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(54) **SYSTEM FOR CONTROLLING AIR FLOW RATE INTO VEHICLE ENGINE COMPARTMENT**

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(51) **Int. Cl.**

| | |
|---|---|
| ***F01P 9/04*** | (2006.01) |
| ***F28D 7/10*** | (2006.01) |
| ***F01P 3/18*** | (2006.01) |
| ***F01P 5/02*** | (2006.01) |
| ***F01P 7/10*** | (2006.01) |
| ***B60K 11/08*** | (2006.01) |

(52) **U.S. Cl.**

CPC ................ ***F01P 3/18*** (2013.01); ***B60K 11/085*** (2013.01); ***F01P 5/02*** (2013.01); ***F01P 7/10*** (2013.01)

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CPC ............. F01P 7/16; F01P 2060/16; F01P 3/18; F01P 2037/00; F01P 2070/10; F01P 5/02; F01P 7/10; F01P 11/02; F01P 2011/205; B60K 11/04; B60K 11/02; B60K 11/085; F02B 29/0462; F24H 3/06; F24H 9/0052; F24H 9/2064

USPC ............. 123/41.04, 41.01, 41.3; 165/140, 10

See application file for complete search history.

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(57) **ABSTRACT**

A system for controlling a flow rate of air into a vehicle engine compartment may include a radiator cooling coolant, a coolant inflow tank provided to one side of the radiator and temporarily storing coolant that cools an engine, a coolant exhaust tank provided to the other side of the radiator and temporarily storing coolant circulating past a cooling fin of the radiator from the coolant inflow tank, Phase Change Material (PCM) tanks provided to an exterior side of the coolant inflow tank and coolant exhaust tank and storing a phase change material heat-exchanging with the coolant stored in the coolant inflow tank and the coolant exhaust tank and a conversion device converting a phase of the phase change material.

**16 Claims, 10 Drawing Sheets**

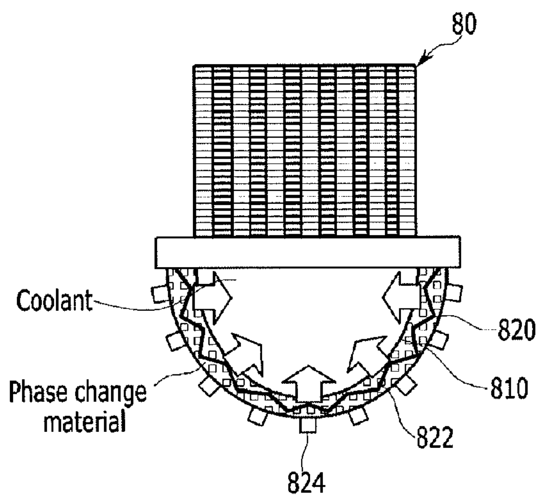

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FIG. 1

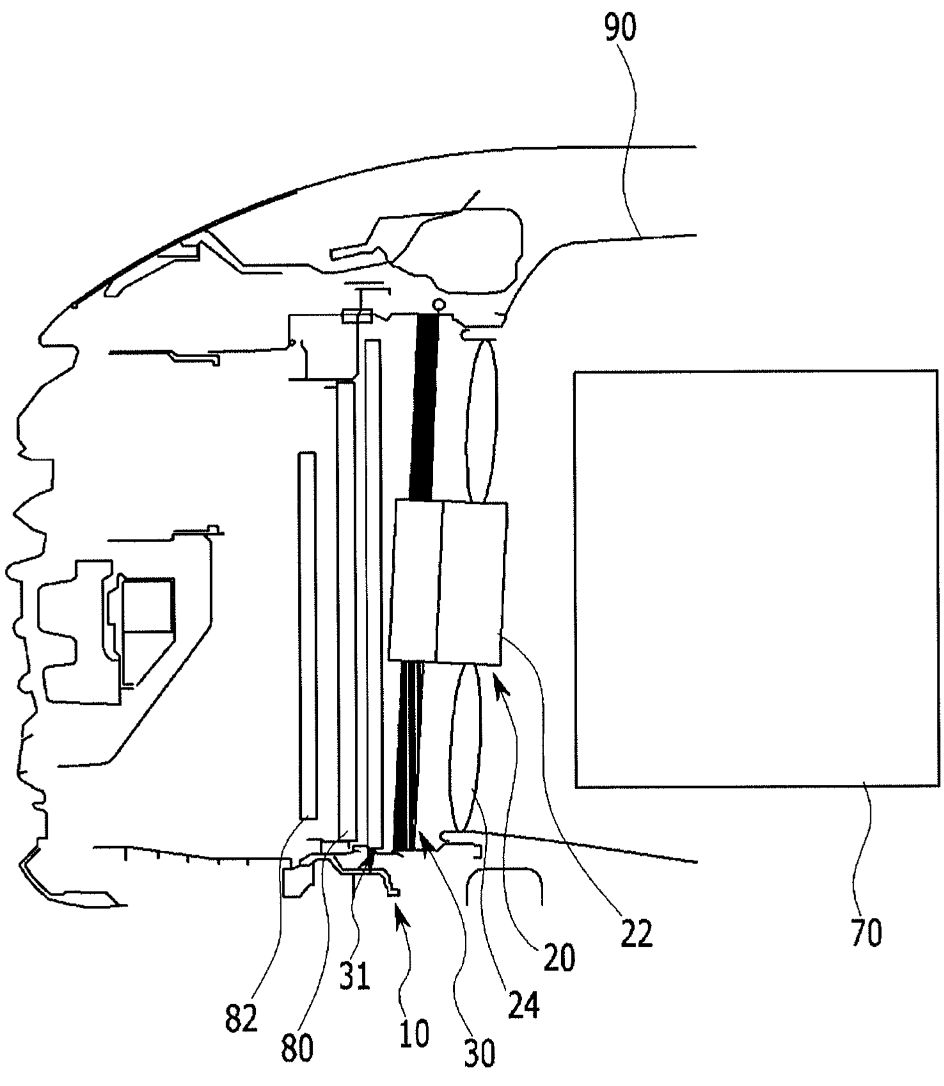


FIG. 2

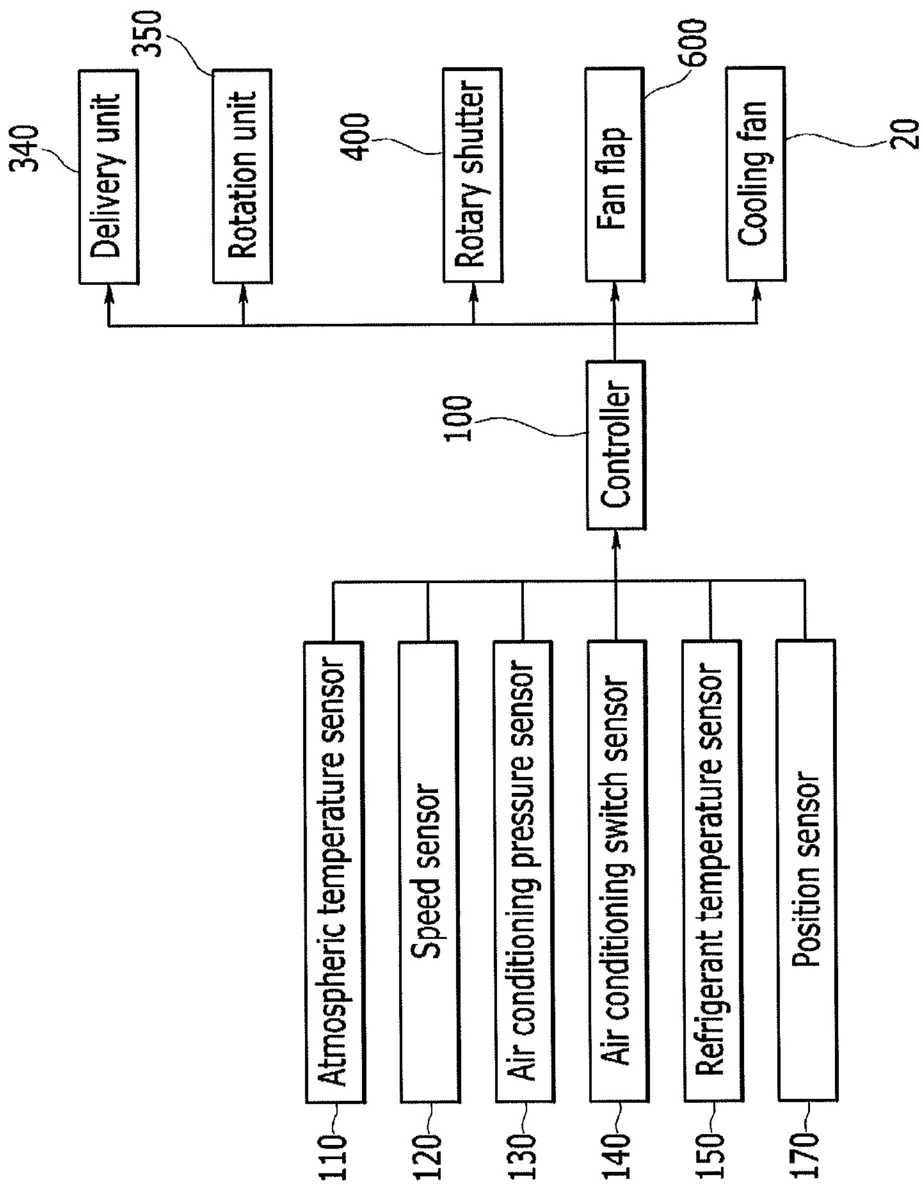

Atmospheric temperature sensor
110
Speed sensor
120
Air conditioning pressure sensor
130
Air conditioning switch sensor
140
Refrigerant temperature sensor
150
Position sensor
170
Controller
100
Delivery unit
340
Rotation unit
350
Rotary shutter
400
Fan flap
600
Cooling fan
20

FIG. 3A

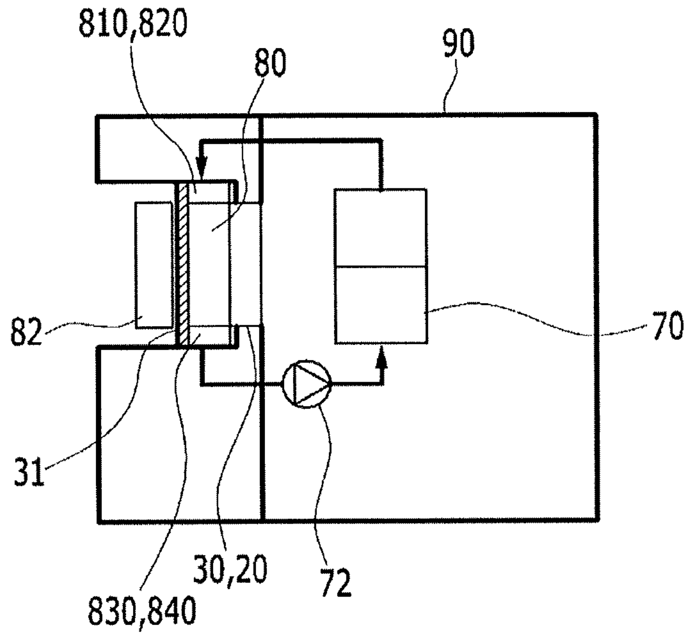

810,820
80
90
82
70
31
30,20
72
830,840

FIG. 3B

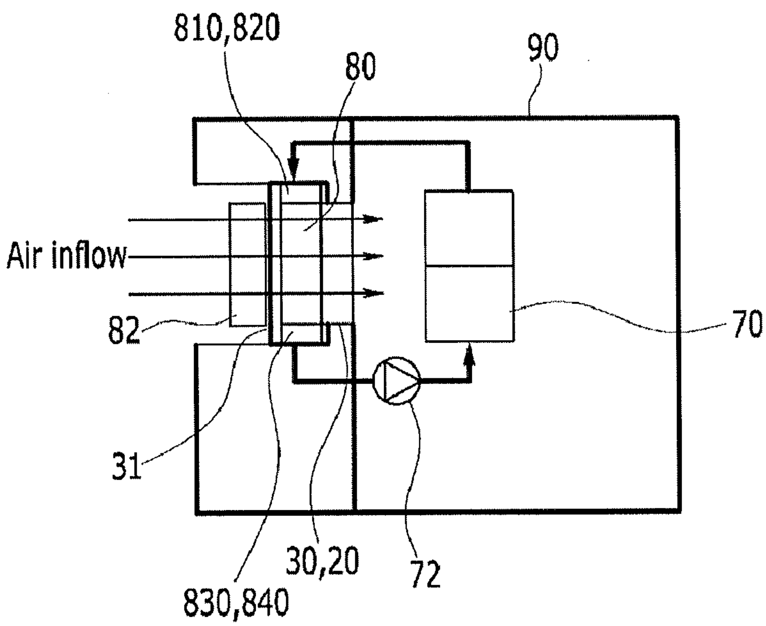

810,820
80
90
Air inflow
82
70
31
30,20
72
830,840

FIG. 4A

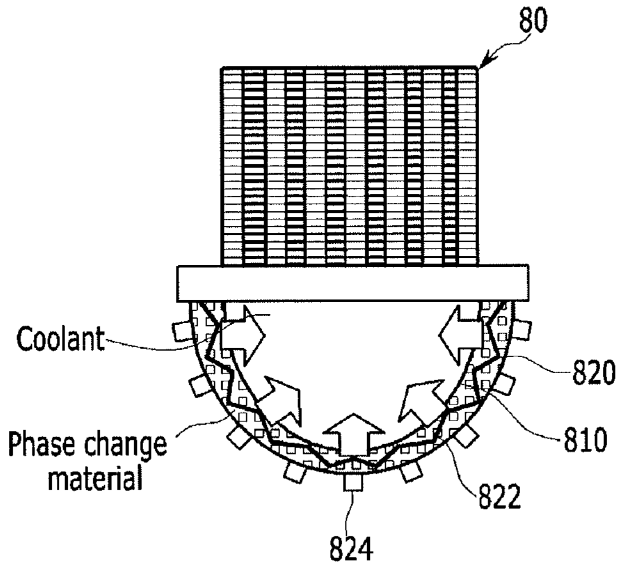

80
Coolant
Phase change material
820
810
822
824

FIG. 4B

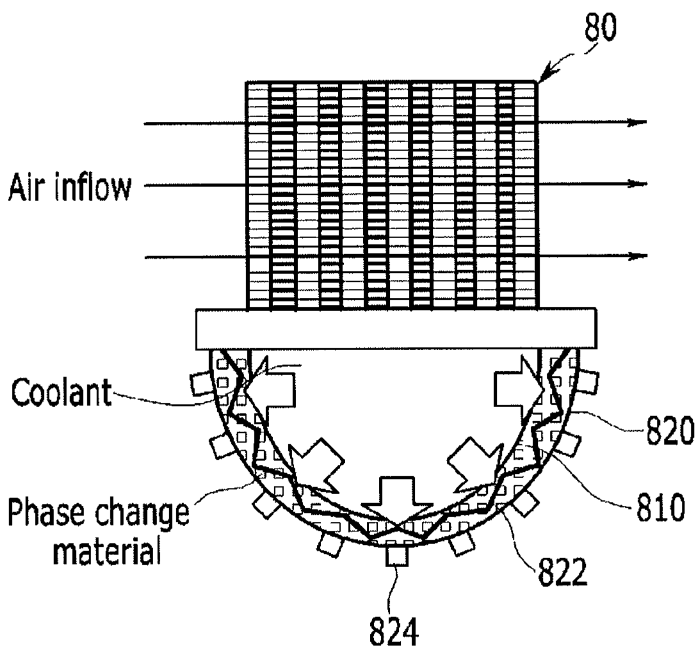

80
Air inflow
Coolant
Phase change material
820
810
822
824

FIG. 5

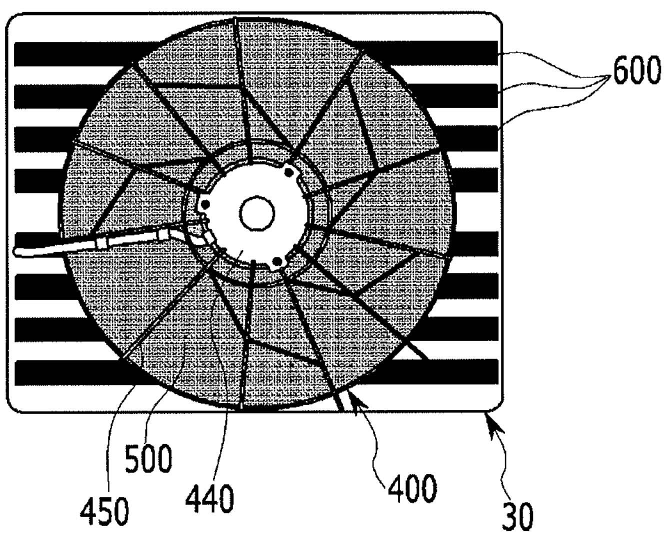


*FIG. 6A*

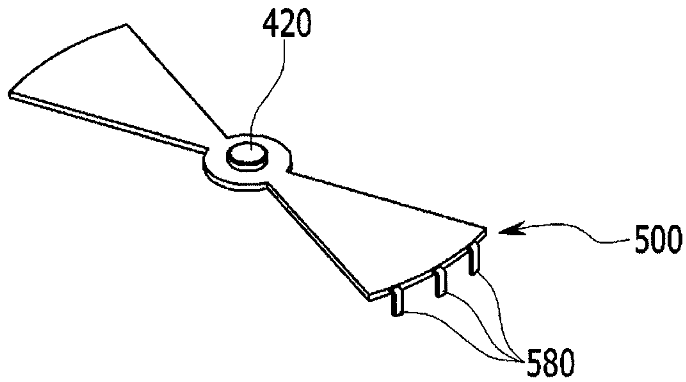



*FIG. 6B*

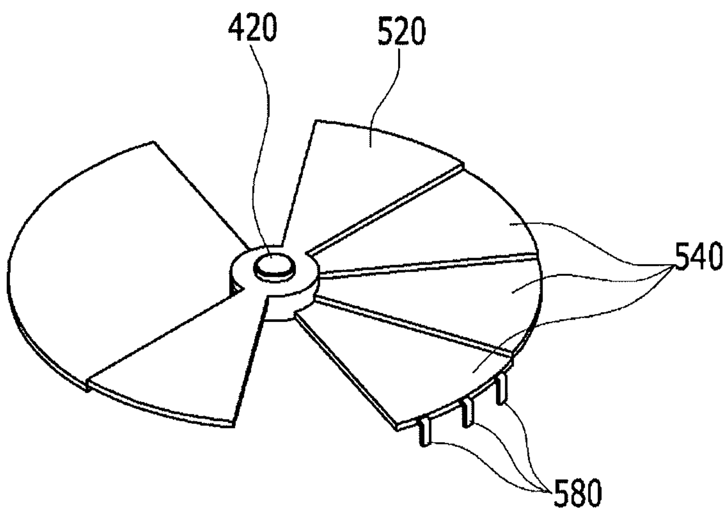


*FIG. 7*

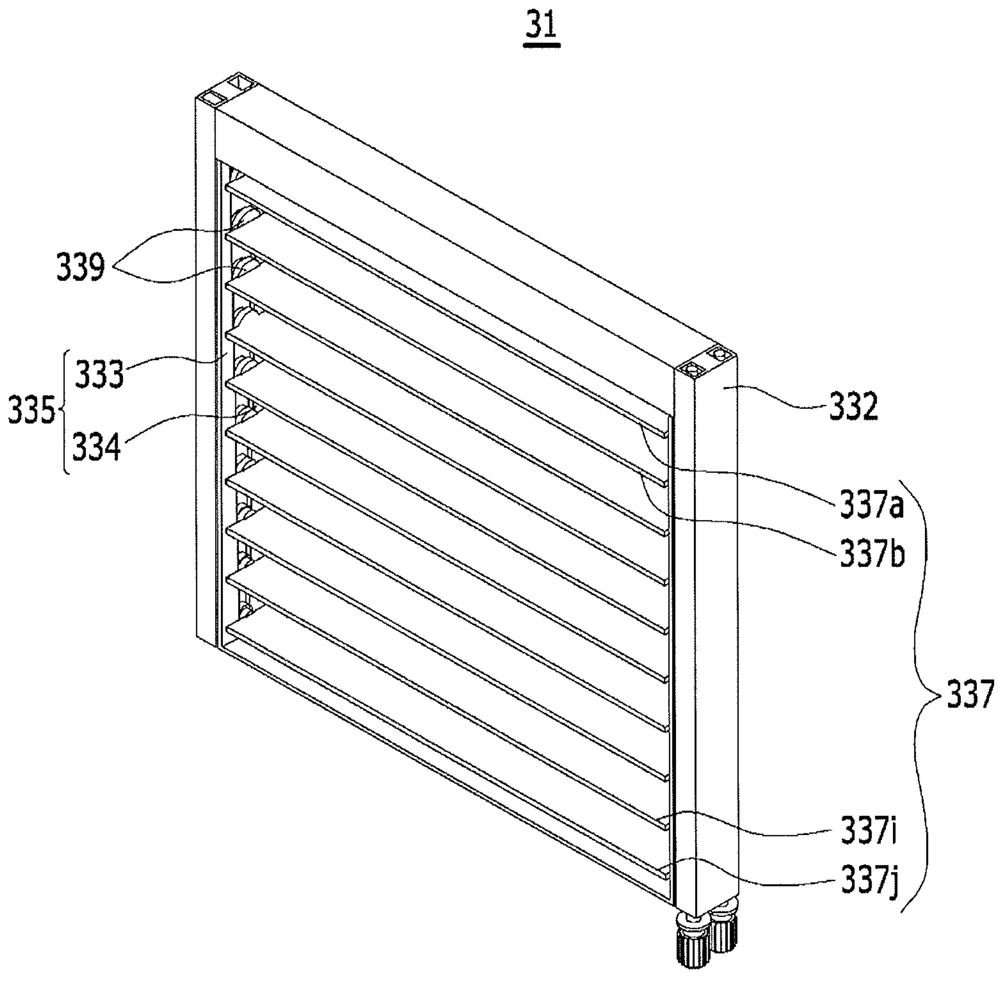


FIG. 8

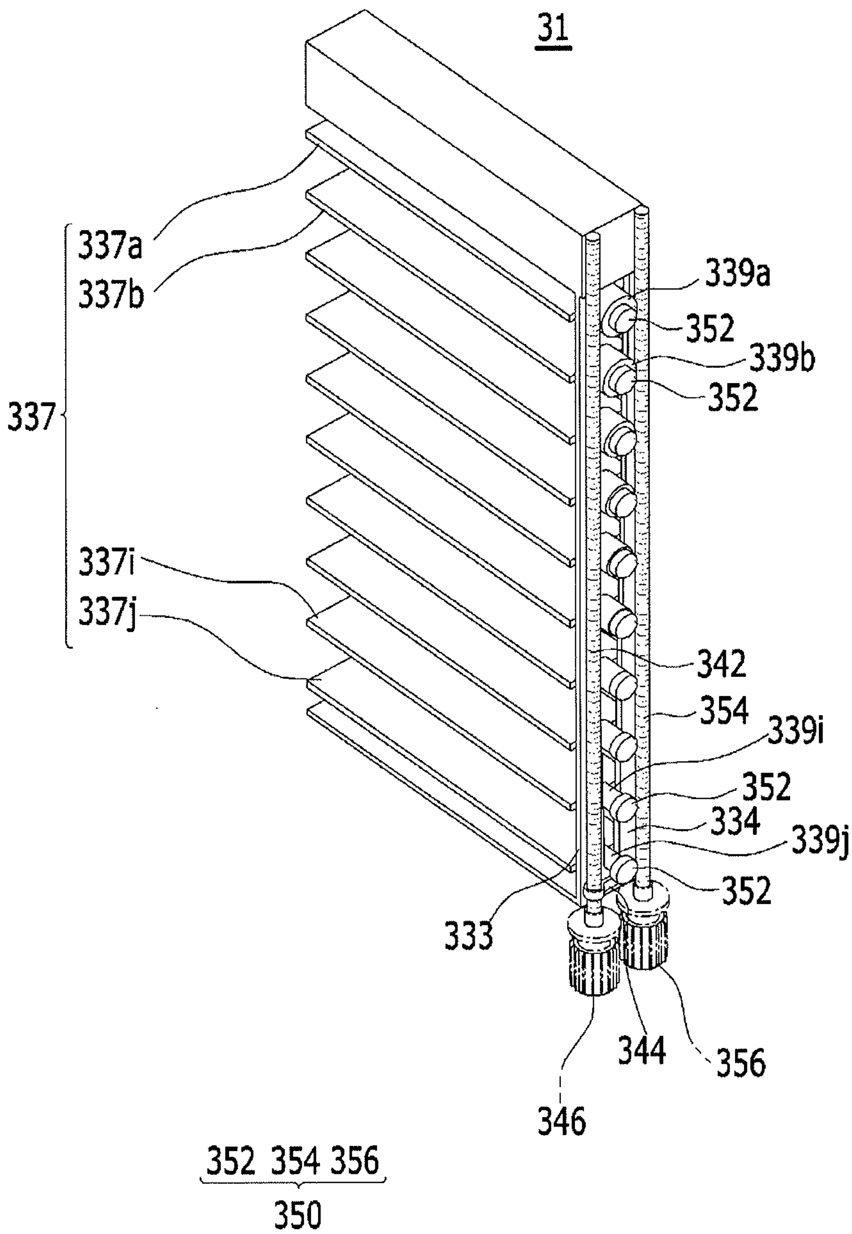

31
337a
337b
337
337i
337j
339a
352
339b
352
342
354
339i
352
334
339j
352
333
344
356
346
352 354 356
350

*FIG. 9*

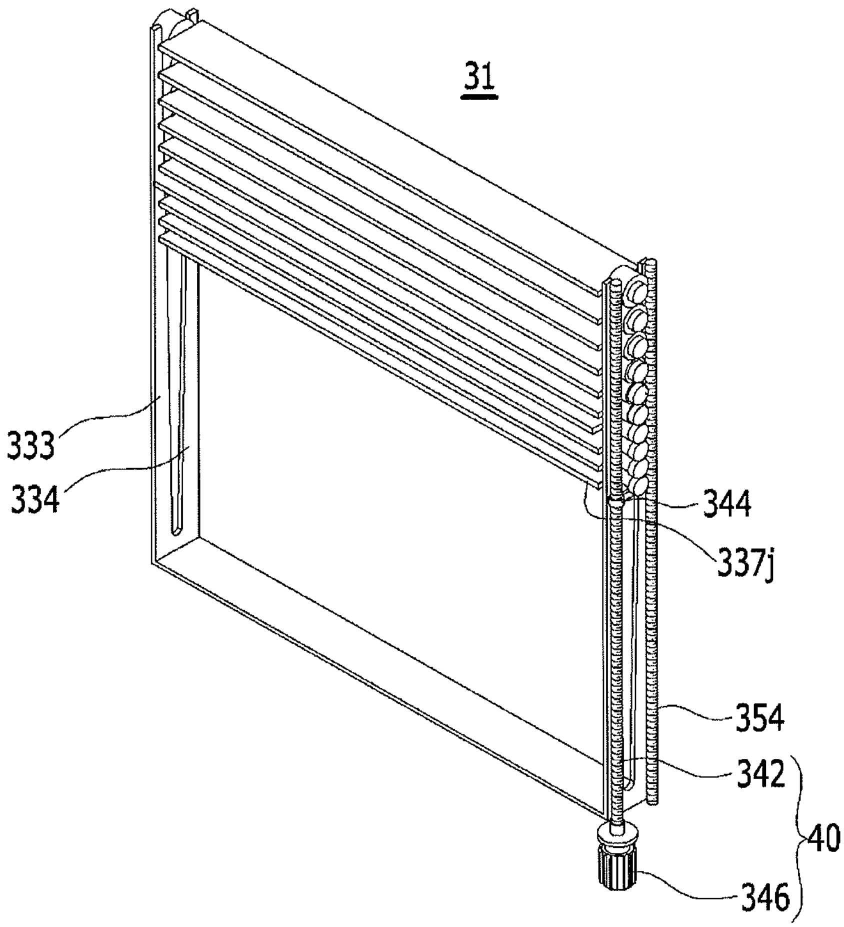


FIG. 10A

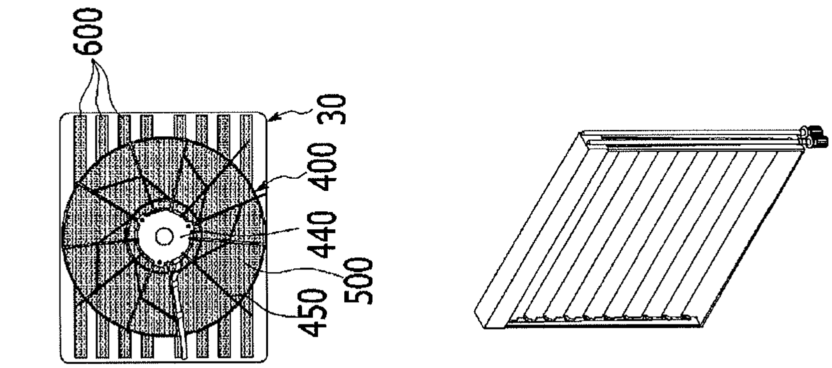



FIG. 10B

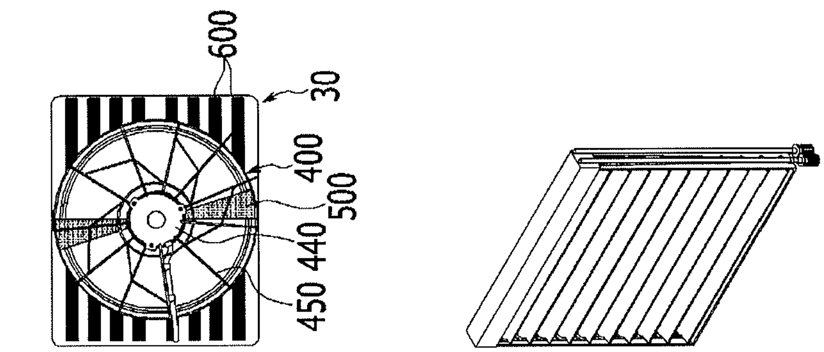



FIG. 10C

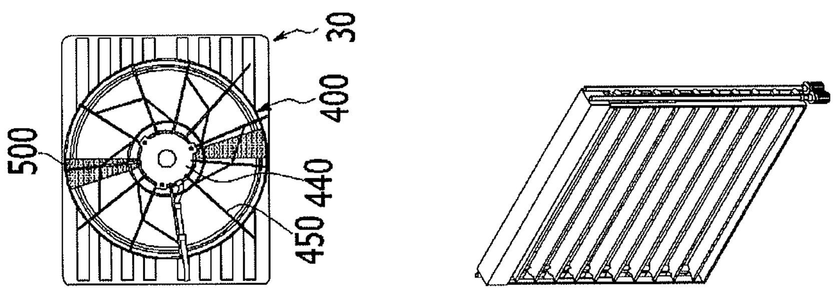
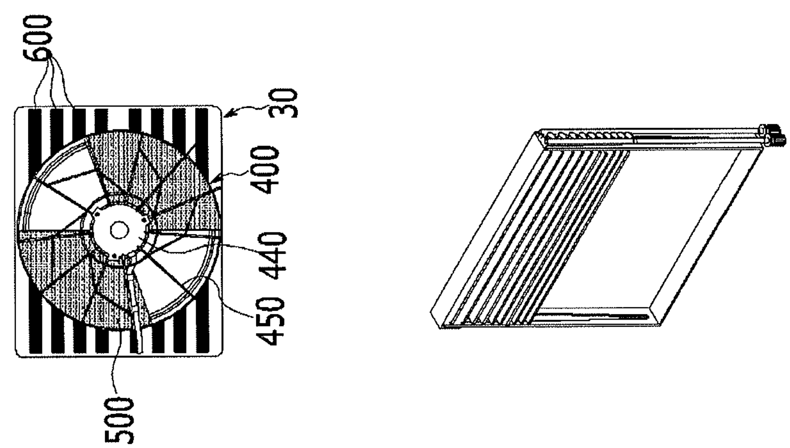



FIG. 10D



# SYSTEM FOR CONTROLLING AIR FLOW RATE INTO VEHICLE ENGINE COMPARTMENT

## CROSS-REFERENCE TO RELATED APPLICATION

The present application claims priority to Korean Patent Application No. 10-2014-0053635 filed May 2, 2014, the entire contents of which is incorporated herein for all purposes by this reference.

## BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a system for controlling a rate of air flow into a vehicle engine compartment and a control method thereof, and more particularly, to a system for controlling a rate of air flow rate into a vehicle engine compartment and a control method thereof which may improve cooling performance and aerodynamic performance of a vehicle.

Description of Related Art

In general, a radiator for cooling an engine and a condenser for condensing a refrigerant in an air conditioner are mounted in a vehicle, and temperatures of the radiator and the condenser are lowered by operating a cooling fan. It is advantageous to quickly raise the temperature of the engine to an appropriate level when the vehicle is initially started in order to improve fuel efficiency, and the temperature of the engine needs to be maintained at an appropriate temperature after the vehicle is started.

The cooling fan is traditionally operated by operation of the engine, but this mechanical method has a drawback in that fuel efficiency of the vehicle deteriorates because the cooling fan is always operated whenever the engine is operated.

Recently, a method of operating an electric motor has been used, and with respect to the above method, the cooling fan is operated only out of necessity in response to a driving state of the vehicle such that there is an effect of improving fuel efficiency, and as a result, the use of this manner is increased.

Meanwhile, aerodynamic characteristics greatly affect fuel efficiency and speed of the vehicle when a traveling speed of the vehicle is increased, and when air flowing into an engine compartment of the vehicle is shut off when the vehicle travels at a high speed, drag, which is generated when air passes through the engine compartment, is reduced so that fuel efficiency may be improved.

The information disclosed in this Background of the Invention section is only for enhancement of understanding of the general background of the invention and should not be taken as an acknowledgement or any form of suggestion that this information forms the prior art already known to a person skilled in the art.

## BRIEF SUMMARY

Various aspects of the present invention are directed to providing a system for controlling a flow rate of air into a vehicle engine compartment and a control method thereof, which may improve cooling performance and aerodynamic performance of a vehicle.

In addition, various aspects of the present invention are directed to providing a system for controlling a flow rate of air into a vehicle engine compartment and a control method thereof, which may reduce drag by minimizing an operation of a cooling fan, and shutting off air flowing into an engine compartment out of necessity.



According to various aspects of the present invention, a system for controlling a flow rate of air into a vehicle engine compartment may include a radiator cooling coolant, a coolant inflow tank provided to one side of the radiator and temporarily storing coolant that cools an engine, a coolant exhaust tank provided to the other side of the radiator and temporarily storing coolant circulating past a cooling fin of the radiator from the coolant inflow tank, Phase Change Material (PCM) tanks provided to an exterior side of the coolant inflow tank and coolant exhaust tank and storing a phase change material heat-exchanging with the coolant stored in the coolant inflow tank and the coolant exhaust tank, and a conversion device converting a phase of the phase change material.

The phase change material may be sodium acetate.

The conversion device may include a metal plate provided in the phase change material, and an electromagnet changing a shape of the metal plate.

The system may further include a fan in which a cooling fan including a fan motor and a fan blade is mounted, the fan shroud being disposed between the radiator and the engine, a rotary shutter which is provided in the fan shroud while corresponding to an operation area of the fan blade, and in which an area through which air passes is varied in a circumferential direction, and a plurality of flaps which are provided in the fan shroud, and that open and close a part of a portion where the rotary shutter is not mounted.

The rotary shutter may include a plurality of shutter blades which are provided to be rotatable about a same rotation shaft, and a shutter actuator which rotates the plurality of shutter blades, and changes an area through which air passes.

The shutter blades may include an operation blade which is rotated about the rotation shaft by an operation of the shutter actuator, and a plurality of sub-blades which are provided to be superimposed on a basis of the rotation shaft so as to be spread or folded fanwise in accordance with rotation of the operation blade.

Operation protrusions may be provided to the shutter blades, respectively, and when the operation blade is spread or folded, any one of the plurality of sub-blades may be spread or folded, and the remaining sub-blades may be sequentially spread or folded.

Electromagnets may be provided on the plurality of flaps so that the plurality of flaps are opened and closed in accordance with an electric current supplied to the electromagnets.

The system may further include an air flow rate control shutter apparatus disposed between the radiator and a condenser disposed at the front of the radiator, in which the air flow rate control shutter apparatus may include vertical supporting portions provided as a pair, a plurality of air flaps provided to the vertical supporting portion so as to be spread or folded, a delivery unit selectively spreading the air flaps, a rotation unit selectively rotating the air flaps, and a controller controlling the delivery unit and the rotation unit according to an operation status of a vehicle.

The vertical supporting portion may include a guide rail having a width which becomes smaller along a lower direction, in which stoppers may be provided in the plurality of air flaps, and the stoppers have a size corresponding to the width of the guide rail so that the plurality of air flaps are positioned at a predetermined position.

The delivery unit may include a delivery screw provided to any one of the guide rails, a delivery plate supporting the lowest air flap of the plurality of air flaps, engaged with the delivery screw, and adjusting a position of the lowest air flap when the delivery screw is rotated, and a delivery motor selectively rotating the delivery screw.

The rotation unit may include rotation gears respectively engaged to the plurality of air flaps, a rotation screw provided to another guide rail and selectively engaged with the rotation gears, and a rotation motor selectively rotating the rotation screw.

The delivery unit may include a delivery screw provided to any one of the guide rails, and a delivery plate supporting the lowest air flap of the plurality of air flaps, engaged with the delivery screw, and adjusting a position of the lowest air flap when the delivery screw is rotated, the rotation unit may include rotation gears respectively engaged to the plurality of air flaps and a rotation screw provided to the other guide rail and selectively engaged with the rotation gears, and the air flow rate control shutter apparatus may further include a driving motor selectively rotating the delivery screw or the rotation screw.

The system may further include an encapsulator which surrounds the engine compartment.

The system may further include a controller controlling an open area of the rotary shutter, operations of opening and closing the plurality of fan flaps, the cooling fan, the delivery unit, and the rotation unit according to an operation status of the vehicle, in which the operation modes of the system may include a first mode in which the plurality of flaps are closed, the rotary shutter is completely closed, the plurality of air flaps are completely closed, and the operation of the cooling fan is turned off, a second mode in which the plurality of fan flaps are closed, the rotary shutter is completely opened, a rotation angle of the air flaps is controlled in a state that the plurality of air flaps are expanded, and the operation of the cooling fan is turned off, a third mode in which the plurality of fan flaps are opened, the rotary shutter is completely opened, the air flaps are completely opened in a state that the plurality of air flaps are expanded, and the operation of the cooling fan is turned off, and a fourth mode in which the plurality of fan flaps are closed, the open area of the rotary shutter is controlled, the plurality of air flaps are folded, and the operation of the cooling fan is controlled.

The system may further include an atmospheric temperature sensor which measures atmospheric temperature, and outputs a corresponding signal, a speed sensor which measures a vehicle speed, and outputs a corresponding signal, an air conditioning pressure sensor which measures air conditioning internal pressure, and outputs a corresponding signal, an air conditioning switch sensor which measures an operational signal of an air conditioning switch, and outputs a corresponding signal, a refrigerant temperature sensor which measures a refrigerant temperature, and outputs a corresponding signal, and a position sensor which measures the open area of the rotary shutter, and outputs a corresponding signal, in which the control unit determines the operating state of the vehicle based on the corresponding signals from the respective sensors, and controls operations of the rotary shutter, the plurality of flaps, and the cooling fan in accordance with the operating state of the vehicle in any one mode of the first to fourth modes.

According to various aspects of the present invention, since the coolant inflow tank and the coolant exhaust tank are provided to both sides of the radiator, an additional refrigerant storing tank does not need to be provided. Therefore, a degree of freedom for designing the vehicle engine compartment is increased.

Further, since the PCM tank is provided to the exterior of the coolant inflow tank and the coolant exhaust tank, cooling efficiency of the radiator is improved through heat-exchange between the coolant and the PCM.

Further, cooling performance may be improved by controlling use of the cooling fan based on the driving state of the vehicle, and aerodynamic performance may be improved by adjusting an amount of air flowing into the vehicle engine compartment.

It is understood that the term “vehicle” or “vehicular” or other similar terms as used herein is inclusive of motor vehicles in general such as passenger automobiles including sports utility vehicles (SUV), buses, trucks, various commercial vehicles, watercraft including a variety of boats and ships, aircraft, and the like, and includes hybrid vehicles, electric vehicles, plug-in hybrid electric vehicles, hydrogen-powered vehicles and other alternative fuel vehicles (e.g., fuel derived from resources other than petroleum). As referred to herein, a hybrid vehicle is a vehicle that has two or more sources of power, for example, both gasoline-powered and electric-powered vehicles.

The methods and apparatuses of the present invention have other features and advantages which will be apparent from or are set forth in more detail in the accompanying drawings, which are incorporated herein, and the following Detailed Description, which together serve to explain certain principles of the present invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional view illustrating an exemplary system for controlling a rate of air flow into a vehicle engine compartment according to the present invention.

FIG. **2** is a block diagram illustrating the exemplary system for controlling the rate of air flow into the vehicle engine compartment according to the present invention.

FIG. **3**A and FIG. **3**B are schematic diagrams illustrating the exemplary system for controlling the rate of air flow into the vehicle engine compartment according to the present invention.

FIG. **4**A and FIG. **4**B are cross-sectional views illustrating a radiator, a refrigerant storing tank, and a PCM tank according to the present invention.

FIG. **5** is a top plan view illustrating a fan shroud according to the present invention.

FIG. **6**A and FIG. **6**B are views illustrating a fan flap of the fan shroud according to the present invention.

FIG. **7** is a perspective view illustrating an air flow rate control shutter apparatus according to the present invention.

FIG. **8** is a partial perspective view illustrating the air flow rate control shutter apparatus according to the present invention.

FIG. **9** is a perspective view illustrating the air flow rate control shutter apparatus in which the air flap is folded according to the present invention.

FIG. **10**A, FIG. **10**B, FIG. **10**C, FIG. **10**D are views illustrating operation modes of the fan shroud and the air flow rate control shutter apparatus according to the present invention.

It should be understood that the appended drawings are not necessarily to scale, presenting a somewhat simplified representation of various features illustrative of the basic principles of the invention. The specific design features of the present invention as disclosed herein, including, for example, specific dimensions, orientations, locations, and shapes will be determined in part by the particular intended application and use environment.

## DETAILED DESCRIPTION

Reference will now be made in detail to various embodiments of the present invention(s), examples of which are illustrated in the accompanying drawings and described below. While the invention(s) will be described in conjunction with exemplary embodiments, it will be understood that the present description is not intended to limit the invention(s) to those exemplary embodiments. On the contrary, the invention(s) is/are intended to cover not only the exemplary embodiments, but also various alternatives, modifications, equivalents and other embodiments, which may be included within the spirit and scope of the invention as defined by the appended claims.

FIG. **1** is a cross-sectional view illustrating a system for controlling a flow rate of air into a vehicle engine compartment according to various embodiments of the present invention. FIG. **2** is a block diagram illustrating the system for controlling the flow rate of air into the vehicle engine compartment according to various embodiments of the present invention. FIG. **3**A and FIG. **3**B are schematic diagrams illustrating the system for controlling a flow rate of air into the vehicle engine compartment according to various embodiments of the present invention. FIG. **3**A illustrates a state in which air flows into an engine compartment, and FIG. **3**B illustrates a state in which air is blocked from the engine compartment.

As shown in FIG. **1**, FIG. **2**, FIG. **3**A and FIG. **3**B, a system for controlling a rate of air flow into a vehicle engine compartment includes a radiator **80** cooling a coolant, a coolant inflow tank **810** and a coolant exhaust tank **830** provided at respective sides of the radiator **80**, an air flow rate control shutter apparatus provided at front of the radiator **80** and controlling an amount of air flowing into an engine **70**, a fan shroud **30**, a cooling fan **20** provided at the rear of the fan shroud **30**, and a controller **100** controlling the fan shroud **30**, the cooling fan **20**, and the air flow rate control shutter apparatus.

A condenser **82** may be provided at the front of the radiator **80**.

The system for controlling the rate of air flow into the vehicle engine compartment according to various embodiments of the present invention may further include an encapsulator **90** that surrounds the engine compartment, and the encapsulator **90** serves to prevent noise and vibration generated by the engine **70** from being transmitted to the outside of the vehicle body **10**, and reduces drag by guiding wind which is generated when the vehicle travels when the wind flows into the engine compartment.

In addition, the encapsulator **90** preserves heat generated in the engine **70**, and may enable the engine **70** to be operated at an optimum operation temperature when the vehicle travels again in a predetermined time after the vehicle stops.

The encapsulator **90** is formed to enclose the upper portion, the side portion, and the lower portion of the engine **70** in the engine compartment. That is, the encapsulator **90** is not formed to enclose the entire engine **70**, and is formed to be opened at a part of the engine.

Referring to FIG. **2**, the system for controlling a rate of air flow into a vehicle engine compartment may include an atmospheric temperature sensor **110** which measures an atmospheric temperature and outputs a corresponding signal, a speed sensor **120** which measures a vehicle speed and outputs a corresponding signal, an air conditioning pressure sensor **130** which measures air conditioning internal pressure and outputs a corresponding signal, an air conditioning switch sensor **140** which measures an operational signal of an air conditioning switch and outputs a corresponding signal, a refrigerant temperature sensor **150** which measures a refrigerant temperature and outputs a corresponding signal, and a position sensor **170** which measures an open area of the rotary shutter **400** and outputs a corresponding signal. The controller **100** receives output signals of respective sensors, determines the operating state of the vehicle based on the corresponding signals from the respective sensors, and controls the cooling fan **20**, the fan shroud **30**, and an air flow rate control shutter apparatus **31**.

FIG. **4**A and FIG. **4**B are cross-sectional views illustrating a radiator, a refrigerant storing tank, and a PCM (phase change material) tank **820** according to various embodiments of the present invention.

As shown in FIG. **4**A and FIG. **4**B, the radiator **80** includes cooling fins, a coolant inflow tank **810**, and a coolant exhaust tank **830**. The radiator **80** cools coolant that cools the engine **70** with air, and thereby has a high temperature. The coolant inflow tank **810** is provided to one side of the radiator **80**, and temporarily stores coolant that cools the engine **70**. The coolant exhaust tank **830** is provided to the other side of the radiator **80**, and temporarily stores coolant that circulates past the cooling fins from the coolant inflow tank **810**.

The PCM tank **820** may be provided to an exterior side of the coolant inflow tank **810** and the coolant exhaust tank **830**, and stores a phase change material. The phase change material (PCM) stored in the PCM tank **820** heat-exchanges with the coolant temporarily stored in the coolant inflow tank **810** and the coolant exhaust tank **830**.

The phase change material may be a supersaturated solution such as sodium acetate tri-hydrate (SAT).

A conversion device for converting the phase of the phase change material is provided in the phase change material. The conversion device includes a metal plate **822** provided in the phase change material and an electromagnet **824** that changes a shape of the metal plate **822**. The electromagnet **824** may be disposed at the exterior of the PCM tank **820**.

The metal plate **822** is a thin plate having elastic force, and the metal plate **822** is formed with a protrusion and depression shape in the PCM tank **820** formed with a hemispheric shape.

When magnetic force is generated by the electromagnet **824**, the metal plate moves in a direction in which the electromagnet **824** is positioned, and is deformed by colliding with the PCM tank. Impact is applied to the phase change material in the PCM tank **820** by the deformation of the metal plate **822**.

Since the supersaturated solution such as sodium acetate is very unstable, the supersaturated solution easily reacts through a small impact. Therefore, when the shape of the metal plate is deformed by the electromagnet and impact is applied to the sodium acetate, an exothermic reaction is generated as the sodium acetate of the liquid state is converted to a solid state. However, when the sodium acetate absorbs heat, the sodium acetate is dissolved and converted back to the liquid state.

By using the above method, the coolant is efficiently cooled, and the temperature of the coolant may be constantly maintained as necessary.

In particular, when the engine **70** needs to be cooled, heat of the coolant stored in the coolant inflow tank **810** and the coolant exhaust tank **830** is transmitted to the phase change material stored in the PCM tank **820**. At this time, the phase change material absorbing heat from the coolant is converted to the liquid state (refer to FIG. **4**A).

As such, heat-exchange occurs between the heated coolant by cooling the engine and the phase change material before and after the coolant passes through the radiator **80**. Therefore, cooling efficiency of the coolant is improved.

On the contrary, when the engine **70** does not need to be cooled, the metal plate **822** in the PCM tank **820** is deformed by the electromagnet **824**. When impact is applied to the phase change material in the PCM tank **820** as the metal plate is deformed, an exothermic reaction is generated as the phase change material in the liquid state is converted to the solid state (refer to FIG. **4**B).

Heat generated from the phase change material is transmitted to the coolant stored in the coolant inflow tank **810** and the coolant exhaust tank **830**. Therefore, the temperature of the coolant can be maintained over a predetermined temperature.

Here, a status when the engine **70** does not need to be cooled may be a status of warm-up of the engine **70** for a predetermined time after the engine **70** starts, a state that the temperature of the engine **70** does not need to be maintained while the engine **70** is turned off, or the vehicle travels at a high speed with a low load.

Since refrigerant storing tanks (the coolant inflow tank and the coolant exhaust tank) are provided at respective sides of the radiator **80**, an additional refrigerant storing tank does not need to be provided in a coolant line. Therefore, a degree of freedom for designing the vehicle engine compartment is increased.

A circulating process of the coolant will now be briefly described. The coolant having a high temperature by circulating in the engine **70** is temporarily stored in the coolant inflow tank **810**. The coolant stored in the coolant inflow tank **810** is heat-exchanged with the phase change material stored in the PCM tank **820**. The coolant temporarily stored in the coolant inflow tank **810** is circulated through the radiator **80** and cooled by heat-exchange with air flowing from the outside. The coolant circulating through the radiator **80** is temporarily stored in the coolant exhaust tank **830**. The coolant temporarily stored in the coolant exhaust tank **830** is heat-exchanged with the phase change material stored in the PCM tank **820**. The coolant stored in the coolant exhaust tank **830** flows again into the engine **70**. The circulation of the coolant is performed by a water pump **72**.

Hereinafter, the fan shroud **30** and the cooling fan **20** will be described in detail. FIG. **5** is a top plan view illustrating a fan shroud according to various embodiments of the present invention. FIG. **6**A and FIG. **6**B are views illustrating a fan flap of the fan shroud according to various embodiments of the present invention.

Referring to FIG. **5**, the fan shroud **30** includes a cooling fan **20** including a fan motor **22** and a fan blade **24**. A rotary shutter **400** is provided in the fan shroud **30** while corresponding to an operation area of the fan blade **24**, and in which an area through which air passes is varied in a circumferential direction. A plurality of fan flaps **600** are provided in the fan shroud **30**, and open and close a part of a portion where the rotary shutter **400** is not mounted. A controller **100** is provided in the fan shroud **30**, controls an open area of the rotary shutter **400**, operations of opening and closing the plurality of fan flaps **600**, and the cooling fan **20** according to an operation status of the vehicle.

The rotary shutter **400** includes a plurality of shutter blades **500** which are provided to be rotatable about a rotation shaft **420**, and a shutter actuator **440** which rotates the plurality of shutter blades **500** and changes an area through which air passes.

The shutter actuator **440** may be a servo motor capable of being rotated in forward and reverse directions, and may be mounted in the fan shroud **30** by mounting supporters **450**.

The shutter blades **500** include an operation blade **520** which is rotated about the rotation shaft **420** by an operation of the shutter actuator **440**, and a plurality of sub-blades **540** which are provided to be superimposed on the basis of the rotation shaft **420** so as to be spread fanwise or folded in accordance with the rotation of the operation blade **520**.

When the operation blade **520** is spread or folded, any one of the plurality of sub-blades **540** may be spread or folded, and then the remaining sub-blades **540** may be sequentially spread or folded.

The operation blade **520** and the sub-blades **540** are superimposed on the basis of the rotation shaft **420**, and when the operation blade **520** is rotated about the rotation shaft **420** at a predetermined angle by an operation of the shutter actuator **440**, the sub-blade **540** which is closest to the operation blade **520** is rotated while a protrusion formed at the sub-blade **540** is caught by the protrusion of the operation blade **520**.

In this manner, the respective sub-blades **540** illustrated in the drawings are sequentially spread fanwise.

On the contrary, when the shutter actuator **440** rotates the operation blade **520** in the reverse direction, the sub-blade **540** which is closest to the operation blade **520** is rotated in the reverse direction while the protrusion of the sub-blade **540** is pushed by the opposite protrusion of the operation blade **520**.

In this manner, the respective sub-blades **540** illustrated in the drawings are sequentially folded.

Mounting protrusions **580** may be formed on the sub-blade **540** that is positioned at the very end among the sub-blades **540** so that the sub-blade **540** may be fixed to the fan shroud **30**.

Electromagnets are provided on the plurality of flaps **600**, such that the plurality of flaps **600** may be opened and closed in accordance with an electric current supplied to the electromagnets, and flap rotation shafts are provided on the flaps **600**, respectively, so that the flaps **600** may be rotated about the rotation shafts, respectively.

The flap rotation shaft may be a torsion spring, and the flap **600** may be maintained in an opened state when the electric current is not supplied to the electromagnet. In the case of failure of an electric current supply device, the flap **600** is maintained in the opened state so as to prevent the engine **70** from being overheated.

Hereinafter, the air flow rate control apparatus will be described in detail. FIG. **7** is a perspective view illustrating an air flow rate control shutter apparatus according to various embodiments of the present invention. FIG. **8** is a partial perspective view illustrating the air flow rate control shutter apparatus according to various embodiments of the present invention. FIG. **9** is a perspective view illustrating the air flow rate control shutter apparatus in which the air flap is folded according to various embodiments of the present invention.

Referring to FIG. **7** to FIG. **9**, the air flow rate control shutter apparatus **31** includes vertical supporting portions provided as pairs, a plurality of air flaps **337** provided to the vertical supporting portion so as to be spread or folded, a delivery unit **340** selectively spreading the air flaps **337**, and a rotation unit **350** selectively rotating the air flaps **337**.

The vertical supporting portion includes a vertical supporting cover **332**, a guide rail **335** provided in the vertical supporting cover **332** and having a width which becomes smaller along a lower direction, and stoppers **339***a* to **339***j* provided in the plurality air flaps **337***a* to **337***j*, wherein the stoppers have a size corresponding to the width of the guide rail **335** so that the plurality of air flaps are positioned at a predetermined position.

The guide rail **335** includes a front guide rail **333** and a rear guide rail **334**, and a distance between the front guide rail **333** and the rear guide rail **334** becomes smaller along a lower direction. A size of the stoppers **339***a* to **339***j* provided to the plurality of air flaps **337***a* to **337***j* is decreased in proportion to the distance between the front guide rail **333** and the rear guide rail **334**.

The delivery unit **340** includes a delivery screw **342** provided to any one of the guide rails **335** (for example, the front guide rail **333**), a delivery plate **344** supporting the lowest air flap of the plurality of air flaps **337***a* to **337***j*, engaged with the delivery screw **342**, and adjusting a position of the lowest air flap when the delivery screw **342** is rotated, and a delivery motor **346** selectively rotating the delivery screw **342**.

The rotation unit **350** includes a rotation gear **352** respectively engaged to the plurality of air flaps, a rotation screw **354** provided to the other guide rail (for example, the rear guide rail **334**) and selectively engaged with the rotation gears **352**, and a rotation motor **356** selectively rotating the rotation screw **354**.

Hereinafter, operation of the air flow rate control shutter apparatus **31** will be described in detail.

When the controller **100** operates the delivery motor **346** in state that the plurality of air flaps **337***a* to **337***j* are folded according to an operation status of the vehicle, the delivery screw **342** is rotated, and the delivery plate **344** engaged with the delivery screw **342** is moved down.

Then, the stoppers **339***a* to **339***j* respectively engaged with the plurality of air flaps **337***a* to **337***j* are positioned to a predetermined position such that the size of the stopper **339***a* to **339***j* corresponds to the distance between the front guide rail **333** and the rear guide rail **334**.

When the controller **100** operates the rotation motor **356** according to the operation status of the vehicle, the rotation screw **354** is rotated, the plurality of air flaps **337***a* to **337***j* are rotated by the rotation gear **352**, and air flowing through the plurality of air flaps **337***a* to **337***j* is controlled.

When the controller **100** folds the plurality of air flaps **337***a* to **337***j* according to the operation status of the vehicle, the controller **100** controls operations of the rotation motor **356** and the delivery motor **346** in reverse order.

Hereinafter, operation of the system for controlling the air flow rate control apparatus for the vehicle according to various embodiments of the present invention will be described in detail with reference to FIG. **10**A, FIG. **10**B, FIG. **10**C, FIG. **10**D.

As shown in FIG. **10**A, FIG. **10**B, FIG. **10**C, FIG. **10**D, operation modes of the system according to various embodiments of the present invention may be divided into the following four modes.

A first mode is one in which the plurality of fan flaps **600** are closed, the rotary shutter **400** is completely closed, the plurality of air flaps **337***a* to **337***j* are completely closed, and the operation of the cooling fan **20** is turned off.

A second mode is one in which the plurality of fan flaps **600** are closed, the rotary shutter **400** is completely opened, a rotation angle of the air flap **337** is controlled in a state that the plurality of air flaps **337***a* to **337***j* are expanded, and the operation of the cooling fan **20** is turned off.

A third mode is one in which the plurality of fan flaps **600** are opened, the rotary shutter **400** is completely opened, the air flaps **337***a* to **337***j* are completely opened in a state that the plurality of air flaps **337***a* to **337***j* are expanded, and the operation of the cooling fan **20** is turned off.

A fourth mode is one in which the plurality of fan flaps **600** are closed, the open area of the rotary shutter **400** is controlled, the plurality of air flaps **337***a* to **337***j* are folded, and the operation of the cooling fan **20** is controlled.

The first mode is a state in which aerodynamic performance required for cooling of the engine is not required, for example, may be a state in which it is necessary to warm up the engine **70** for a predetermined time after the engine of the vehicle starts, a state in which it is necessary to maintain a temperature of the engine **70** when turning off the engine, or a state in which the vehicle travels in a high-speed and low-load condition. The corresponding condition may be stored in a predetermined map in advance, and the control unit **100** may compare the map with the operating state of the vehicle so as to determine the first mode.

The second mode is a state in which aerodynamic performance and cooling of the engine can be simultaneously optimized, the open area of the air flap **337** is controlled without operation of the cooling fan **20**, and the engine speed is low. The corresponding condition may be stored in a predetermined map in advance, and the control unit **100** may compare the map with the operating state of the vehicle so as to determine the second mode.

The third mode may be a state which corresponds to a high-speed and high-load condition, and the engine **70** can be cooled without operation of the cooling fan **20** at a high speed. The corresponding condition may be stored in a predetermined map in advance, and the control unit **100** may compare the map with the operating state of the vehicle so as to determine the third mode.

The fourth mode may be a state in which cooling performance is maintained at a low-speed and high-load condition, and operation of the cooling fan **20** can be determined by a coolant temperature, a vehicle speed, etc. The corresponding condition may be stored in a predetermined map in advance, and the control unit **100** may compare the map with the operating state of the vehicle so as to determine the fourth mode.

The low-speed or the high-speed condition, for example, may be that of a vehicle speed of about 30-40 kph or about 90-110 kph, but is not limited thereto. The high-load condition, for example, may be that of the engine RPM of about 2000-4000, but is not limited thereto.

As described above, according to the system for controlling a flow rate of air into a vehicle engine compartment according to various embodiments of the present invention, cooling performance may be improved by controlling use of the cooling fan **20**, the fan shroud **30**, and the air flow rate control shutter apparatus **31** based on the driving state of the vehicle, and aerodynamic performance may be improved by adjusting an amount of air flowing into the vehicle engine compartment.

Further, the coolant having a relatively high temperature temporally stored in the coolant inflow tank **810** and the coolant exhaust tank is heat-exchanged with the phase change material having a relatively low temperature stored in PCM tank **820** during circulation of the coolant cooling the engine. Therefore, cooling performance of the engine **70** is improved.

Further, when cooling of the engine is not required, the phase change material having a relatively high temperature stored in the PCM tank **820** is heat-exchanged with the coolant having a relatively low temperature stored in the coolant inflow tank **810** and the coolant exhaust tank **830**. Therefore, when a temperature of the engine compartment needs to be maintained at a predetermined temperature, it becomes easy to maintain the temperature of the engine compartment.

For convenience in explanation and accurate definition in the appended claims, the terms "upper", "lower", "inner" and "outer" are used to describe features of the exemplary embodiments with reference to the positions of such features as displayed in the figures.

The foregoing descriptions of specific exemplary embodiments of the present invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teachings. The exemplary embodiments were chosen and described in order to explain certain principles of the invention and their practical application, to thereby enable others skilled in the art to make and utilize various exemplary embodiments of the present invention, as well as various alternatives and modifications thereof. It is intended that the scope of the invention be defined by the Claims appended hereto and their equivalents.

What is claimed is:

**1**. A system for controlling a flow rate of air into a vehicle engine compartment, comprising:

a radiator cooling coolant;

a coolant inflow tank provided to one side of the radiator and temporarily storing coolant that cools an engine;

a coolant exhaust tank provided to the other side of the radiator and temporarily storing coolant circulating past a cooling fin of the radiator from the coolant inflow tank;

Phase Change Material (PCM) tanks provided to an exterior side of the coolant inflow tank and coolant exhaust tank and storing a phase change material heat-exchanging with the coolant stored in the coolant inflow tank and the coolant exhaust tank; and

a conversion device converting a phase of the phase change material.

**2**. The system of claim **1**, wherein the phase change material is sodium acetate.

**3**. The system of claim **1**, wherein the conversion device comprises:

a metal plate provided in the phase change material; and

an electromagnet changing a shape of the metal plate.

**4**. The system of claim **1**, further comprising:

a fan shroud in which a cooling fan including a fan motor and a fan blade is mounted, the fan shroud being disposed between the radiator and the engine;

a rotary shutter which is provided in the fan shroud while corresponding to an operation area of the fan blade, and in which an area through which air passes is varied in a circumferential direction; and

a plurality of flaps which are provided in the fan shroud, and that open and close a part of a portion where the rotary shutter is not mounted.

**5**. The system of claim **4**, wherein the rotary shutter includes:

a plurality of shutter blades which are provided to be rotatable about a same rotation shaft; and

a shutter actuator which rotates the plurality of shutter blades, and changes an area through which air passes.

**6**. The system of claim **5**, wherein the shutter blades include:

an operation blade which is rotated about the rotation shaft by an operation of the shutter actuator; and

a plurality of sub-blades which are provided to be superimposed on a basis of the rotation shaft so as to be spread or folded fanwise in accordance with rotation of the operation blade.

**7**. The system of claim **6**, wherein operation protrusions are provided to the shutter blades, respectively, and

when the operation blade is spread or folded, any one of the plurality of sub-blades is spread or folded, and the remaining sub-blades are sequentially spread or folded.

**8**. The system of claim **4**,

wherein electromagnets are provided on the plurality of flaps so that the plurality of flaps are opened and closed in accordance with an electric current supplied to the electromagnets.

**9**. The system of claim **4**, further comprising

a controller controlling an open area of the rotary shutter, operations of opening and closing the plurality of fan flaps, the cooling fan, the delivery unit, and the rotation unit according to an operation status of a vehicle,

wherein the operation modes of the system include:

a first mode in which the plurality of flaps are closed, the rotary shutter is completely closed, the plurality of air flaps are completely closed, and the operation of the cooling fan is turned off;

a second mode in which the plurality of fan flaps are closed, the rotary shutter is completely opened, a rotation angle of the air flaps is controlled in a state that the plurality of air flaps are expanded, and the operation of the cooling fan is turned off;

a third mode in which the plurality of fan flaps are opened, the rotary shutter is completely opened, the air flaps are completely opened in a state that the plurality of air flaps are expanded, and the operation of the cooling fan is turned off; and

a fourth mode in which the plurality of fan flaps are closed, the open area of the rotary shutter is controlled, the plurality of air flaps are folded, and the operation of the cooling fan is controlled.

**10**. The system of claim **9**, further comprising:

an atmospheric temperature sensor which measures atmospheric temperature, and outputs a corresponding signal;

a speed sensor which measures a vehicle speed, and outputs a corresponding signal;

an air conditioning pressure sensor which measures air conditioning internal pressure, and outputs a corresponding signal;

an air conditioning switch sensor which measures an operational signal of an air conditioning switch, and outputs a corresponding signal;

a refrigerant temperature sensor which measures a refrigerant temperature, and outputs a corresponding signal; and

a position sensor which measures the open area of the rotary shutter, and outputs a corresponding signal,

wherein the control unit determines the operating state of the vehicle based on the corresponding signals from the respective sensors, and controls operations of the rotary shutter, the plurality of flaps, and the cooling fan in accordance with the operating state of the vehicle in any one mode of the first to fourth modes.

**11**. The system of claim **1**, further comprising:

an air flow rate control shutter apparatus disposed between the radiator and a condenser disposed at the front of the radiator, wherein the air flow rate control shutter apparatus includes:

vertical supporting portions provided as a pair;

a plurality of air flaps provided to the vertical supporting portions so as to be spread or folded;

a delivery unit selectively spreading the air flaps;

a rotation unit selectively rotating the air flaps; and

a controller controlling the delivery unit and the rotation unit according to an operation status of a vehicle.

**12**. The system of claim **11**,

wherein the vertical supporting portion includes:

a guide rail having a width which becomes smaller along a lower direction,

wherein stoppers are provided in the plurality of air flaps, and the stoppers have a size corresponding to the width of the guide rail so that the plurality of air flaps are positioned at a predetermined position.

**13**. The system of claim **11**,

wherein the delivery unit includes:

a delivery screw provided to any one of the guide rails;

a delivery plate supporting the lowest air flap of the plurality of air flaps, engaged with the delivery screw, and adjusting a position of the lowest air flap when the delivery screw is rotated; and

a delivery motor selectively rotating the delivery screw.

**14**. The system of claim **11**,

wherein the rotation unit includes:

rotation gears respectively engaged to the plurality of air flaps;

a rotation screw provided to another guide rail and selectively engaged with the rotation gears; and

a rotation motor selectively rotating the rotation screw.

**15**. The system of claim **11**,

wherein the delivery unit includes:

a delivery screw provided to any one of the guide rails; and

a delivery plate supporting the lowest air flap of the plurality of air flaps, engaged with the delivery screw, and adjusting a position of the lowest air flap when the delivery screw is rotated,

wherein the rotation unit includes:

rotation gears respectively engaged to the plurality of air flaps; and

a rotation screw provided to another guide rail and selectively engaged with the rotation gears, and

wherein the air flow rate control shutter apparatus further includes a driving motor selectively rotating the delivery screw or the rotation screw.

**16**. The system of claim **1**, further comprising an encapsulator which surrounds the engine compartment.

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