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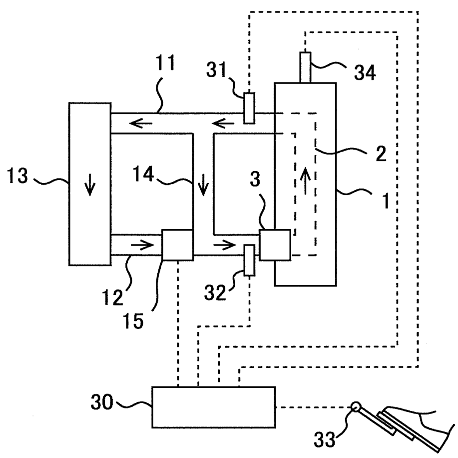
(54) ## COOLING SYSTEM FOR INTERNAL COMBUSTION ENGINE

(57) An opening and closing condition of a thermostat (15) is optimized. In a cooling system for an internal combustion engine (1) in which a cooling water, in which its specific heat becomes larger at a predetermined temperature than at other temperatures, is caused to circulates through a cooling water passage, there are provided a radiator (13), a bypass passage (14) that bypasses the radiator (13), and a thermostat (15) that interrupts the circulation of the cooling water to the radiator (13) and circulates the cooling water to the bypass passage (14) when it closes, and circulates the cooling water to at least the radiator (13) when it opens, wherein the thermostat (15) is set to open at the time when the temperature of the cooling water is higher than a predetermined temperature.

[Fig. 1]



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Description

[TECHNICAL FIELD]

[0001] The present invention relates to a cooling system for an internal combustion engine.

[BACKGROUND ART]

[0002] There has been known a technique in which the temperature of cooling water is set in such a manner that an internal combustion engine is not overheated, and an electronic thermostat is controlled so that the cooling water becomes a cooling water temperature thus set (for example, refer to a first patent document). In addition, there has also been known a cooling water in which its specific heat changes at a predetermined temperature (for example, refer to a second patent document). This cooling water is prepared by dispersing in a liquid capsules in each of which a substance adapted to cause a phase transition is filled.

[0003] Here, in cases where the cooling water, in which its specific heat changes at the predetermined temperature, is used in a system in which the electronic thermostat is controlled so that the cooling water becomes the thus set cooling water temperature, if the electronic thermostat is controlled in the manner as conventional, it can not be said that the characteristic of the cooling water that its specific heat changes is utilized to a sufficient extent.

[PRIOR ART REFERENCES]

[PATENT DOCUMENTS]

[0004]

[First Patent Document] Japanese patent application laid-open No. 2004-353602
[Second Patent Document] Japanese patent application laid-open No. 2010-168538

[SUMMARY OF THE INVENTION]

[TO BE SOLVED BY THE INVENTION]

[0005] The present invention has been made in view of the problems as mentioned above, and has for its object to provide a technique to optimize the opening and closing (on and off) condition of a thermostat.

[MEANS FOR SOLVING THE PROBLEMS]

[0006] In order to achieve the above-mentioned object, a cooling system for an internal combustion engine according to the present invention, in which a cooling water, in which its specific heat becomes larger at a predetermined temperature than at other temperatures, is caused to circulate through a cooling water passage, is provided with:

a radiator that is arranged in said cooling water passage and takes heat from said cooling water;
a bypass passage that bypasses said radiator; and
a thermostat that interrupts the circulation of the cooling water to said radiator and circulates the cooling water to said bypass passage when it closes, and circulates the cooling water to at least said radiator when it opens;
wherein said thermostat opens when the temperature of said cooling water is higher than said predetermined temperature.

[0007] The predetermined temperature can be a temperature at which a structural phase transition occurs in a substance included in the cooling water, for example. That is, heat is released or heat is absorbed due to the structural phase transition, so the specific heat of the cooling water becomes higher at the temperature at which the structural phase transition occurs. For this reason, at the predetermined temperature, the temperature of the cooling water becomes substantially constant, even if there is some incoming and outgoing of heat.

[0008] Here, when the thermostat opens, the cooling water will flow to the radiator, so the temperature rise of the cooling water is suppressed. If the thermostat opens at the time when the temperature of the cooling water is lower than the predetermined temperature, the temperature of the cooling water will be suppressed from going up to the predetermined temperature, and hence, the characteristic of the specific heat becoming larger is not utilized. On the other hand, if the thermostat is set to open when the temperature of the cooling water is higher than the predetermined temperature, the specific heat of the cooling water can become larger when the thermostat is in a closed state, so that the characteristic of the specific heat becoming larger can be utilized. That is, the temperature of the cooling water can be maintained constant when the thermostat is in the closed state, and hence, it becomes unnecessary to perform control corresponding to the variation in the temperature of the cooling water. For this reason, the operating state of the internal combustion engine can be stabilized. In this manner, the opening and closing condition of the thermostat can be optimized.

[0009] In addition, in the present invention, there can be provided
an operation region in which said thermostat opens when the temperature of said cooling water is higher than said predetermined temperature, and
an operation region in which said thermostat opens when the temperature of said cooling water is lower than said predetermined temperature.

[0010] That is, the cooling capacity required for the cooling system varies in accordance with the operating state of the internal combustion engine, so it is possible to set the temperature at which the thermostat opens according to the required cooling capacity. As a result of this, it becomes possible to carry out the temperature control of the cooling water according to the operating regions.

[0011] Moreover, in the present invention, said thermostat may open when the temperature of the cooling water flowing out of said internal combustion engine into said cooling water passage is higher than said predetermined temperature.

[0012] Because the cooling water flowing out of the internal combustion engine into the cooling water passage is the cooling water immediately after receiving heat from the internal combustion engine, the temperature thereof is difficult to go up until the cooling water flows into the internal combustion engine again. That is, the temperature of the cooling water flowing out of the internal combustion engine into the cooling water passage is higher than that of cooling water in other parts. For this reason, if the thermostat opens according to the temperature of the cooling water flowing out of the internal combustion engine into the cooling water passage, it will be possible to suppress overheating of the internal combustion engine, and at the same time to utilize the characteristic that the specific heat of the cooling water becomes larger.

[0013] Further, in the present invention, there can be provided

an operation region in which said thermostat opens when the temperature of the cooling water flowing out of said internal combustion engine into said cooling water passage is higher than said predetermined temperature, and when the temperature of the cooling water flowing out of said cooling water passage into said internal combustion engine is higher than said predetermined temperature, and

an operation region in which said thermostat opens when the temperature of the cooling water flowing out of said internal combustion engine into said cooling water passage is higher than said predetermined temperature, and when the temperature of the cooling water flowing out of said cooling water passage into said internal combustion engine is lower than said predetermined temperature.

[0014] Here, because the cooling water flowing out of the cooling water passage into the internal combustion engine is the cooling water immediately before receiving heat from the internal combustion engine, the temperature thereof is low. On the other hand, because the cooling water flowing out of the internal combustion engine into the cooling water passage is the cooling water immediately after receiving heat from the internal combustion engine, the temperature thereof is high. In this manner, even among the cooling water, there exist a part in which the temperature thereof is high, and a part in which the temperature thereof is low.

[0015] Then, when the temperature of the cooling water flowing out of the cooling water passage into the internal combustion engine is higher than the predetermined temperature, it can be said that the temperature of the cooling water as a whole is higher than the predetermined temperature. For this reason, if the thermostat is set to open when the temperature of the cooling water flowing out of the cooling water passage into the internal combustion engine is higher than the predetermined temperature, the temperature of the cooling water as a whole will be maintained in a state higher than the predetermined temperature. For example, in an operation region where the cooling capacity to be required is low, it becomes possible to make the temperature of the cooling water as a whole higher than the predetermined temperature, as a result of which fuel economy can be improved. Here, note that the operation region where the cooling capacity to be required is low may also be a region where the internal combustion engine is operated at low rotation speed and under low load.

[0016] On the other hand, if said thermostat opens when the temperature of the cooling water flowing out of said internal combustion engine into said cooling water passage is higher than said predetermined temperature, and when the temperature of the cooling water flowing out of said cooling water passage into said internal combustion engine is lower than said predetermined temperature, the temperature of the cooling water within the internal combustion engine will become the predetermined temperature. For this reason, the specific heat of the cooling water within the internal combustion engine becomes high, so the temperature rise of the cooling water can be suppressed. For example, in an operation region where the cooling capacity to be required is high, the specific heat of the cooling water within the internal combustion engine becomes high, whereby the temperature of the cooling water within the internal combustion engine can be made constant. As a result of this, the operating state of the internal combustion engine can be stabilized. Here, note that the operation region where the cooling capacity to be required is high may also be a region where the internal combustion engine is operated at high rotation speed and under high load.

[EFFECT OF THE INVENTION]

[0017] According to the present invention, it is possible to optimize the opening and closing condition of the thermostat.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0018]

[Fig. 1] is a view showing the schematic construction of a cooling system for an internal combustion engine according to an embodiment of the present invention.

[Fig. 2] is a time chart showing the change over time of an outlet side temperature at the time of warming up of the internal combustion engine.

[Fig. 3] is a view showing the relation between the temperature of cooling water and the specific heat of the cooling water.

[Fig. 4] is a view showing the relation among the number of engine revolutions per minute, the engine load, and the temperature at which a thermostat opens.

[MODE FOR CARRYING OUT THE INVENTION]

[0019] Hereinafter, reference will be made to a specific embodiment of a cooling system for an internal combustion engine according to the present invention based on the attached drawings.

[First Embodiment]

[0020] Fig. 1 is a view showing the schematic construction of a cooling system for an internal combustion engine according to this embodiment of the present invention. An internal combustion engine 1 shown in Fig. 1 is a water cooled type internal combustion engine.

[0021] A water jacket 2 for circulating cooling water is formed in the interior of the internal combustion engine 1. In addition, a first cooling water passage 11 and a second cooling water passage 12 are connected to the internal combustion engine 1. A radiator 13 and a bypass passage 14 are connected to these first cooling water passage 11 and second cooling water passage 12.

[0022] The first cooling water passage 11 provides a connection between an outlet side of the water jacket 2 and an inlet side of the radiator 13. That is, the first cooling water passage 11 is a passage for discharging the cooling water from the water jacket 2. Also, the second cooling water passage 12 provides a connection between an outlet side of the radiator 13 and an inlet side of the water jacket 2. That is, the second cooling water passage 12 is a passage for supplying the cooling water to the water jacket 2.

[0023] In addition, a water pump 3, which serves to deliver the cooling water from the side of the second cooling water passage 12 to the side of the water jacket 2, is formed at a connection part between the second cooling water passage 12 and the water jacket 2.

[0024] The bypass passage 14 serves to place the first cooling water passage 11 and the second cooling water passage 12 in communication with each other, thereby bypassing the radiator 13.

[0025] Moreover, a thermostat 15 of an electronic controlled type is arranged in the second cooling water passage 12 at a location near the radiator 13 from the connection part between the second cooling water passage 12 and the bypass passage 14. The degree of opening of this thermostat 15 is adjusted according to a signal from an ECU 30 which will be described later. Then, the amount of the cooling water supplied to the radiator 13 is adjusted by controlling the degree of opening of the thermostat 15.

[0026] When the thermostat 15 is in a closed state, the cooling water having flowed out of the water jacket 2 into the first cooling water passage 11 is again sent to the water jacket 2 by way of the bypass passage 14. By such a circulation of the cooling water, the cooling water is warmed in a gradual manner, so that the warming up of the internal combustion engine 1 is facilitated.

[0027] In addition, when the thermostat 15 is open, the cooling water circulates by way of the radiator 13 and the bypass passage 14. Here, note that without regard to the state of the thermostat 15, the cooling water also circulates to those parts other than the radiator 13 and the bypass passage 14, which are omitted in Fig. 1.

[0028] Further, an outlet side temperature sensor 31, which serves to measure the temperature of the cooling water flowing out of the water jacket 2 (hereinafter, referred to as an outlet side temperature) , is mounted on the first cooling water passage 11 at a location between its connection part with the water jacket 2 and its connection part with the bypass passage 14. Also, an inlet side temperature sensor 32, which serves to measure the temperature of the cooling water flowing into the water jacket 2 (hereinafter, referred to as an inlet side temperature) , is mounted on the second cooling water passage 12 at a location between its connection part with the water jacket 2 and its connection part with the bypass passage 14.

[0029] In the internal combustion engine 1 constructed as stated above, there is arranged in combination therewith the ECU 30 which is an electronic control unit for controlling the internal combustion engine 1. This ECU 30 controls the internal combustion engine 1 in accordance with the operating conditions of the internal combustion engine 1 and/or driver's requirements.

[0030] In addition, besides the above-mentioned sensors, an accelerator opening sensor 33, which serves to detect an engine load by outputting an electrical signal corresponding to a degree of opening (i.e., an amount of depression) of an accelerator pedal, and a crank position sensor 34, which serves to detect the number of revolutions per minute of the engine, are connected to the ECU 30 through electrical wiring, and, output signals of these sensors are inputted to the ECU 30. On the other hand, the thermostat 15 is connected to the ECU 30 through electrical wiring, so that this thermostat 15 is controlled by the ECU 30.

[0031] Here, the cooling water in this embodiment has a specific heat which changes at a predetermined temperature. For example, the cooling water is composed of including a substance which performs a phase transition from a solid to a liquid or from a liquid to a solid, at the predetermined temperature. That is, when the temperature of the cooling water becomes the predetermined temperature in the process of becoming higher, the substance included in the cooling water will change from a solid to a liquid, and at this time, will absorb heat from the surroundings. On the other hand, when the temperature of the cooling water becomes the predetermined temperature in the process of becoming lower, the substance included in the cooling water will change from a liquid to a solid, and at this time, will release heat to the surroundings. In this manner, at the time when a phase transition is carried out between a liquid and a solid, the specific heat of the cooling water changes.

[0032] Fig. 2 is a time chart showing the change over time of the outlet side temperature at the time of warming up of the internal combustion engine 1. In a period of time from A to B in Fig. 2, the outlet side temperature of the cooling water becomes constant at a predetermined temperature D. In addition, at a time point indicated by C, the outlet side temperature of the cooling water becomes an opening temperature E of the thermostat 15, and so the thermostat 15 is open. As a result of this, the cooling water flows through the radiator 13, so that the outlet side temperature of the cooling water becomes substantially constant.

[0033] Further, Fig. 3 is a view showing the relation between the cooling water temperature and the specific heat of the cooling water. As shown in Fig. 3, at the predetermined temperature D, the specific heat of the cooling water becomes higher than that at other temperatures. For this reason, as shown in Fig. 2, in the period of time from A to B, the outlet side temperature of the cooling water becomes constant at the predetermined temperature D. In addition, Fig. 2 shows the case where the temperature E at which the thermostat 15 opens is higher than the predetermined temperature D.

[0034] In this manner, if the thermostat 15 is set to open at the time when the outlet side temperature of the cooling water is higher than the predetermined temperature D, it will be possible to utilize the characteristic that the specific heat of the cooling water becomes higher, i.e., the characteristic of the cooling water temperature becoming constant. That is, when the cooling water temperature goes up, the rise of the temperature can be suppressed by taking heat, whereas when the cooling water temperature goes down, the fall of the temperature can be suppressed by giving heat. For this reason, the variation of the cooling water temperature can be suppressed, thus making it possible to stabilize the operating state of the internal combustion engine 1.

[0035] Here, note that the temperature E at which the thermostat 15 is opened may also be set, for example, as a temperature at which the warming up of the internal combustion engine 1 is completed, but is not limited to this. In addition, the components included in the cooling water may be decided in such a manner that the predetermined temperature D becomes lower than the temperature at which the warming up of the internal combustion engine 1 is completed. An optimum value of the temperature E at which the thermostat 15 is opened and an optimum value of the predetermined temperature D can be obtained through experiments, etc.

[0036] In addition, in the above-mentioned explanation, the thermostat 15 is controlled by the ECU 30, but a thermostat which is automatically opened and closed at a prescribed temperature can also be used.

[0037] Moreover, the time at which the thermostat 15 is opened can also be set, in further consideration of the inlet side temperature, i.e., the temperature of the cooling water which flows through the second cooling water passage 12. That is, in an operating state in which a high cooling capacity is required, the thermostat 15 is set to open at the time when the inlet side temperature of the cooling water is lower than the predetermined temperature D. On the other hand, in an operating state in which the cooling capacity may be low, the thermostat 15 is set to open at the time when the inlet side temperature of the cooling water is higher than the predetermined temperature D.

[0038] Here, note that the operating state in which a high cooling capacity is required is, for example, in a state where at least one of the number of engine revolutions per minute and the engine load is relatively high. This may also be a time in which the internal combustion engine is at high rotation speed and under high load or in an accelerating operation. On the other hand, the operating state in which the cooling capacity may be low is, for example, in a state where the number of engine revolutions per minute and the engine load are relatively low. This may also be a time in which the internal combustion engine is at low rotation speed and under low load or in a steady state operation.

[0039] Fig. 4 is a view showing the relation among the number of engine revolutions per minute, the engine load, and the temperature at which the thermostat 15 opens. In Fig. 4, F indicates an operation region in which a high cooling capacity is required (a region in which at least one of the number of engine revolutions per minute and the engine load is relatively high), and G indicates an operation region in which the cooling capacity may be low (a region in which the number of engine revolutions per unit time and the engine load are relatively low).

[0040] In the operation region F in which a high cooling capacity is required, the thermostat 15 is opened so that the following relation is satisfied.

The inlet side temperature < the predetermined temperature D < the outlet side temperature

That is, the predetermined temperature D becomes higher than the inlet side temperature, and the outlet side temperature becomes higher than the predetermined temperature D. For this reason, the cooling water becomes the predetermined temperature D when it flows through the water jacket 2. Accordingly, the specific heat of the cooling water becomes high in the interior of the internal combustion engine 1, so the temperature rise of the cooling water in the interior of the internal combustion engine 1 can be suppressed. As a result of this, the operating state of the internal combustion engine 1 can be stabilized.

[0041] On the other hand, in the operation region G in which the cooling capacity may be low, the thermostat 15 is opened so that the following relation is satisfied.

The predetermined temperature D < the inlet side tem-

perature < the outlet side temperature
That is, the inlet side temperature becomes higher than the predetermined temperature D. As a result of this, the cooling water temperature is maintained in a high state, thus making it possible to improve fuel economy.

[0042] Here, note that a boundary between the region indicated by F in Fig. 4 and the region indicated by G changes, for example, according to whether priority is given to the stability of the operating state of the internal combustion engine 1, or the improvement in fuel economy, and hence, an optimum value is obtained through experiments, etc.

[EXPLANATION OF REFERENCE NUMERALS AND CHARACTERS]

[0043]

1 internal combustion engine
2 water jacket
3 water pump
11 first cooling water passage
12 second cooling water passage
13 radiator
14 bypass passage
15 thermostat
30 ECU
31 outlet side temperature sensor
32 inlet side temperature sensor
33 accelerator opening sensor
34 crank position sensor

Claims

1. A cooling system for an internal combustion engine in which a cooling water, in which its specific heat becomes larger at a predetermined temperature than at other temperatures, is caused to circulate through a cooling water passage, said cooling system comprising:

   a radiator that is arranged in said cooling water passage and takes heat from said cooling water;
   a bypass passage that bypasses said radiator; and
   a thermostat that interrupts the circulation of the cooling water to said radiator and circulates the cooling water to said bypass passage when it closes, and circulates the cooling water to at least said radiator when it opens;
   wherein said thermostat opens when the temperature of said cooling water is higher than said predetermined temperature.

2. The cooling system for an internal combustion engine as set forth in claim 1, wherein
   said cooling system is provided with:

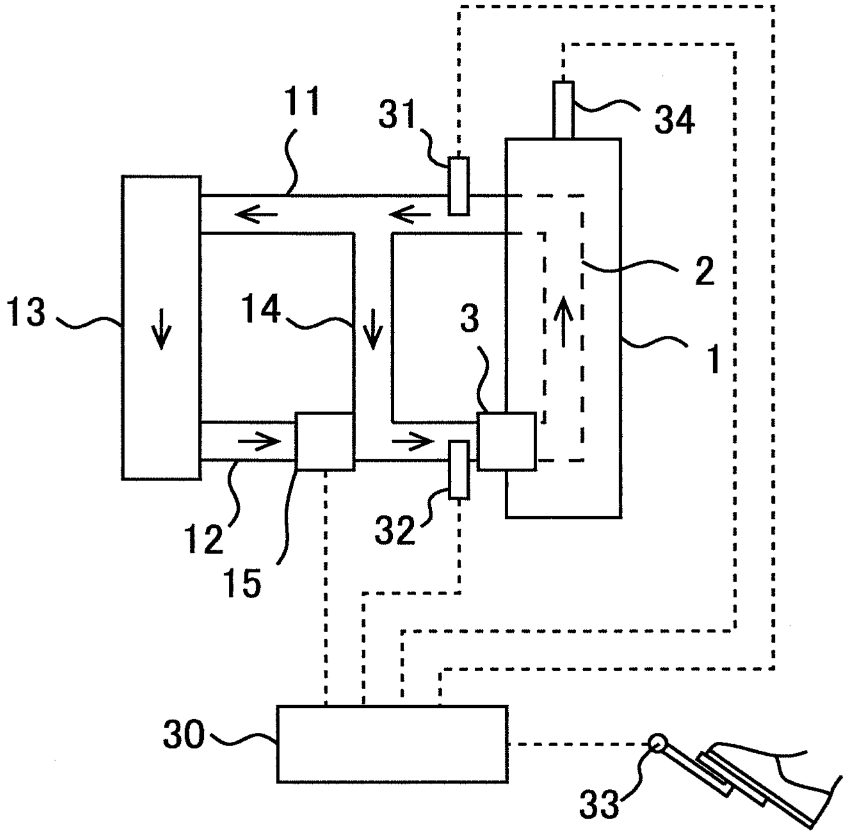
   an operation region in which said thermostat opens when the temperature of said cooling water is higher than said predetermined temperature; and
   an operation region in which said thermostat opens when the temperature of said cooling water is lower than said predetermined temperature.

3. The cooling system for an internal combustion engine as set forth in claim 1, wherein
   said thermostat opens when the temperature of the cooling water flowing out of said internal combustion engine into said cooling water passage is higher than said predetermined temperature.

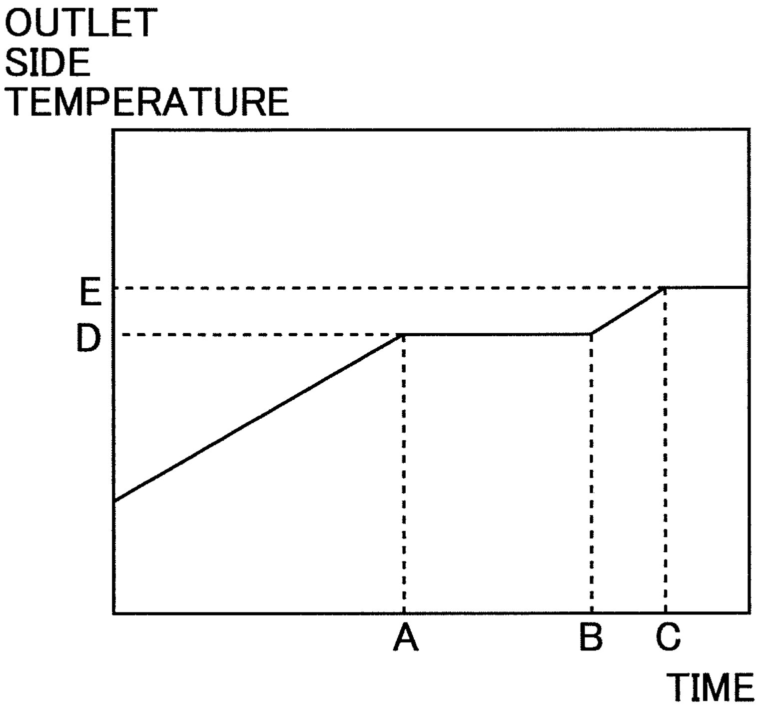
4. The cooling system for an internal combustion engine as set forth in claim 1, wherein
   said cooling system is provided with:

   an operation region in which said thermostat opens when the temperature of the cooling water flowing out of said internal combustion engine into said cooling water passage is higher than said predetermined temperature, and when the temperature of the cooling water flowing out of said cooling water passage into said internal combustion engine is higher than said predetermined temperature; and
   an operation region in which said thermostat opens when the temperature of the cooling water flowing out of said internal combustion engine into said cooling water passage is higher than said predetermined temperature, and when the temperature of the cooling water flowing out of said cooling water passage into said internal combustion engine is lower than said predetermined temperature.

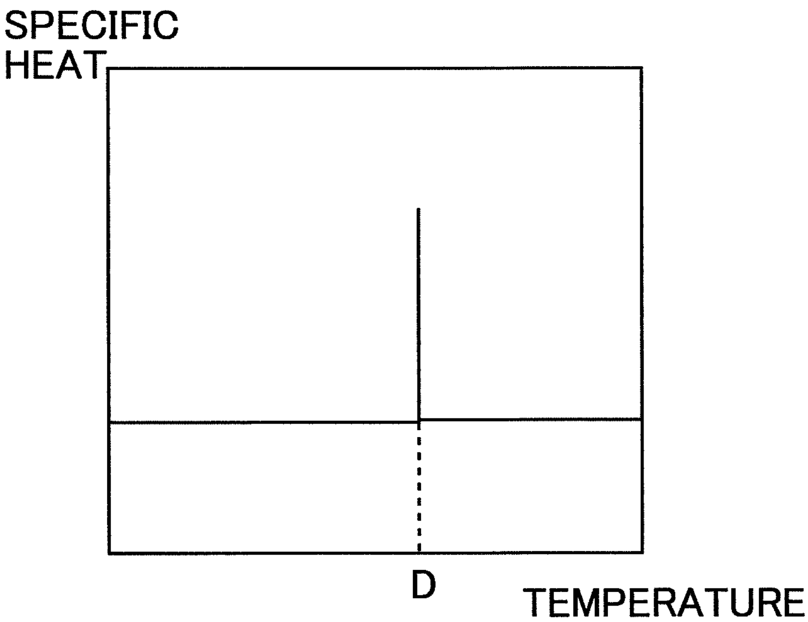
[Fig. 1]



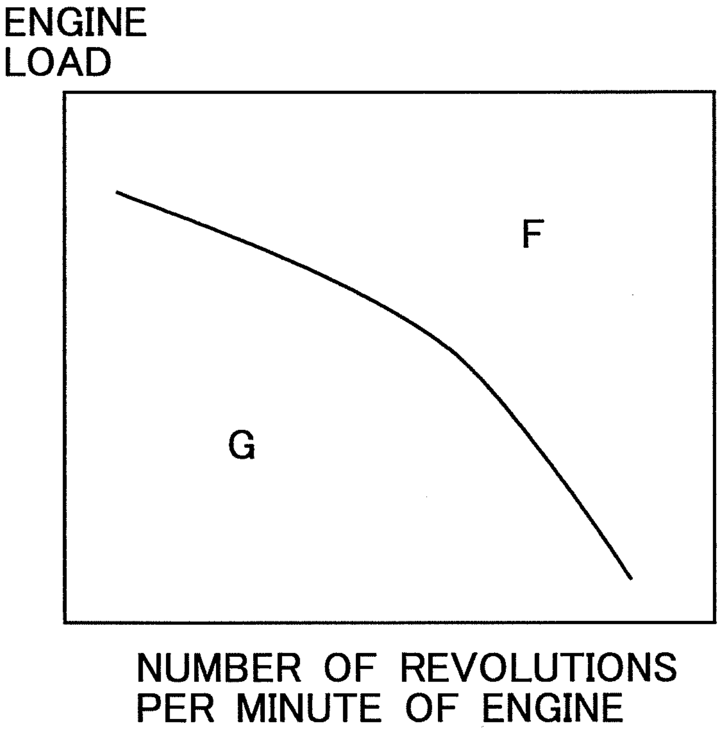
[Fig. 2]


OUTLET
SIDE
TEMPERATURE
E
D
A
B
C
TIME

[Fig. 3]


SPECIFIC
HEAT
D
TEMPERATURE

[Fig. 4]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/069434

A. CLASSIFICATION OF SUBJECT MATTER
F01P7/16(2006.01)i, *F01P11/14*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01P7/16, F01P11/14

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2007-321633 A (Nissan Motor Co., Ltd.), 13 December 2007 (13.12.2007), paragraphs [0014] to [0046]; fig. 1 to 4 (Family: none)	1,3,4 2
Y	JP 2010-174663 A (Nissan Motor Co., Ltd.), 12 August 2010 (12.08.2010), abstract (Family: none)	2
A	JP 2009-044896 A (Nissan Motor Co., Ltd.), 26 February 2009 (26.02.2009), entire text; all drawings (Family: none)	1-4

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search 17 November, 2010 (17.11.10)	Date of mailing of the international search report 30 November, 2010 (30.11.10)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/069434

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2006-240501 A (Nissan Motor Co., Ltd.), 14 September 2006 (14.09.2006), entire text; all drawings (Family: none)	1-4

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2004353602 A **[0004]**
- JP 2010168538 A **[0004]**