature of the blow-by gas. Alternatively, the regions are determined based on the condition of the temperature of the intake air, the vehicle speed, and either the speed gear stage or the speed-change stage. The control means may estimate the ice increase or decrease amount at the joining portion according to a continuation time in the determined region. This makes it possible to more appropriately estimate the ice increase or decrease amount at the joining portion.

**[0017]** In the forcible blow-by gas temperature rising step, the control means may increase the amount of fuel injected into a combustion chamber of the engine and delay ignition timing of the fuel. Alternatively, the control means may increase an amount of fuel injected into the combustion chamber and reduce an amount of the intake air supplied to the combustion chamber. As a result, it is possible to appropriately increase the temperature of the blow-by gas without increasing the output power of the internal combustion engine.

**[0018]** According to another aspect of the invention, when the vehicle speed is equal to or greater than a predetermined speed, or when a load of the internal combustion engine is equal to or greater than a predetermined load, the control means may temporarily suspend the execution of the forcible blow-by gas temperature rising step. That is, when it is determined that the engine is in an operational condition in which the forcible blow-by gas temperature rising step should not be executed, the control means temporarily suspends the forcible blow-by gas temperature rising step. This helps to achieve an enhancement in safety.

**[0019]** According to another aspect of the invention, the control device controls the internal combustion engine so as to achieve at least one of the above-mentioned control methods. Thus, the control device is of a simple construction and can be easily mounted in the engine room.

**[0020]** Additional objects, features, and advantages, of the present invention will be readily understood after reading the following detailed description together with the claims and the accompanying drawings, in which:

FIG. 1 is a schematic view of a control system for an internal combustion engine;

FIG. 2 is a flowchart for the first procedure for a controller in the internal combustion engine;

FIG. 3 is a graph of intake air temperature vs. blow-by gas temperature in the first procedure;

FIG. 4 is a graph of elapsed time vs. amount of ice generation for showing accumulation of ice and/or a melting of accumulated ice;

FIG. 5 is a flowchart for a second procedure for the controller;

FIG. 6 is a graph of intake air temperature vs. the speed of a vehicle in 6th gear;

FIG. 7 is a graph of the intake air temperature vs.

the speed of a vehicle in 5th gear; and  
FIG. 8 is a graph of the intake air temperature vs.  
ice generation amount in the second procedure.

**[0021]** Each of the additional features and teachings disclosed above and below may be utilized separately or in conjunction with other features and teachings to provide improved control methods and controllers. Representative examples of the present invention, which utilize many of these additional features and teachings both separately and in conjunction with one another, will now be described in detail with reference to the attached drawings. This detailed description is merely intended to teach a person of ordinary skill in the art further details for practicing preferred aspects of the present teachings and is not intended to limit the scope of the invention. Only the claims define the scope of the claimed invention. Therefore, combinations of features and steps disclosed in the following detailed description may not be necessary to practice the invention in the broadest sense, and are instead taught merely to particularly describe representative examples of the invention. Moreover, various features of the representative examples and the dependent claims may be combined in ways that are not specifically enumerated in order to provide additional useful configurations of the present teachings.

**[0022]** In the following, an embodiment of the present invention will be described. As shown in FIG. 1, an internal combustion engine 1 consists, for example, of a diesel engine, and has an engine main body 10. The rotational speed of an output shaft in the engine main body 10 is changed by a transmission 20. The internal combustion engine 1 is provided with a turbo charger 30, etc. In an intake passage of the internal combustion engine 1, there is provided an air cleaner (not shown), an upstream side intake pipe 31A, a compressor of the turbo charger 30, and a downstream side intake pipe 32A in that order from the upstream side. The downstream side intake pipe 32A is provided with a throttle valve (diesel throttle) (not shown). The upstream side intake pipe 31A and the downstream side intake pipe 32A constitute the intake pipe.

**[0023]** In an exhaust passage of the internal combustion engine 1, there is provided an upstream side exhaust pipe 32B, a turbine of the turbo charger 30, a downstream side exhaust pipe 31B, and a post-exhaust processing device (not shown) in that order from the upstream side. An exhaust gas from the engine main body 10 is discharged into the upstream side exhaust pipe 32B to rotate a turbine impeller 33B in the turbine. As a result, a compressor impeller 33A in the compressor connected with the turbine impeller 33B rotates. The compressor impeller 33A compresses the intake air taken in through the upstream side intake pipe 31A. The compressor impeller 33A supplies the compressed air to the engine main body 10 through the downstream side intake pipe 32A. The turbo charger 30 is equipped with a variable valve mechanism (not shown).

**[0024]** When, pressure in a combustion chamber of the engine main body 10 increases during combustion stroke, a minute amount of half-combusted gas may leak into a crankcase through a gap or the like between a piston and a cylinder. The leaked, half-combusted gas (blow-by gas) may accumulate in the engine main body 10. There is provided blow-by gas piping 12 for returning the blow-by gas accumulated in the engine main body 10 to the upstream side intake pipe 31A. The blow-by gas piping 12 connects an interior of the engine main body 10 to the upstream side intake pipe 31A.

**[0025]** Provided in the upstream side intake pipe 31A is an intake air temperature detection means (sensor) 51 for detecting the temperature of the intake air. The blow-by gas piping 12 is provided with a blow-by gas temperature detection means (sensor) 52 for detecting the temperature of the blow-by gas. The blow-by gas temperature detection means 52 is installed in the vicinity of the joining portion (connection portion) between the blow-by gas piping 12 and the upstream side intake pipe 31A. In a first procedure (described in a first embodiment), the blow-by gas temperature detection means 52 is necessary. In a second procedure (described in a second embodiment), the blow-by gas temperature detection means 52 is not needed.

**[0026]** Detection signals sent by the intake air temperature detection means 51 and the blow-by gas temperature detection means 52 are input to a controller 40. Based on the detection signals, the controller 40 detects or calculates the temperature of the intake air taken in through the upstream side intake pipe 31A and the temperature of the blow-by gas. A warning means (device) 53 such as a lamp or a buzzer is connected to the controller 40. The warning means 53 can output a warning signal for a driver of the vehicle in which the internal combustion engine is mounted.

**[0027]** Various kinds of detection means (not shown) such as a throttle opening detection means (sensor) and a crank angle detection means (sensor) are connected to the controller 40. The controller 40 detects or determines an operational condition of the internal combustion engine 1 based on the signals from the detection means (sensors), and calculates a fuel injection amount, a fuel injection timing, etc. based on the operational condition. The controller 40 controls an injector 71 so as to inject a calculated injection amount fuel with calculated injection timing.

**[0028]** The blow-by gas piping 12 may be provided with a PCV 72. The PCV is a valve configured to control an opening and closing of the blow-by gas piping 12. The PCV 72 can be controlled by a signal transmitted from the controller 40. The PCV valve 72 may be omitted. A blow-by gas circulating means (device) includes the blow-by gas piping 12, and may include the PCV valve 72.

**[0029]** The controller 40 may be electrically connected to a vehicle speed detection means (sensor) 56, a speed gear stage detection means (sensor) 55, and an AT controller 60. The vehicle speed detection means 56 detects

a speed of the vehicle. The speed gear stage detection means 55 detects a speed gear stage when a transmission 20 is a manual transmission. The AT controller 60 outputs speed-change information when the transmission 20 is an automatic transmission. In the second embodiment, the controller 40 receives signals sensed by the vehicle speed detection means 56, the speed gear stage detection means 55, and the AT controller 60, and utilizes them. In the first embodiment, the controller 40 does not require these signals.

**[0030]** A first procedure performed by the controller 40 according to the first embodiment will be described with reference to FIGS. 2 to 4. The controller 40 utilizes the signals input from the intake air temperature detection means 51 and the blow-by gas temperature detection means 52. The controller 40 does not require the signals sent by the vehicle speed detection means 56 and the speed gear stage detection means 55 (or the AT controller 60) in order to operate.

**[0031]** At predetermined time intervals, for example, the controller 40 executes the processes shown in the flowchart of FIG. 2. A storage means of the controller 40 previously stores a program for executing the processes outlined below.

**[0032]** In step S10, the controller 40 detects an environmental condition of the internal combustion engine 1 and the procedure advances to step S20. In step S10, the controller 40 detects the intake air temperature of the upstream side intake pipe 31A based on the detection signal from the intake air temperature detection means 51. The controller 40 detects the temperature of the blow-by gas in the blow-by gas piping 12 through the blow-by gas temperature detection means 52 in the vicinity of the joining portion. The joining portion typically is located between the blow-by gas piping 12 and the upstream side intake pipe 31A.

**[0033]** In step S20, the controller 40 estimates the ice increase or decrease amount at the joining portion located between the blow-by gas piping 12 and the upstream side intake pipe 31A. This estimation is based on the environmental condition detected. Afterwards, the procedure advances to step S30. The storage means of the controller 40 may, for example, store the intake-air-temperature/blow-by-gas-temperature characteristics shown in FIG. 3. Based on the intake-air-temperature/blow-by-gas-temperature characteristics, the controller 40 determines the state of the following regions: region A, region B, and region C. The regions correspond to conditions defined by the intake air temperature and the blow-by gas temperature. The controller 40 estimates the ice increase or decrease amount according to the determined state of the region and the continuation time in that region.

**[0034]** Region C is a frost generation region where frost is generated at the joining portion. When it is determined that the condition corresponds to region C, the controller 40 estimates the ice increase amount in correspondence with the continuation time in region C. Region B is a water

generation region where water droplets are generated at the joining portion. When it is determined that the condition corresponds to region B, the controller 40 estimates the ice increase amount in correspondence with the continuation time in region B. Region A is a dry region where neither frost nor water droplets are generated at the joining portion. When it is determined that the condition corresponds to region A, the controller 40 estimates the ice decrease amount in correspondence with the continuation time in region A.

**[0035]** In step S30, the controller 40 accumulates the ice increase or decrease amount estimated in step S20 to estimate the ice generation amount (accumulated generation amount), and the procedure advances to step S40. It is to be assumed that the ice generation amount is not less than zero. It is to be assumed that in the case where the decrease amount is accumulated, the lower limit is zero.

**[0036]** In step S40, the controller 40 determines whether or not an ice melting operation mode (forcible blow-by gas temperature rising step) is being presently executed. When the ice melting operation mode is being executed (YES in step S40), the procedure advances to step S50A. When the ice melting operation mode is not being executed (NO in step S40), the procedure advances to step S50B.

**[0037]** In step S50A, the controller 40 determines whether or not the ice generation amount is equal to or greater than a first predetermined amount. When the ice generation amount is equal to or greater than the first predetermined amount (YES in step S50A), the procedure advances to step S60. When the ice generation amount is less than the first predetermined amount (NO in step S50A), the procedure advances to step S80A.

**[0038]** In step S50B, the controller 40 determines whether or not the ice generation amount is equal to or greater than a second predetermined amount. This second predetermined amount is larger than the first predetermined amount (the second predetermined amount > the first predetermined amount; see FIG. 4). When the ice generation amount is equal to or greater than the second predetermined amount (YES in step S50B), the procedure advances to step S60. When the ice generation amount is less than the second predetermined amount (NO in step S50B), the procedure advances to step S80A. Steps S10 to S50A, S50B correspond to the environmental condition determination steps.

**[0039]** In step S60, the controller 40 determines whether or not transition to the ice melting operation mode is possible. For example, the controller 40 obtains the load of the internal combustion engine 1 from the output RPM and/or the throttle opening, etc. of the internal combustion engine 1. The controller 40 determines whether or not the load obtained is equal to or less than a predetermined load. Alternatively, the controller 40 detects the speed of the vehicle. The controller 40 determines whether or not the vehicle speed detected is equal to or less than a predetermined speed. In the case where the ve-

hicle speed is utilized, the vehicle speed detection means 56 is needed. When the load is equal to or less than the predetermined load or when the vehicle speed is equal to or less than the predetermined speed, etc., the controller 40 determines that transition to the ice melting operation mode is possible. When it is determined that transition to the ice melting operation mode is possible (YES in step S60), the procedure advances to step S80C. When it is determined that transition to the ice melting operation mode is not possible (NO in step S60), the procedure advances to step S70.

**[0040]** In step S70, the controller 40 determines whether or not the ice generation amount is equal to or greater than a third predetermined amount (the third predetermined amount > the second predetermined amount; see FIG. 4). When the ice generation amount is equal to or greater than the third predetermined amount (YES in step S70), the procedure advances to step S80B. When the ice generation amount is less than the third predetermined amount (NO in step S70), the procedure advances to step S80A.

**[0041]** In step S80A, the controller 40 cancels the ice melting operation mode. The mode is restored to normal control. The controller 40 stops the output of a warning from the warning means 53, whereby the processing is completed.

**[0042]** In step S80B, the controller 40 cancels the ice melting operation mode. The mode is restored to normal control. The controller 40 causes a warning to be output from the warning means 53 in order to inform the driver of the progress of the accumulation of ice. Then, the processing is completed.

**[0043]** In step S80C, the controller 40 executes the ice melting operation mode. The controller 40 stops the output of a warning from the warning means 53 to thereby complete the processing. When executing the ice melting operation mode, the controller 40 increases the temperature of the blow-by gas without increasing the output of the internal combustion engine 1. The ice melting operation mode executed in step S80C corresponds to the forcible blow-by gas temperature rising step.

**[0044]** When the internal combustion engine is a diesel engine, the controller 40 forcibly increases the amount of fuel injected by the injector 71 of FIG. 1, and forcibly delays the fuel injection timing. As a result, the ignition timing in the combustion chamber is delayed. Alternatively, the controller 40 forcibly increases the amount of fuel injected by the injector 71, and forcibly reduces the amount of intake air supplied to the combustion chamber. For example, the variable valve of the turbo charger 30 is controlled to forcibly reduce the supercharging pressure.

**[0045]** When the internal combustion engine is a gasoline engine which is to be controlled by theoretical air fuel ratio, the throttle opening, for example, is controlled. As a result, the intake air amount is forcibly increased, and the amount of fuel injected is increased. At the same time, the ignition time is forcibly delayed to delay the ig-

niton timing in the combustion chamber.

**[0046]** FIG. 4 shows an example of the above control condition. During the period up to time T1, when it is determined that the engine is in region B (the water generation region) or region C (the frost generation region), as shown in FIG. 3, the controller 40 accumulates the increase amounts obtained according to the continuation time thereof to increase the ice generation amount. In FIG. 3, for example, the ice generation amount is increased at point P1.

**[0047]** When it is determined that the ice generation amount has become equal to or greater than the second predetermined amount at time T1 and that transition to the ice melting operation mode is possible, the controller 40 starts the execution of the ice melting operation mode. In the ice melting operation mode, the temperature of the blow-by gas is increased without increasing the output power of the internal combustion engine. In FIG. 3, for example, the condition is changed from point P1 to point P2.

**[0048]** When the temperature of the blow-by gas is increased, the controller 40 determines that the engine is in region A (the drying region) in FIG. 3. In this case, the controller 40 accumulates the decrease amount according to the continuation time in region A to reduce the ice generation amount. In FIG. 4, for example, the ice generation amount decreases from time T1 to time T2.

**[0049]** When it is determined that the ice generation amount has become less than the first predetermined amount at time T2, the controller 40 cancels the execution of the ice melting operation mode. The mode is restored to normal control. In FIG. 3, for example, the condition is changed from point P2 to P1.

**[0050]** The ice generation amount increases during the period from time T2 to time T3. The controller 40 determines that the ice generation amount has become equal to or greater than the second predetermined amount at time T3. The controller 40 determines that transition to the ice melting operation mode is impossible. In this case, the controller 40 temporarily suspends the execution of the ice melting operation mode. FIG. 4 shows an example in which it has been determined that transition to the ice melting operation mode is impossible from time T3 onward.

**[0051]** The state in which the ice melting operation mode is suspended continues. The ice generation amount becomes equal to or greater than the third predetermined amount at time T4. In this case, the controller 40 causes the warning means 53 to output a warning from time T4 onward. Thus, the warning causes attention of the driver.

**[0052]** The second procedure for the controller 40 discussed with respect to the second embodiment will be described with reference to FIGS. 5 to 8. The controller 40 uses input signals from the intake air temperature detection means 51, the vehicle speed detection means 56, and the speed gear stage detection means 55 (or the AT controller 60). The controller 40 does not need the input

signal from the blow-by gas temperature detection means 52. In many cases, the intake air temperature detection means 51, the vehicle speed detection means 56, and the speed gear stage detection means 55 (or the AT controller 60) have already been provided. Thus, there is no need to provide a new detection means for the present control.

**[0053]** The flowchart of FIG. 5 (the second embodiment) has steps S22, S24A, and S24B instead of step S20 of the flowchart of FIG. 2 (the first embodiment). Like the flowchart of FIG. 2, the flowchart of FIG. 5 has step S10 and the steps from step S30 onward. In the following the second embodiment will be described centering on the differences between the first and second embodiments.

**[0054]** Referring to FIG. 5, the controller 40 detects the environmental condition of the internal combustion engine 1 in step S10, and the procedure advances to step S22. The controller 40 detects the intake air temperature of the upstream side intake pipe 31A based on the detection signal from the intake air temperature detection means 51. The controller 40 detects the speed of the vehicle based on the detection signal from the vehicle speed detection means 56. In the case of an MT vehicle, the controller 40 detects the speed gear stage based on the detection signal from the speed gear stage detection means 55. In the case of an AT vehicle, the controller 40 detects the speed-change stage based on speed-change information sent by the AT controller 60.

**[0055]** In step S22, the controller 40 determines whether or not the ice melting operation mode is being executed. When the ice melting operation mode is being executed (YES in step S22), the procedure advances to step S24B. When the ice melting operation mode is not being executed (NO in step S22), the procedure advances to step S24A.

**[0056]** In step S24B, the controller 40 estimates the ice decrease amount due to the ice melting operation mode and then the procedure advances to step S30. For example, data regarding the ice decrease amount according to the continuation time of the ice melting operation mode is stored in advance.

**[0057]** In step S24A, the controller 40 estimates the ice increase or decrease amount at the joining portion between the blow-by gas piping 12 and the upstream side intake pipe 31A by using a map as shown in FIG. 6, 7, or 8, and the procedure advances to step S30. As shown in FIGS. 6, 7, for example, the storage means of the controller 40 stores the intake air temperature/vehicle speed characteristics etc. for each speed gear stage. FIG. 6 shows the characteristics of a manual transmission in 6th gear. FIG. 7 shows the characteristics of a manual transmission in 5th gear. Reference to the manual transmission in the 1st through the 4th gears is omitted.

**[0058]** In connection with the intake air temperature/vehicle speed characteristics, there are shown regions such as region A, region B, region C1, and region C2.

Region A is, for example, a drying region. When the condition of the intake air temperature, the vehicle speed and the speed gear stage continues for  $n1$  minutes in region A, the ice decrease amount is estimated to be  $m1$  g. Region B is, for example, a steam generation region. When the condition of the intake air temperature, the vehicle speed and the speed gear stage continues for  $n1$  minutes in region B, the ice increase amount is estimated to be  $m2$  g. Region C1 is, for example, a light frost generation region. When the condition of the intake air temperature, the vehicle speed and the speed gear stage continues for  $n1$  minutes in region C1, the ice increase amount is estimated to be  $m3$  g. Region C2 is, for example, a heavy frost generation region. When the condition of the intake air temperature, the vehicle speed and the speed gear stage continues for  $n1$  minutes in region C2, the ice increase amount is estimated to be  $m4$  g ( $m4 > m3$ ).

**[0059]** The storage means of the controller 40 may store the intake air temperature/ice generation amount characteristics as shown in FIG. 8, alternatively. The controller 40 estimates the ice-increase or decrease amount from the characteristics. In the intake air temperature/ice generation amount characteristics as shown in FIG. 8, graph lines indicating different speed gear stages and vehicle speeds are stored in advance. Graph line G4n indicates the case where the vehicle is in the 4th gear and where the vehicle speed is 50 km/h. Graph line G5n indicates a case where the vehicle is in the 5th gear and where the vehicle speed is 60 km/h. Graph line G6n indicates a case where the vehicle is in the 6th gear and where the vehicle speed is 80 km/h.

**[0060]** For the intake air temperature/ice generation amount characteristics, there are previously stored graph lines indicating various speeds (e.g., 10, 20, 30, ... [km/h]) at the different speed gear stages (1st to 6th speed gear stages). It is possible to obtain the ice generation amount from the intake air temperature, the speed gear stage, and the vehicle speed. In FIG. 8, when the intake air temperature/ice generation amount characteristics continue for a predetermined period of time in the region where the ice generation amount is above zero, it is possible to obtain the ice increase amount. When the intake air temperature/ice generation amount characteristics continue for a predetermined period of time in the region where the ice generation amount is below zero, it is possible to obtain the ice decrease amount.

**[0061]** It is also possible for the storage means to store the intake air temperature/ice generation amount characteristics for each speed gear stage, setting graph lines for the intake air temperature/ice generation amount characteristics.

**[0062]** As in the first embodiment, in the second embodiment also, steps S10 to S50A, S50B correspond to the environmental condition determination steps. The processing from step S30 onward in the second embodiment is the same as that in the first embodiment, so a description thereof will be left out.

**[0063]** In the first embodiment, the newly required member for the processing procedures (control method) of the controller (control means) 40 is a blow-by gas temperature detection means of a relatively small size. In the second embodiment, no new member is required for the processing procedures (control method) of the controller (control means) 40. Thus, the member required for the processing by the controller 40 is of a simple construction and easy to mount in the engine. The processing by the controller 40 helps to appropriately suppress accumulation of ice generated at the joining portion where fresh intake air and blow-by gas join each other.

**[0064]** While the embodiments of invention have been described with reference to specific configurations, it will be apparent to those skilled in the art that many alternatives, modifications and variations may be made without departing from the scope of the present invention. Accordingly, embodiments of the present invention are intended to embrace all such alternatives, modifications and variations that may fall within the spirit and scope of the appended claims. For example, embodiments of the present invention should not be limited to the representative configurations, but may be modified, for example, as described below.

**[0065]** In the above description, the expressions: "greater than or equal to ( $\geq$ )," "less than or equal to ( $\leq$ )," "greater than ( $>$ )," "less than ( $<$ )," etc. may or may not be signs having an equal sign.

**[0066]** The values employed in the description of the above embodiments are only given by way of example, and should not be limited to the above values.

**[0067]** The control executed in the forcible blow-by gas temperature rising step is not restricted to the one described in connection with the present embodiment. Embodiments of the present invention may include an internal combustion engine (1) equipped with a blow-by gas circulating means and a control means (40). An intake pipe (31A) is connected to the engine (1), and blow-by gas piping (12) for circulating blow-by gas to the engine (1) is connected to the intake pipe (31A). An internal combustion engine (1) control method includes an environmental condition determination step and a forcible blow-by gas temperature rising step. In the environmental condition determination step, the control means (40) determines whether or not the engine (1) is in an environmental condition in which ice can be generated at a joining portion between the blow-by gas piping (12) and the intake pipe (31A) based at least on a temperature of intake air taken-in through the intake pipe (31A). When it is determined that the engine (1) is in an environmental condition in which ice is generated, the control means (40) changes the operational condition of the engine (1) such that a temperature of the blow-by gas increases in the forcible blow-by gas temperature rising step.

## Claims

1. An internal combustion engine (1) control method comprising:

an environmental condition determination step, in which a control means (40) determines whether or not the engine (1) is in an environmental condition in which ice can be generated at a joining portion between an intake pipe (31A) and a blow-by gas piping (12) based at least on a temperature of an intake air taken-in through the intake pipe (31A), wherein the intake pipe (31A) is connected to the engine (1), wherein the blow-by gas piping (12) connects the engine (1) to the intake pipe (31A) for circulating blow-by gas; and,

a forcible blow-by gas temperature rising step, in which the control means (40) changes an operational condition of the engine (1) such that a temperature of the blow-by gas increases, when it is determined that the engine (1) is in an environmental condition in which the ice can be generated at the joining portion.

2. The internal combustion engine (1) control method of claim 1, wherein in the environmental condition determination step, the control means (40) estimates an ice increase or decrease amount at the joining portion based at least on the temperature of the intake air, and wherein the control means (40) estimates an ice generation amount through accumulation of the estimated ice increase or decrease amount, and wherein the control means (40) determines that the engine (1) is in an environmental condition in which ice is generated when it is determined that the estimated ice generation amount is equal to or greater than a predetermined amount.

3. The internal combustion engine (1) control method of claim 2, wherein in the environmental condition determination step, the control means (40) estimates the ice increase or decrease amount based on the temperature of the intake air and the temperature of the blow-by gas, or based on the temperature of the intake air, a vehicle speed, and either a speed gear stage or speed-change stage.

4. The internal combustion engine (1) control method of claim 3, wherein in the environmental condition determination step, when estimating the ice increase or decrease amount at the joining portion, the control means (40) determines whether any of the following regions are generated: (C) a frost generation region where frost is generated, (B) a water generation region where water droplets are generated, and (A) a dry region where neither frost or water droplets are generated, wherein the regions are determined

based on the condition of the temperature of the intake air and the temperature of the blow-by gas, or based on the condition of the temperature of the intake air, the vehicle speed, and either the speed gear stage or the speed-change stage, wherein the control means (40) estimates the ice increase or decrease amount at the joining portion according to a continuation time in the determined region. 5

5. The internal combustion engine (1) control method of claim 1, 2, 3 or 4, wherein in the forcible blow-by gas temperature rising step, the control means (40) increases an amount of fuel injected into a combustion chamber of the engine (1), and delays ignition timing of the fuel, alternatively the control means (40) increases an amount of fuel injected into the combustion chamber, and reduces an amount of the intake air supplied to the combustion chamber. 10 15
6. The internal combustion engine (1) control method of claim 1, 2, 3, 4 or 5, wherein the control means (40) temporarily suspends an execution of the forcible blow-by gas temperature rising step when a vehicle speed is equal to or greater than a predetermined speed or when a load of the engine (1) is equal to or greater than a predetermined load. 20 25
7. A control device for controlling the internal combustion engine (1) so as to achieve the control method of claim 1, 2, 3, 4, 5 or 6. 30

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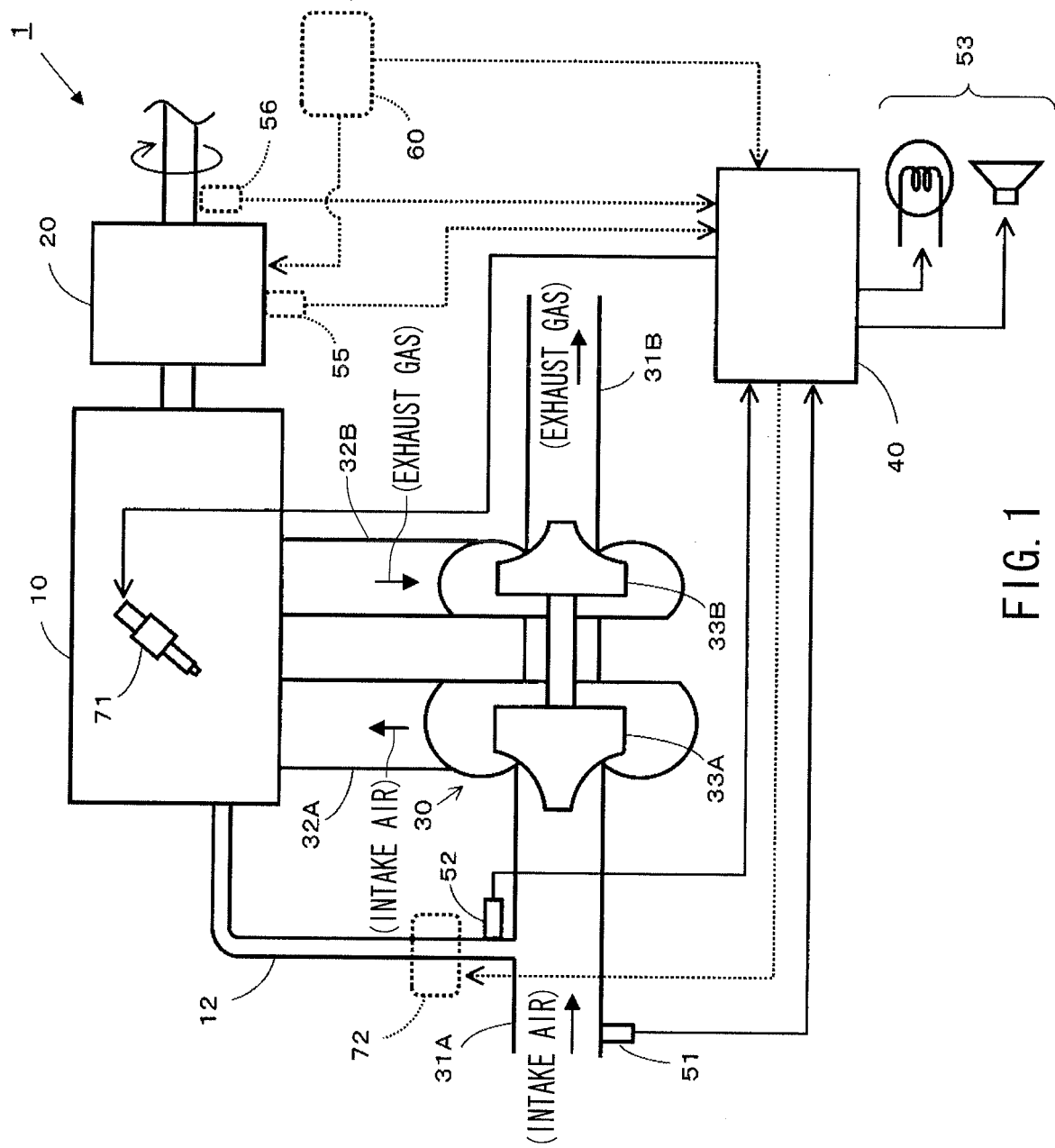


FIG. 1

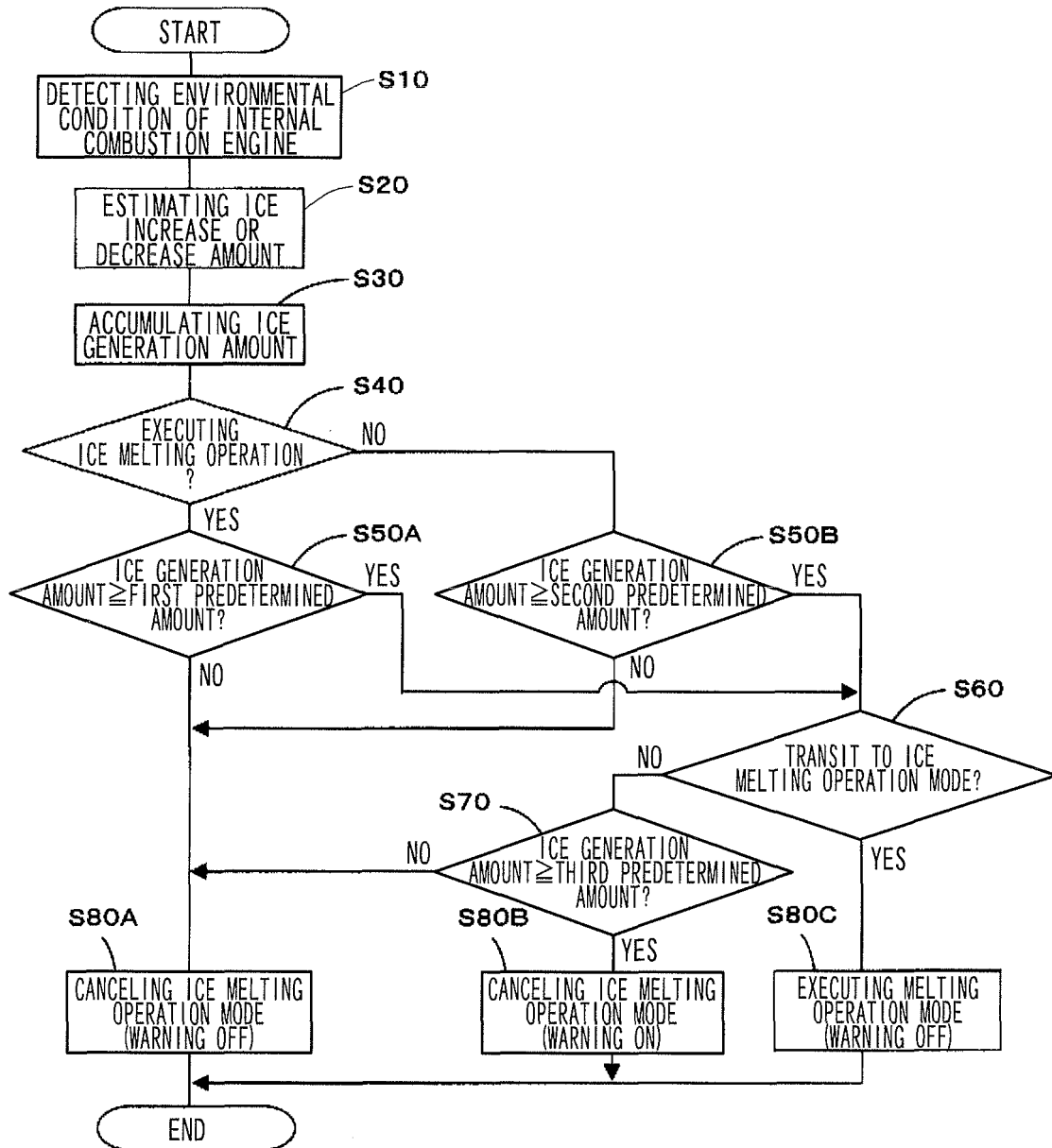


FIG. 2

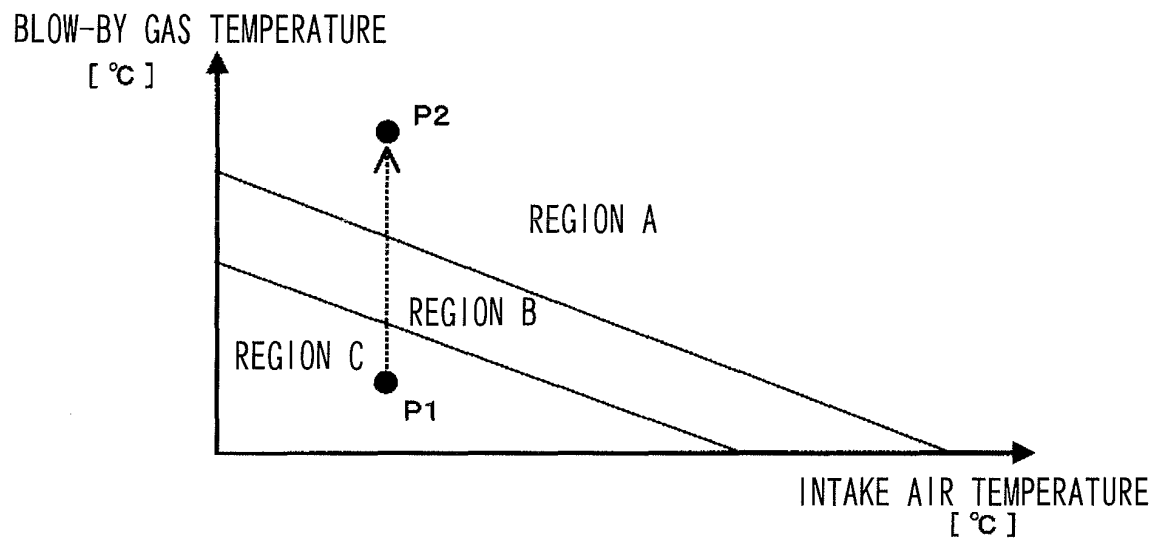


FIG. 3

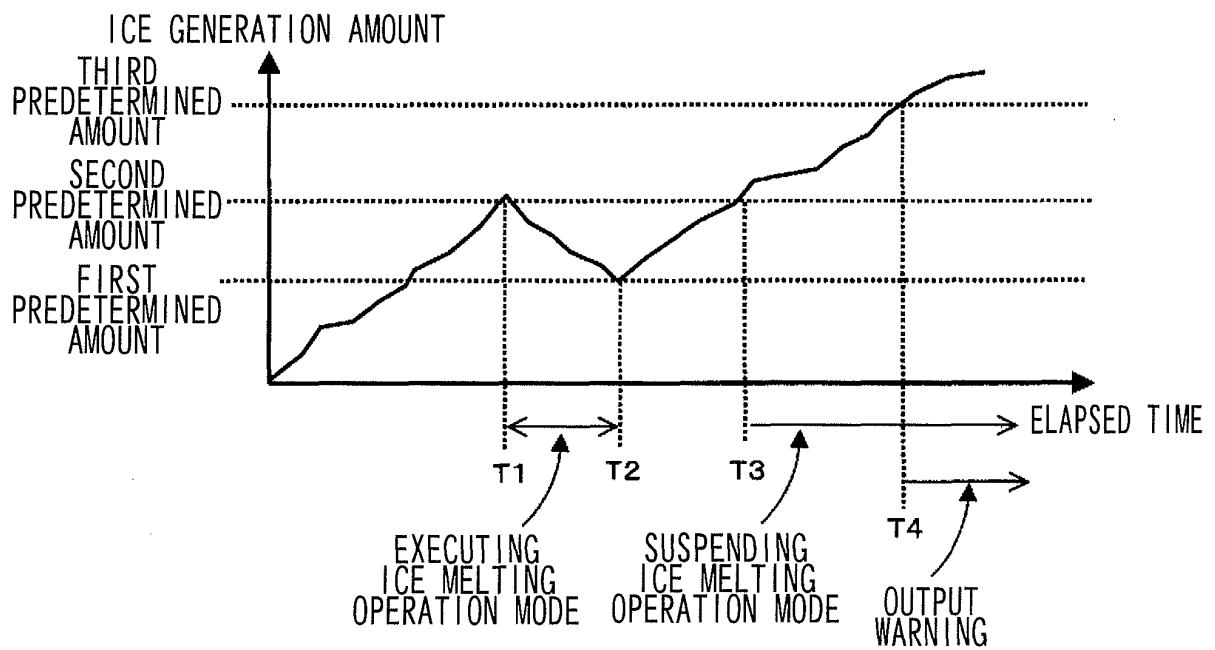


FIG. 4

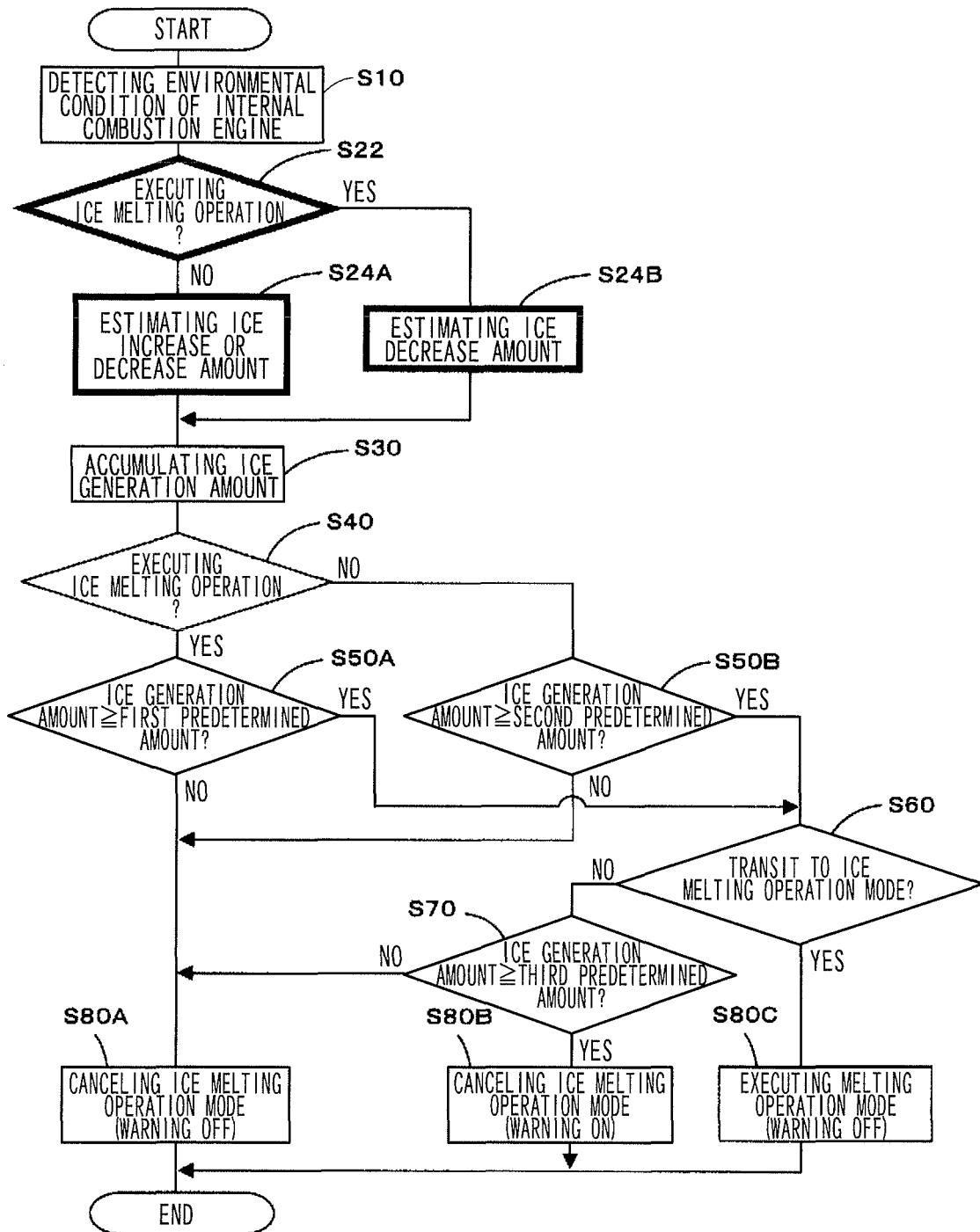


FIG. 5

STATE OF MANUAL TRANSMISSION IN 6TH GEAR

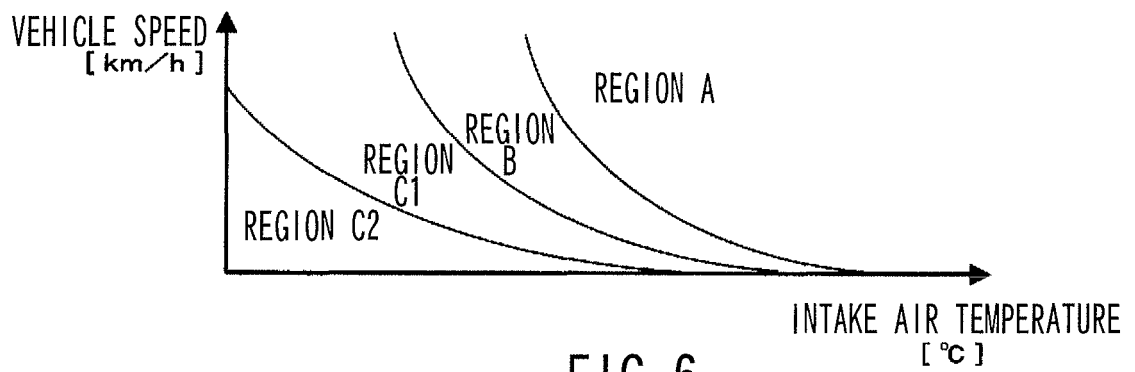


FIG. 6

STATE OF MANUAL TRANSMISSION IN 5TH GEAR

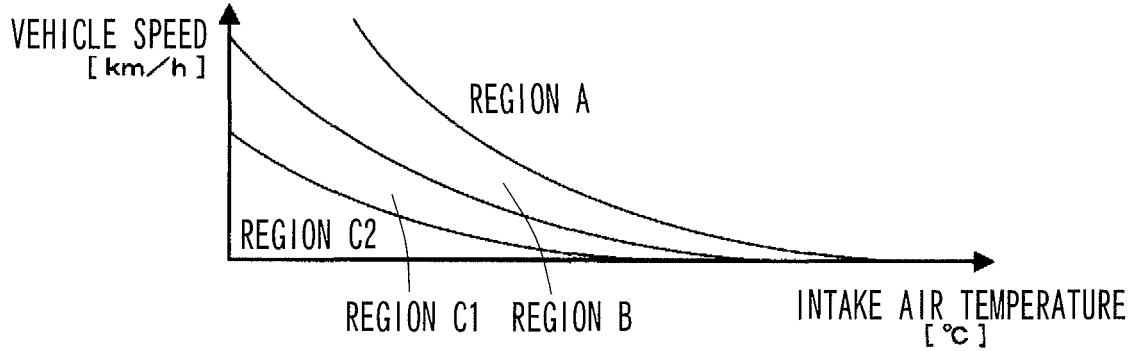


FIG. 7

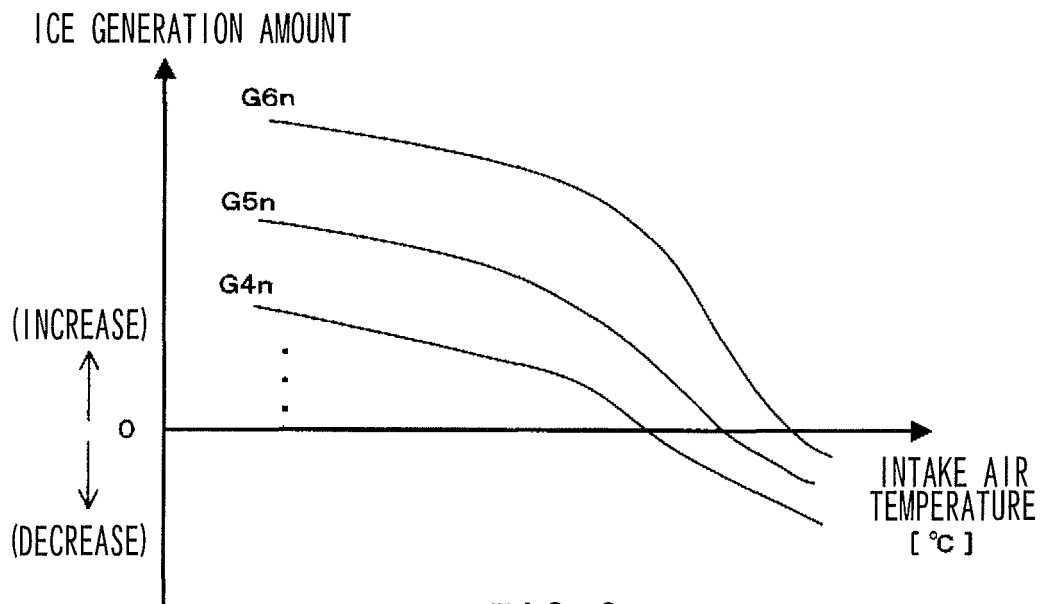


FIG. 8



## EUROPEAN SEARCH REPORT

Application Number  
EP 13 18 7486

| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                    |                                                      |                                         |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|------------------------------------------------------|-----------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Citation of document with indication, where appropriate, of relevant passages                      | Relevant to claim                                    | CLASSIFICATION OF THE APPLICATION (IPC) |
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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                    |                                                      | F01M<br>F02D                            |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                    |                                                      |                                         |
| Place of search<br>The Hague                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                    | Date of completion of the search<br>27 November 2013 | Examiner<br>Flamme, Emmanuel            |
| <p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone<br/>Y : particularly relevant if combined with another document of the same category<br/>A : technological background<br/>O : non-written disclosure<br/>P : intermediate document</p> <p>T : theory or principle underlying the invention<br/>E : earlier patent document, but published on, or after the filing date<br/>D : document cited in the application<br/>L : document cited for other reasons<br/>&amp; : member of the same patent family, corresponding document</p> |                                                                                                    |                                                      |                                         |

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**ANNEX TO THE EUROPEAN SEARCH REPORT  
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