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(54) **AIR CONDITIONER FOR A VEHICLE AND CONTROLLING METHOD THEREOF**

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(57) **ABSTRACT**

An object of the present invention is to provide an air conditioner and a controlling method thereof capable of effectively conditioning air in an operator cab of a vehicle even if a windshield or door of the operator cab is opened. The air conditioner comprises: a heating unit for heating an upper half of an operator's body; an open/close sensor for detecting opening and closing of the operator cab; and a controller for setting a heating power of the heating unit when the open/close sensor detects that the operator cab is opened, to be higher than the heating power of the heating unit when the operator cab is closed.

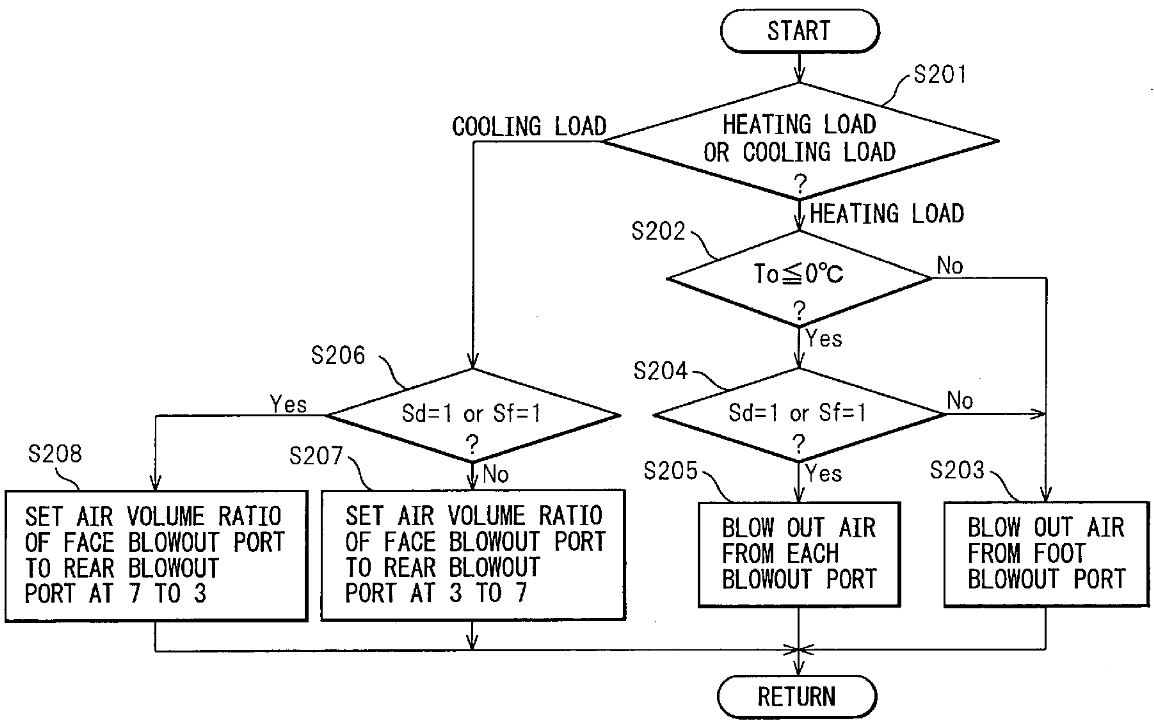


Fig. 1

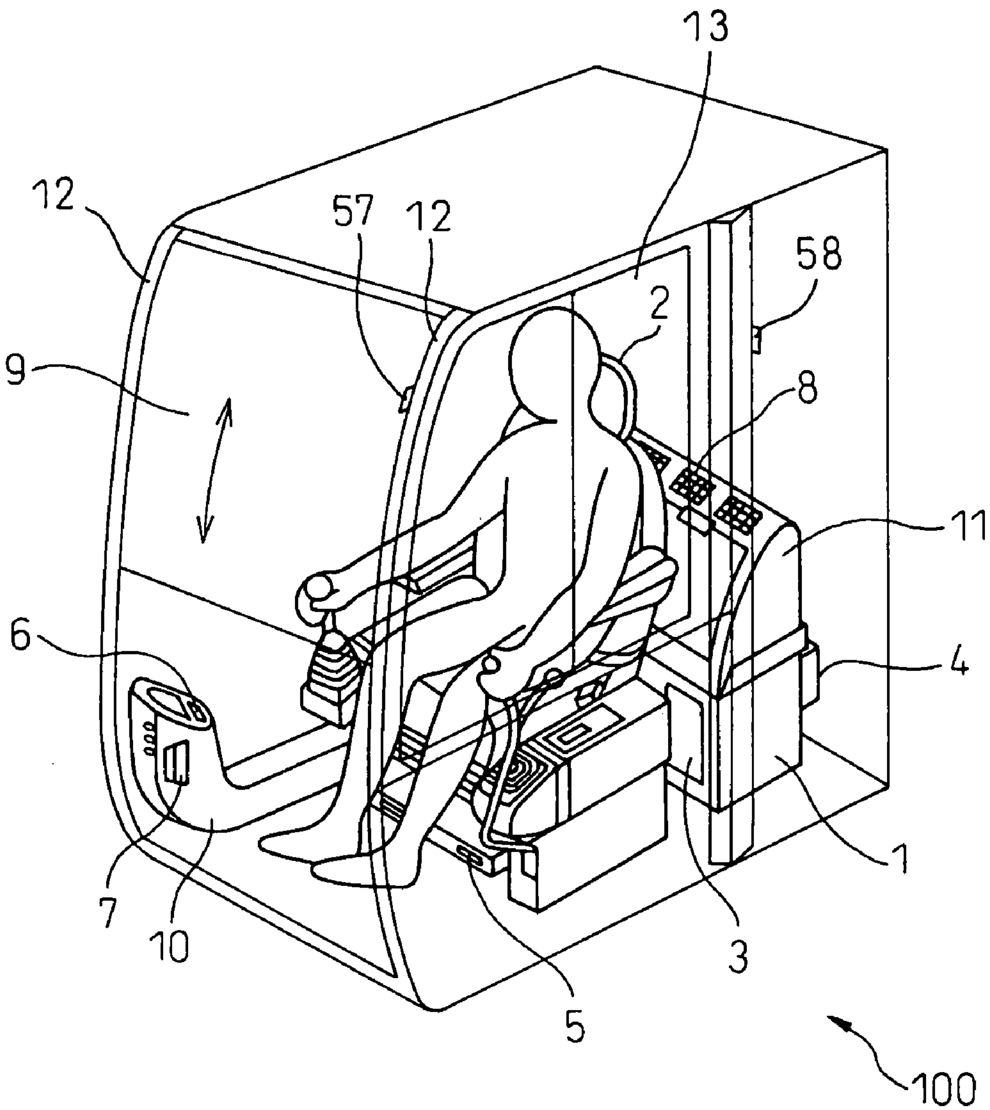
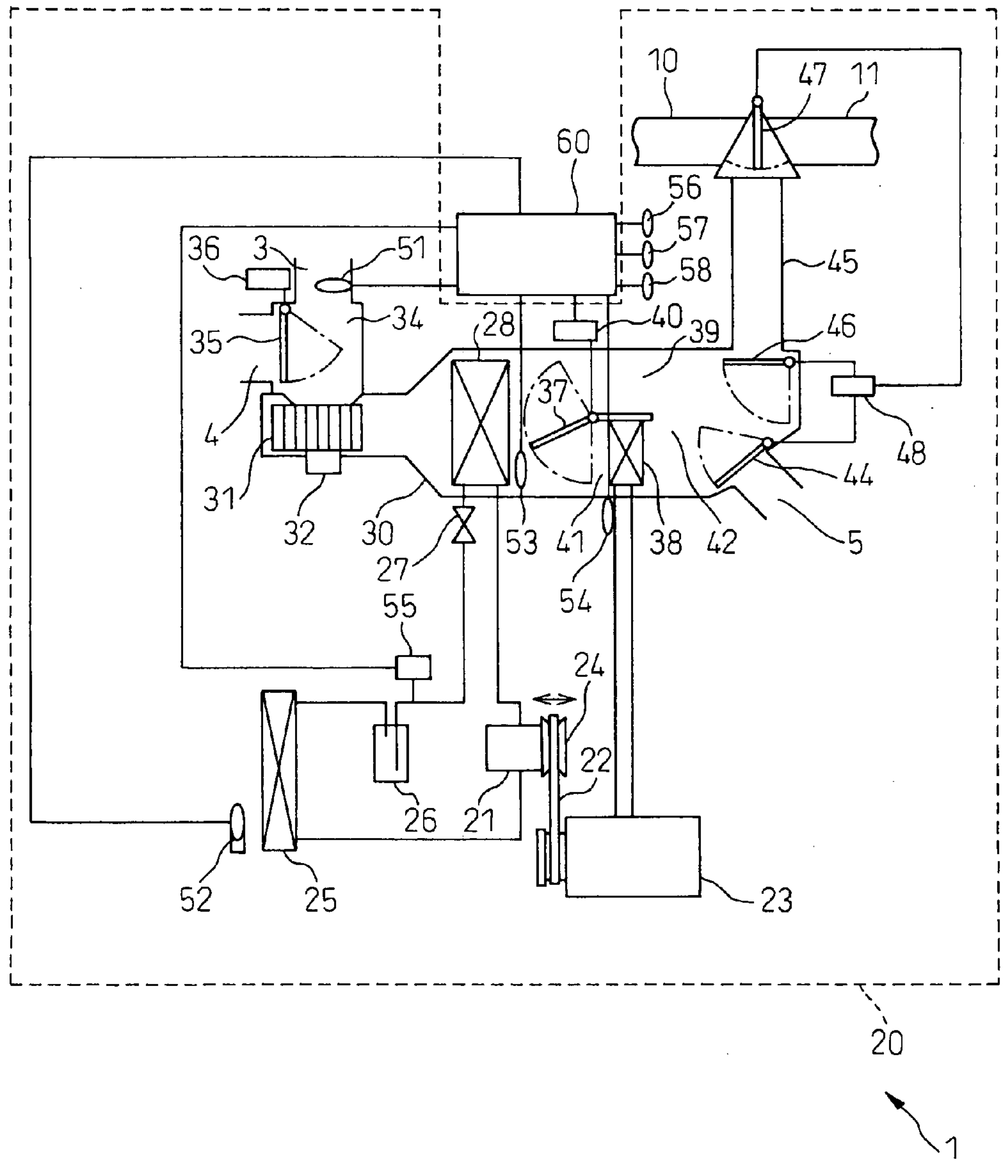


Fig.2



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1

Fig.3

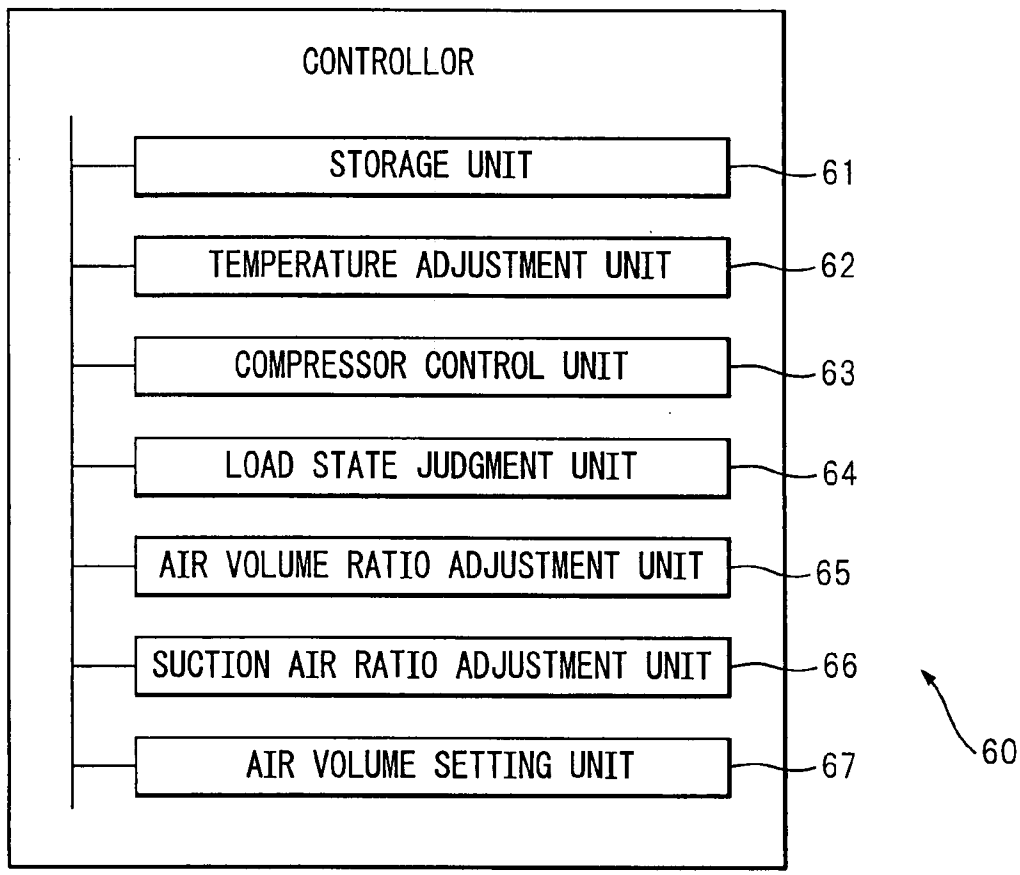

CONTROLLOR
STORAGE UNIT
61
TEMPERATURE ADJUSTMENT UNIT
62
COMPRESSOR CONTROL UNIT
63
LOAD STATE JUDGMENT UNIT
64
AIR VOLUME RATIO ADJUSTMENT UNIT
65
SUCTION AIR RATIO ADJUSTMENT UNIT
66
AIR VOLUME SETTING UNIT
67
60

Fig.4

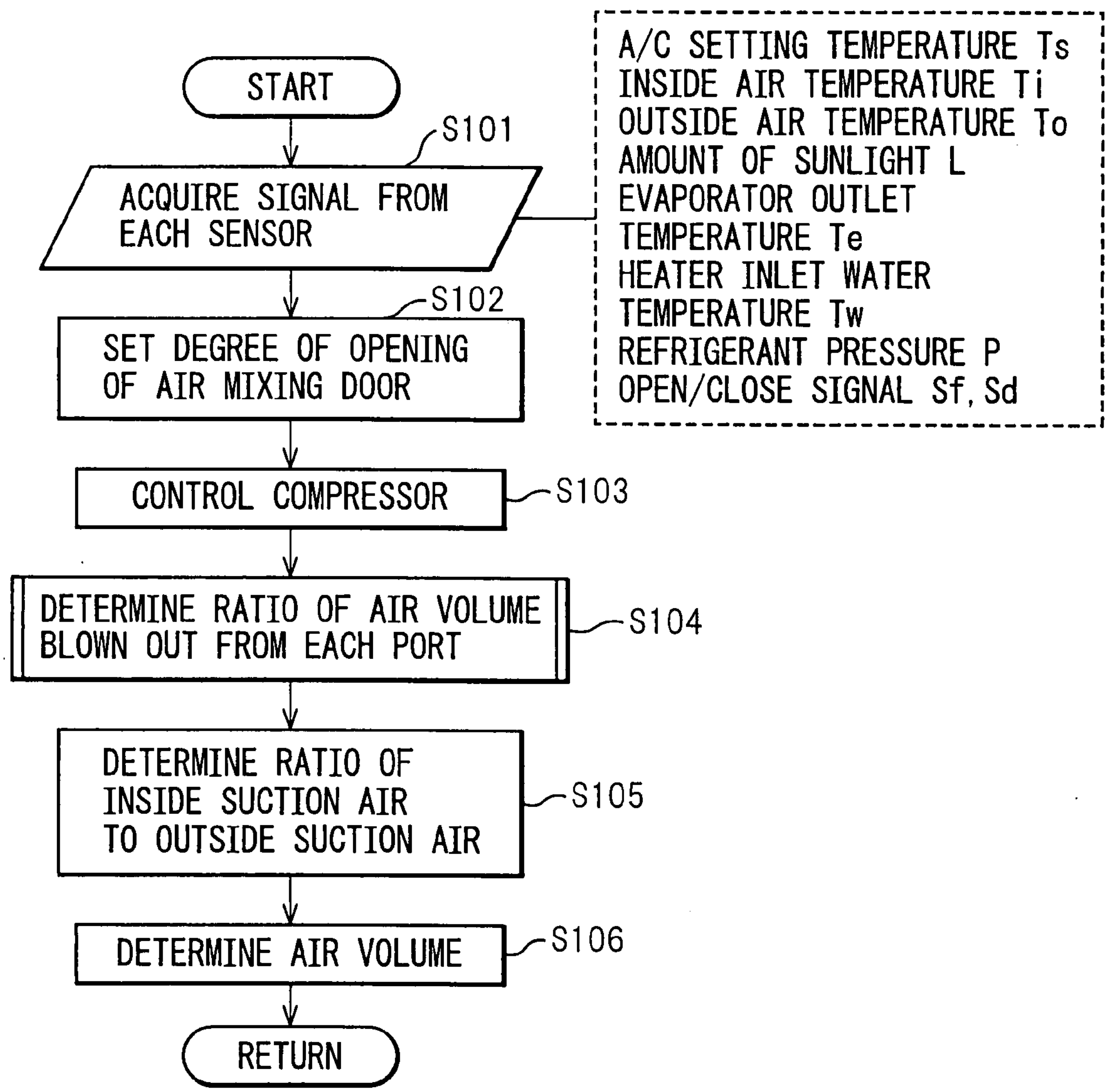
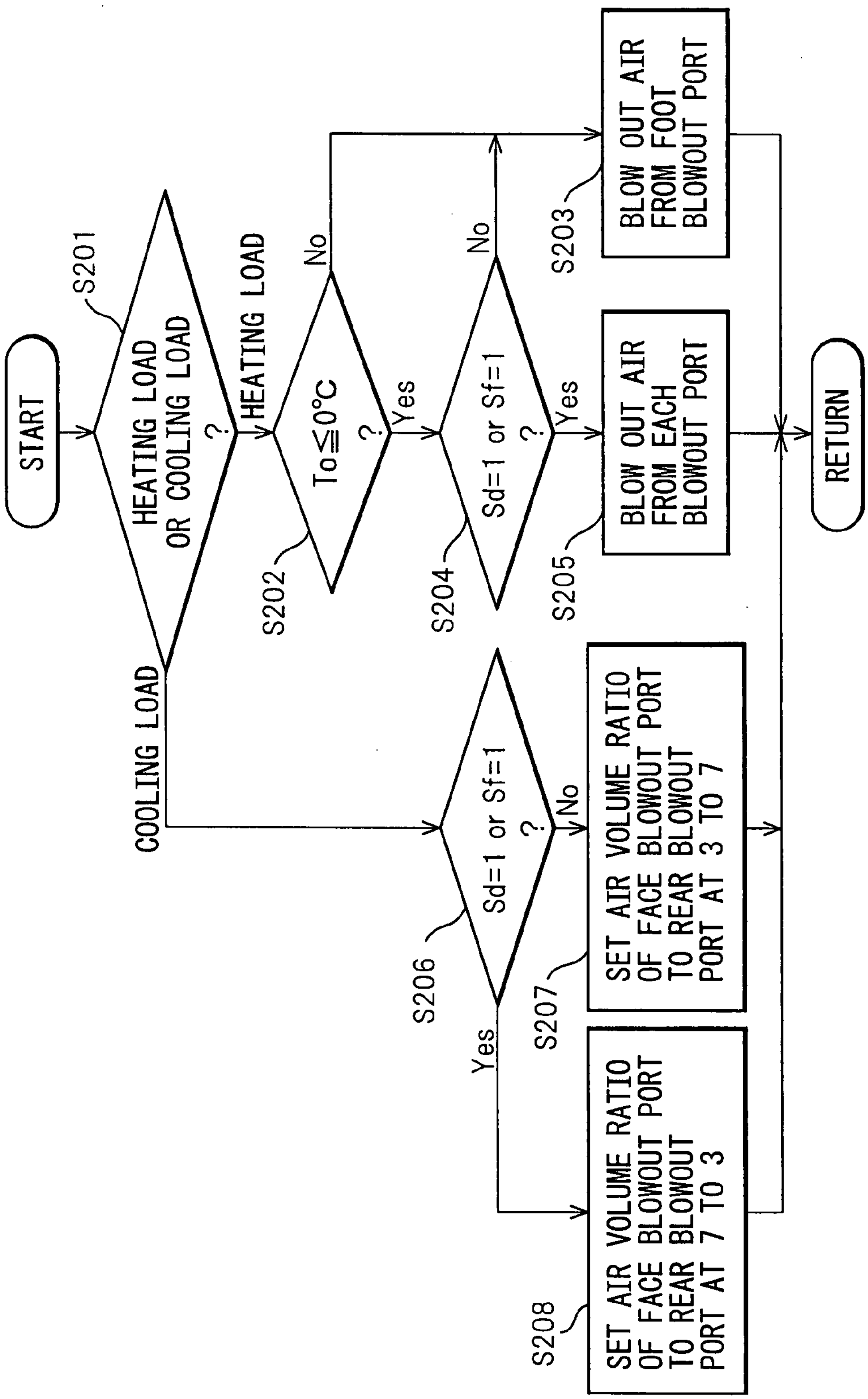

START
S101
ACQUIRE SIGNAL FROM EACH SENSOR
A/C SETTING TEMPERATURE Ts
INSIDE AIR TEMPERATURE Ti
OUTSIDE AIR TEMPERATURE To
AMOUNT OF SUNLIGHT L
EVAPORATOR OUTLET TEMPERATURE Te
HEATER INLET WATER TEMPERATURE Tw
REFRIGERANT PRESSURE P
OPEN/CLOSE SIGNAL Sf, Sd
S102
SET DEGREE OF OPENING OF AIR MIXING DOOR
CONTROL COMPRESSOR
S103
DETERMINE RATIO OF AIR VOLUME BLOWN OUT FROM EACH PORT
S104
DETERMINE RATIO OF INSIDE SUCTION AIR TO OUTSIDE SUCTION AIR
S105
DETERMINE AIR VOLUME
S106
RETURN

Fig.5


START
HEATING LOAD OR COOLING LOAD ?
S201
HEATING LOAD
COOLING LOAD
To≦0°C ?
S202
Yes
No
Sd=1 or Sf=1 ?
S204
Yes
No
BLOW OUT AIR FROM FOOT BLOWOUT PORT
S203
BLOW OUT AIR FROM EACH BLOWOUT PORT
S205
Sd=1 or Sf=1 ?
S206
Yes
No
SET AIR VOLUME RATIO OF FACE BLOWOUT PORT TO REAR BLOWOUT PORT AT 3 TO 7
S207
SET AIR VOLUME RATIO OF FACE BLOWOUT PORT TO REAR BLOWOUT PORT AT 7 TO 3
S208
RETURN

AIR CONDITIONER FOR A VEHICLE AND CONTROLLING METHOD THEREOF

[0001] The applicant claims the right of priority based on Japanese Patent Application JP 2006-219996, filed on Aug. 11, 2006, and the entire content of JP-2006-219996 is hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to an air conditioner for a vehicle and a controlling method thereof. More particularly, the present invention relates to an air conditioner for a construction vehicle and a controlling method thereof.

BACKGROUND OF THE INVENTION

[0003] Recently, even on a construction vehicle such as a power shovel, an air conditioner is mounted so that the operator cab can be maintained in a comfortable state. However, sometimes, the operator operates the construction vehicle, while a windshield or an entrance door of the operator cab is kept open, in order for the operator to communicate with a worker that is working outside the operator cab or in order for the operator to ensure a good field of vision. When the operator operates the construction vehicle while the windshield or the door is kept open, a large volume of outside air enters into the operator cab. Accordingly, it is impossible for the air conditioner to effectively condition air in the operator cab. Therefore, it is difficult to maintain the operator cab in a comfortable state.

[0004] In order to solve the above problems, Japanese patent application JP-A-2000-052742 by Asami et al. discloses an air conditioner for a construction vehicle, which enhances the cooling or the heating power thereof. When a sensor detects that the windshield or door is open, the air conditioner cools or heats according to its maximum capacity, and increases the volume of air blown out from a front face blowout port or a spot blowout port in order to blow conditioned air around the operator's seat. Due to the foregoing, it is possible to provide a comfortable cooling or heating state by the air conditioner without changing its setting.

[0005] However, when the operator opens the windshield or the door in order to ensure a good field of vision, the windshield or the door has to be fully opened in many cases. Therefore, when the windshield is open, even when the air conditioning capacity is simply enhanced so as to increase the volume of conditioned air to be blown out, most of the conditioned air immediately flows outside the operator cab. Accordingly, the effect of air conditioning cannot be improved much. On the contrary, the operational noise of the air conditioner is increased, which makes the operator feel uncomfortable.

SUMMARY OF THE INVENTION

[0006] An object of the present invention is to provide an air conditioner and a controlling method thereof capable of effectively conditioning air in an operator cab of a vehicle even if a windshield or door of the operator cab is opened.

[0007] According to one aspect of the present invention, an air conditioner for conditioning air in an operator cab of a vehicle is provided. The air conditioner comprises: a heating unit for heating the upper half of the body of the operator; an open/close sensor for detecting that the operator cab is opened or closed; and a controller for setting a heating power of the heating unit in the case where the open/close sensor detects that the operator cab is opened, to be higher than the heating power of the heating unit when the operator cab is closed. Due to the above constitution, while the operator cab is opened, the air conditioner intensively heats the upper half of the operator's body, ant thus, can effectively execute air-conditioning in the operator cab.

[0008] It is preferable that the heating unit comprises a front face heating unit for heating a front face of the operator. It is preferable that the controller sets a heating power of the front face heating unit when the open/close sensor detects that the operator is opened, to be higher than that when the operator cab is closed.

[0009] According to another aspect of the present invention, an air conditioner for conditioning air in an operator cab of a vehicle is provided. The air conditioner comprises: an air conditioning unit for generating conditioned air; at least a first blowout port for blowing out conditioned air, toward the upper half of the operator's body; a second blowout port for blowing the conditioned air; an open/close sensor for detecting whether the operator cab is opened or closed; and a controller for setting a ratio of volume of the conditioned air, which is blown out from the first blowout port in the conditioned air, which is blown out from each blowout port when the open/close sensor detects that the operator cab is opened, to be higher than the ratio of conditioned air when the operator cab is closed. Due to the above constitution, while the operator cab is opened, the conditioned air is concentrated on the periphery of the upper half of the operator's body. Therefore, the air conditioner can effectively execute air-conditioning in the operator cab.

[0010] It is preferable that the conditioned air is heated.

[0011] It is preferable that the above air conditioner is used for a construction vehicle.

[0012] It is preferable that the at least one first blowout port comprises a face blowout port for blowing out conditioned air to a front side of the operator. It is preferable that the controller sets the ratio of conditioned air which is blown out from the face blowout port in the conditioned air which is blown out from each blowout port, when the open/close sensor detects that the operator cab is opened to be higher than the ratio of conditioned air when the operator cab is closed. According to this constitution, the air conditioner increase a volume of air blown out to the face of the operator, which easily feels an effect of air conditioning. Therefore, the operator can feel more comfortable.

[0013] Further, it is preferable that the second blowout port is a blowout port arranged at the rear of a operator's seat. It is preferable that when the open/close sensor detects that the operator cab is opened, the controller sets the ratio of volume of the conditioned air so that the conditioned air is blown out from both the first blowout port and the second blowout port, and when the open/close sensor detects that the operator cab is closed, the controller sets the ratio of volume of the conditioned air so that the conditioned air is blown out only from the second blowout port.

[0014] Preferably, the air conditioner further comprises a temperature sensor for measuring a temperature of air in the operator cab or a temperature of air out the operator cab, and when the open/close sensor detects that the operator cab is opened and the measured outside air temperature or the measured inside air temperature is not higher than a predetermined temperature, the controller sets the ratio of volume of the conditioned air to be higher than the ratio of volume of the conditioned air when the operator cab is closed. By referring to the temperature of the outside air or the inside air, the air conditioner can only increase the volume of the conditioned air which is blown out from the first blowout port, in a cold season. Therefore, it is possible to prevent heating the operator cab too much.

[0015] It is preferable that the above air conditioner is used for a construction vehicle. The construction vehicle is usually a one-operator vehicle. Therefore, the operator cab of the construction vehicle is small. Accordingly, when the operator cab is opened, the temperature in the operator cab is remarkably changed. Therefore, by applying the air conditioner of the present invention to the construction vehicle, the air conditioning effect can be greatly improved while the operator cab is opened.

[0016] According to still another aspect of the present invention, the present invention provides a control method of an air conditioner for conditioning air in an operator cab of a vehicle, the air conditioner comprising a heating unit for heating the upper half of the operator's body working in the operator cab. The control method comprises detecting whether the operator cab is opened or closed, and setting the heating power of the heating unit when it is detected that the operator cab is opened, to be higher than the heating power when it is detected that the operator cab is closed.

[0017] According to still another aspect of the present invention, the present invention provides a control method of controlling an air conditioner for conditioning air in an operator cab of a vehicle, the air conditioner comprising an air conditioning unit for generating conditioned air, at least one first blowout port for blowing conditioned air to the upper half of the operator's body and a second blowout port for blowing the conditioner air. The control method comprises: detecting whether the operator cab is opened or closed and setting a ratio of volume of the conditioned air which blown out from the first blowout port when it is detected that the operator cab is opened, to be higher than the ratio of volume of the conditioned air when it is detected that the operator cab is closed.

DESCRIPTION OF THE DRAWINGS

[0018] These and other features and advantages of the present invention will be better understood by reading the following detailed description, taken together with the drawings wherein:

[0019] FIG. **1** shows an arrangement view of an operator cab of a vehicle having an air conditioner according to the present invention;

[0020] FIG. **2** shows an overall arrangement view of an air conditioner according to the present invention;

[0021] FIG. **3** shows a functional block diagram of a controller of an air conditioner;

[0022] FIG. **4** shows a flow chart of a control operation of an air conditioner according to the present invention; and

[0023] FIG. **5** shows a flow chart of an air volume ratio adjusting operation of an air conditioner according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0024] Referring to the drawings, an air conditioner according to one embodiment of the present invention will be explained below. However, it should be noted that the present invention is not limited by the following explanations. Variations may be made without departing from the scope of the claim of the present invention.

[0025] The air conditioner according to the present invention, changes a ratio of volume of the conditioned air blown out from each blowout port and concentrates the conditioned air on the periphery of the upper half of the operator's body, when it is detected that a windshield or an entrance door are opened. Therefore, even if the operator works in the operator cab while the operator cab is opened, the air conditioner can perform effectively air conditioning.

[0026] FIG. **1** shows an arrangement view of an outline of an operator cab **100** of a construction vehicle having an air conditioner **1** according to the present invention.

[0027] As shown in FIG. **1**, a seat **2** for an operator is arranged in the operator cab **100**. In a rear lower portion of the seat, an air conditioner **1** is arranged. The air conditioner **1** takes in air from the operator cab **100** through an inside air suction port **3**, which is arranged close to the air conditioner **1** and provided with an opening directed toward the operator cab **100**. In the same manner, the air conditioner **1** takes in air from the outside of the operator cab **100** through an outside air suction port **4**, which is provided with an opening directed outside of the operator cab **100**. The air conditioner **1** heats or cools air taken in through the inside air suction port **3** or the outside air suction port **4**. A foot blowout port (FOOT) **5** arranged in a portion close to the foot of the operator, a face blowout port (FACE) **6** arranged close to a windshield **9** and open toward the operator, a defroster blowout port (DEF) **7** having an opening directed toward the windshield **9** and a rear blowout port (REAR) **8** having an opening directed upward from the rear of the seat **2**, are arranged in the operator cab **100**. In this structure, the face blowout port **6** and the rear blowout port **8** function as an air conditioning unit for the upper half of the operator's body which blows out conditioned air to the upper half of the operator's body. The face blowout port **6** and the defroster blowout port **7** are connected to the air conditioner **1** through a front duct **10**. In the same manner, the rear blowout port **8** is connected to the air conditioner **1** through a rear duct **11**. Air heated or cooled by the air conditioner **1** is sent out from each blowout port arranged in the operator cab **100**, so that the temperature in the operator cab **100** can be adjusted or the windshield **9** can be defogged.

[0028] The windshield **9** provided on the front of the operator cab can be slid in the vertical direction along rails **12** arranged on both sides of the windshield **9**. When the operator lifts the windshield **9**, the operator cab can be opened. An open/close sensor **57** is attached to one of the rails **12**. The open/close sensor **57** detects whether or not the windshield **9** is opened. Further, the door **13** is arranged on the side of the operator cab **100**, and then the operator can get into and off the operator cab through the door **13**. The door **13** can rotate around the front side end of the door **13** as a rotary shaft in order to open or close. In a frame portion of the operator cab coming into contact with the door **13** when the door **13** is closed, an open/close sensor **58** is arranged. The open/close sensor **58** detects whether or not the door **13** has been opened.

[0029] FIG. **2** shows an overall arrangement view of the air conditioner **1**. As shown in FIG. **2**, the air conditioner **1**

comprises: an air conditioning device **20** having a mechanical constitution and a controller **60** for controlling the air conditioning device **20**.

[0030] First, a constitution of the refrigerating cycle R of the air conditioning device **20** will be explained below. The refrigerating cycle R of the air conditioner **1** is composed of a closed cycle. The closed cycle includes a compressor **21**, a condenser **25**, a receiver **26**, an expansion valve **27** and an evaporator **28**. These components are arranged clockwise in the order of the compressor **21**, the condenser **25**, the receiver **26**, the expansion valve **27** and the evaporator **28**. The compressor **21** compresses refrigerant so as to make high pressure gas. The compressor **21** has an electromagnetic clutch **24** which is used for transmitting or shutting off power transmitted from a vehicle engine **23** through a belt **22**. The condenser **25** cools and liquidizes refrigerant gas of a high temperature and pressure sent from the compressor **21**. The receiver **26** stores the liquidized refrigerant so as to adjust the amount of refrigerant circulating in the refrigerating cycle R. In order to prevent the cooling performance from deteriorating, the receiver **26** removes bubbles contained in the liquidized refrigerant and only the liquidized refrigerant is sent to the expansion valve **27**. The expansion valve **27** adiabatically expands the liquidized refrigerant so that the temperature and pressure of the refrigerant can be reduced. After that, the low temperature and pressure refrigerant is sent to the evaporator **28**. In the evaporator **28**, heat is exchanged between the refrigerant and the air sent to the evaporator **28**, so that the air can be cooled.

[0031] Next, a constitution inside the air conditioning case **30** of the air conditioning device **20** will be explained below. A blower **31** is arranged on the upstream side of the evaporator **28**. The blower **31** is composed of a centrifugal fan and driven by a drive motor **32**. An inside and outside air changeover box **34** is arranged on the suction side of the blower **31**. An inside and outside air changeover door **35**, which is driven by an inside and outside servo motor **36**, is arranged in the inside and outside air changeover box **34**. The inside and outside air changeover door **35** changes over between the inside air suction port **3** and the outside air suction port **4** and opens and closes the inside air suction port **3** and the outside air suction port **4**. Air, which has been taken in through the inside air suction port **3** or the outside air suction port **4**, is sent to the evaporator **28** by the blower **31** through the inside and outside air changeover box **34**. In this connection, when the rotating speed of the blower **31** is adjusted, the volume of air sent out from the air conditioner **1** can be adjusted.

[0032] On the downstream side of the evaporator **28**, an air mixing door **37** and a heater core **38** are arranged in this order from the evaporator **28** side. In order to heat air passing through the heater core **38**, coolant used for cooling the vehicle engine **23** is supplied to the heater core **38** being circulated. In the air conditioning case **30**, a bypass passage **39** is arranged which bypasses the heater core **38**. The air mixing door **37** is rotated by a temperature control servo motor **40** so as to adjust a ratio of the volume of hot air, which is sent from the passage **41** passing through the heater core **38**, to the volume of cold air passing through the bypass passage **39** so that a temperature of air sent out from each blowout port can be adjusted at a predetermined value.

[0033] On the downstream side of an air mixing unit **42** in which cold air passing through the bypass passage **39** and hot air sent from the passage **41** passing through the heater core **38** are mixed with each other, a foot door **44** for opening and closing the foot blowout port **5** and a duct door **46** for opening and closing an entrance of the duct **45**, which is connected with the face blowout port **6** and the rear blowout port **8**, are arranged. In the duct **45**, a front duct **10**, which is connected with the face blowout port **6** and the defroster blowout port **7**, and a front and rear air distribution adjustment door **47** for adjusting the volume of air flowing to the rear duct **11** connected with the rear blowout port **8** are arranged. The doors **44**, **46**, **47** are driven by a mode servo motor **48**. In this connection, concerning the foot door **44** and the duct door **46**, instead of the usual door which is rotated around a shaft of one end of the door, a slide door may be used. Concerning the front and rear air distribution adjusting door **47**, a rotary door or a film door may be used. Alternatively, slide doors may be arranged at the entrance of the front duct **10** and the entrance of the rear duct **11**, respectively.

[0034] Next, various sensors incorporated into the air conditioner **1** will be explained below. An inside air temperature sensor **51** is arranged in an opening portion on the inside air suction port **3** side of the inside and outside air changeover box **34** so as to measure temperature T_i in the operator cab. An outside air temperature sensor **52** is arranged in the periphery of the operator cab so as to measure the temperature T_o outside the operator cab. In this connection, the outside air temperature sensor **52** may be arranged on the front face of the condenser **25**. In order to measure the temperature of air blown out from the evaporator **28**, that is, in order to measure the evaporator blowout temperature T_e, an evaporator outlet temperature sensor **53** is arranged in the periphery of the blowout port of the air passage on air mixing door **37** side of the evaporator **28**. In the periphery of the inlet of the engine coolant to the heater core **38**, a heater inlet temperature sensor **54** for measuring the coolant temperature T_w is arranged.

[0035] A pressure sensor **55** for measuring the pressure P of the refrigerant, which circulates in the refrigerating cycle R, is attached in the periphery of the blowout port of the receiver **26**. Further, in order to measure the intensity L of sunlight shining in the operator cab, a sunlight sensor **56** is attached to the periphery of the windshield of the operator cab. In this connection, the sunlight sensor **56** is composed of an illuminance sensor.

[0036] As described above, the open/close sensors **57** and **58** are arranged so that opening and closing of the windshield **9** and the door **13** can be detected. The open/close sensor **57** sends an open/close signal S_f of the windshield **9** to the controller **60**. On the other hand, in the case where the windshield **9** is opened, the controller **60** acquires the open/close signal S_f as 1 bit signal having the value "1". In the case where the windshield **9** is closed, the controller **60** acquires the open/close signal S_f as 1 bit signal having the value "0". In the same manner, the open/close sensor **58** sends an open/close signal S_d of the door **13** to the controller **60**. On the other hand, in the case where the door **13** is opened, the controller **60** acquires the open/close signal S_d as 1 bit signal having the value "1". In the case where the door **13** is closed, the controller **60** acquires the open/close signal S_d as 1 bit signal having the value "0". In this connection, the open/close sensors **57** and **58** can comprise well known various sensors for detecting a contact or proximity of an object such as a mechanical type contact sensor or an optical type proximity sensor. The open/close sensors **57** and **58** can detect as to whether or not the windshield **9** or the door **13** is closed, by detecting that the windshield **9** or the door **13** comes into contact or comes close to a predetermined range from the sensors.

[0037] The sensors **51** to **58** described above are connected to the controller **60**. A measurement value acquired by each sensor is sent to the controller **60**. The controller **60** controls the electromagnetic clutch **24** according to the measurement values and the operation signal acquired by A/C operation panel (not shown) so as to turn on and off the compressor **21**. Further, the controller **60** controls a rotating speed of the blower **31** by controlling the drive motor **32**. Furthermore, the controller **60** controls an inside and outside air servo motor **36**, a temperature control servo motor **40** and a mode servo motor **48** so as to adjust a degree of opening of each door. When the controller **60** controls them as described above, the temperature and volume of air of the hot air or the cold air blown out from each blowout port are adjusted so that a temperature in the operator cab can become close to the setting temperature which has been set by the operator.

[0038] FIG. **3** shows a functional block diagram of the controller **60** of the air conditioner **1**.

[0039] The controller **60** comprises: one or a plurality of microcomputers composed of a CUP, ROM and RAM not shown in the drawing; peripheral circuits of the microcomputers; and a storage unit **61** such as a nonvolatile memory which can be electrically rewritten.

[0040] The controller **60** further comprises: a temperature adjustment unit **62**; a compressor control unit **63**; a load state judgment unit **64**; an air volume ratio adjustment unit **65**; a suction air ratio adjustment unit **66**; and an air volume setting unit **67**, wherein these units are functional modules which are implemented by the microcomputer and by a computer program executed in the microcomputer. These units will be explained below.

[0041] The temperature adjustment unit **62** determines the degrees of the openings of the air mixing door **37**, based on the setting temperature T_s acquired from the A/C operation panel and measurement signals of the temperature sensors **51** to **53**, the coolant temperature sensor **54** and the sunlight sensor **56**. The temperature adjustment unit **62** sends a control signal to the temperature adjustment servo motor **40** so that the degree of opening of the air mixing door **37** can be a setting position. For example, the temperature adjustment unit **62** decides the degree of opening of the air mixing door **37** according to a relational equation, the output of which is the degree of opening of the air mixing door **37**, when a value, which is obtained when a difference between the inside air temperature T_i and the setting temperature T_s is corrected by the outside temperature T_o and the quantity of sunlight L, is used as an input. In this case, the temperature adjustment unit **62** can stably control the air mixing door **37** by determining the degree of opening of the air mixing door **37** at certain time intervals (for example, for each second) using each measurement value obtained in the past. A relational equation between each measurement value and the degree of opening of the air mixing door **37** is shown as follows.

$$Y_n = \alpha \sum_{j=1}^{n-1} [Ti_j - (Ts_j + \beta To_j + \gamma L_j)] + Ti_n - (Ts_n + \beta To_n + \gamma L_n)$$

$$Do = aY_n + b$$

[0042] In the above equation, D_o represents a degree of opening of the air mixing door **37**. Coefficients α, β, γ, a and b are constants. T_{sj}, T_{ij}, T_{oj}, L_j (j=1, 2, . . . , n) respectively represent a setting temperature, inside air temperature, outside air temperature and a quantity of sunlight at the point of time of the measurement made by J times. However, the degree of the opening D_o of the air mixing door **37** is set in such a manner that the degree of opening D_o of the air mixing door **37** is 100% when the passage **41** passing through the heater core **38** is closed, that is, only when the cooling operation is conducted and that the degree of the opening D_o of the air mixing door **37** is 0% when the bypass passage **39** is closed, that is, only heating operation is conducted.

[0043] In this connection, the temperature adjustment unit **62** may decide the air conditioning temperature and the degree of opening of the air mixing door **37** by another well known control method. The calculated degree of opening of the air mixing door **37** is stored in the storage unit **61** so that the degree of opening can be referred in the other unit of the controller **60**.

[0044] The load state judgment unit **64** judges whether the load state of the air conditioner **1** corresponds to a cooling operation or a heating operation, based on the setting temperature T_s acquired from the A/C operation panel and the measurement signals acquired from the temperature sensors **51** to **53**.

[0045] For example, in the case where the setting temperature T_s is higher than the inside air temperature T_i, the load state judgment unit **64** judges that it is a heating load. On the contrary, in the case where the inside air temperature T_i is not less than the setting temperature T_s, the load state judgment unit **64** judges that it is a cooling load. Alternatively, the load state judgment unit **64** may judge whether or not it is the heating load based on the degree of opening of the air mixing door **37** determined by the above temperature adjustment unit **62**. For example, in the case where the degree of opening of the air mixing door **37** is set in such a manner that the passage **41** on the heater core **38** is wider than the bypass passage **39**, the load state judgment unit **64** judges that it is the heating load. In the case where the degree of opening of the air mixing door **37** is set in such a manner that the passage **41** on the heater core **38** is narrower than the bypass passage **39**, the load state judgment unit **64** judges that it is a cooling load.

[0046] In the case where the setting of heating and/or cooling is manually set by an operator, the load state judgment unit **64** judges whether or not it is a heating load by referring to a heating/cooling changeover signal sent from A/C operation panel.

[0047] For example, the result of judgment is prescribed as a binary variable of 1 bit and stored in the storage section **61** so that it can be referred by the other unit in the controller **60**.

[0048] The compressor control unit **63** controls the compressor **21** so as to turn on and off the compressor **21** based on the evaporator outlet temperature T_e and the load state of the air conditioner **1**, which is judged by the load state judgment unit **64**. For example, in the case where the result of judgment made by the load state judgment unit **64** is the cooling load, the compressor control unit **63** turns on the compressor **21** in principle. In this connection, when a temperature of the evaporator **28** is decreased to a value not more than 0° C., the evaporator **28** is frosted over. When the evaporator **28** is frosted over, frost is generated among the fins of the evaporator **28**. Therefore, it becomes very difficult for air to flow among the fins. Accordingly, it is impossible for the evaporator **28** to sufficiently exchange heat. In order to prevent the evaporator **28** from being frosted over, when the evaporator outlet temperature T_e is decreased to the frost limit temperature T_f, the compressor control unit **63** stops the compressor **21**, that is, the compressor control unit **63** disconnects the electromagnetic clutch **24** so that power can not be transmitted from the vehicle engine **23** to the compressor **21**. For example, the frost limit temperature T_f is set at about 1° C. On the other hand, in the case where the evaporator outlet temperature T_e is higher than the frost limit temperature T_f, the compressor control unit **63** makes the compressor **21** continue to operate.

[0049] After the compressor **21** has stopped, the compressor control unit **63** restarts the compressor **21** when the temperature of the evaporator **28** has somewhat increased, that is, the compressor control unit **63** connects the electromagnetic clutch **24** so that power can be transmitted from the vehicle engine **23** to the compressor **21**. Therefore, the compressor operation starting temperature T_{on}, at which the compressor **21** restarts, is set at a temperature higher than a threshold value temperature, at which the compressor **21** is stopped, by a predetermined value. For example, the compressor operation starting temperature T_{on} can be set 5° C. higher than the frost limit temperature T_f. The compressor control unit **63** compares the evaporator outlet temperature T_e with the compressor operation starting temperature T_{on}. In the case where the evaporator outlet temperature T_e exceeds the compressor operation starting temperature T_{on}, the compressor control unit **63** makes the compressor **21** restart.

[0050] In the case where the load state judged by the load state judgment unit **64** is a heating load, the compressor control unit **63** stops the compressor **21** in principle. However, in the case where an operation signal to operate the defroster is received from the A/C control panel, the compressor control unit **63** makes the compressor **21** operate in order to defrost the windshield **9**.

[0051] The air volume ratio adjustment unit **65** determines a ratio of air volume of the conditioned air blown out from each blowout port based on the result of judgment by the load state judgment unit **64**, the open/close signal S_f of the windshield **9** acquired from the open/close sensor **57** and the open/close signal S_d of the door **13** acquired from the open/close sensor **58**. Further, the air volume ratio adjustment unit **65** determines degrees of opening of the foot door **44**, the duct door **46** and the front and rear air distribution adjusting door **47** so that the degrees correspond to the air volume ratio. The air volume ratio adjustment unit **65** controls the mode servo motor **48** so that each door has the determined degree of opening.

[0052] For example, in the case where the load state of the air conditioner **1** is a heating load and both the windshield **9** and the door **13** are closed (S_f=0 and S_d=0, that is, the operator cab is closed), the air volume ratio adjustment unit **65** opens only the foot door **44** and closes the duct door **46** so that the conditioned air can be blown out from only the foot blowout port **5**. On the other hand, in the case where it is detected that the windshield **9** is opened (S_f=1) or the door **13** is opened (S_d=1), that is, in the case where it is detected that the operator cab is opened, the air volume ratio adjustment unit **65** opens both the duct door **46** and the foot door **44** so that the conditioned air can be blown out from the face blowout port **6**, the rear blowout port **8** and the foot blowout port **5**.

[0053] For example, in the case where the load state of the air conditioner **1** is a cooling load, the air volume ratio adjustment unit **65** closes the foot door **44** and opens the duct door **46** so that the conditioned air can be blown out from the face blowout port **6** and the rear blowout port **8**. When it is detected that the operator cab is opened, the air volume ratio adjustment unit **65** adjusts a degree of opening of the front and rear air distribution adjusting door **47** so that the ratio of volume of the conditioned air blown out from the face blowout port **6** can be increased as compared with the case in which the operator cab is closed.

[0054] In this connection, the air volume ratio adjustment unit **65** may adjust the air volume ratio by referring to the inside air temperature T_i acquired from the inside air temperature sensor **51** and the outside air temperature T_o acquired from the outside air temperature sensor **52**. According to this embodiment, in the case where the load state of the air conditioner **1** is a heating load, the condition for increasing the ratio of volume of the conditioned air blown out from the face blowout port **6** is that the windshield **9** or the door **13** is opened, and the outside air temperature T_o is not more than 0° C. In this connection, the air volume ratio adjustment unit **65** may increase the ratio of the air volume blown out from the face blowout port **6** in accordance with a decrease in the inside air temperature T_i. The relationship between the open/close signals S_d, S_f, the outside air temperature T_o and the degree of the opening of the duct door **46** and the relationship between S_d, S_f, T_o, and the degree of the opening of the front and rear air distribution adjusting door **47** are determined by a lookup table. The lookup table is previously prepared and stored in the storage unit **61**. When the open/close signals S_d, S_f and the outside temperature T_o are acquired, the air volume ratio adjustment unit **65** refers to the lookup table and decides the degrees of opening of the duct door **46** and the front and rear air distribution adjusting door **47**.

[0055] The suction air ratio adjustment unit **66** sets a ratio of the air, which is sucked from the inside air suction port **3** by the air conditioner **1**, to the air, which is sucked from the outside air suction port **4**, based on the inside air temperature T_i, the suction setting, and the setting temperature T_s acquired from the A/C operation panel. The suction air ratio adjustment unit **66** determines a degree of opening of the inside and outside air changeover door **35** based on a relational equation which represents a relation of the difference between the inside air temperature T_i and the setting temperature T_s with the suction air ratio. This relational equation is previously set and incorporated into a computer program executed by the controller **60**. In this connection, the suction air ratio adjustment unit **66** can determine the degree of opening of the inside and outside air changeover door **35** using another well known method. The suction air ratio adjustment unit **66** controls the inside and outside air servo motor **36** and rotates the inside and outside air changeover door **35** so that the suction air ratio can be the determined value.

[0056] The air volume setting unit **67** determines a rotating speed of the blower **31** based on the setting temperature and the air volume setting value acquired from the A/C operation panel, and the measurement signals acquired from the temperature sensors **51** to **53** and the sunlight sensor **56**. The air volume setting unit **67** sends a control signal to the drive motor **32** so that the rotating speed of the blower **31** can be the determined value. For example, in the case where the air volume is manually set, the air volume setting unit **67** decides a rotating speed of the blower **31** so that the air volume can be the air volume setting value acquired from the A/C operation panel. In the case where the air volume is automatically set, the air volume setting unit **67** decides a rotating speed of the blower **31** according to a relational equation which represents a relation between the inside air temperature and the air volume or a relation between a difference of the inside air temperature and the setting temperature, and the air volume. This relational equation is previously set and incorporated into a computer program executed by the controller **60**. In this connection, the air volume setting unit **67** can decide a rotating speed of the blower **31** using another well known method.

[0057] Referring to the flow chart shown in FIG. **4**, the air conditioning control operation of the air conditioner **1** according to the present invention, will be explained below. In this connection, the controller **60** controls the air conditioning device **20** by the computer program incorporated into the controller **60**.

[0058] As shown in FIG. **4**, first of all, when the controller **60** receives a signal to operate the air conditioner **1** from the A/C operation panel, the controller **60** makes the air conditioner **1** start. The controller **60** acquires a measurement signal from each sensor (step S**101**). Next, the temperature adjustment unit **62** of the controller **60** determines the degree of opening of the air mixing door **37** so that the temperature of the conditioned air blown out from each blowout port is a predetermined temperature based on the signal of each sensor and the setting temperature, which is acquired from the A/C operation panel (step S**102**). Then, the temperature adjustment unit **62** drives the temperature adjusting servo motor **40** and rotates the air mixing door **37** so that the degree of opening of the air mixing door **37** is determined.

[0059] Next, the compressor control unit **63** of the controller **60** turns on or off the compressor **21** based on the load state of the air conditioner **1** judged by the load state judgment unit **64** and whether or not defogging is to be performed (step S**103**). Alternatively, the compressor control unit **63** may turn on or off the compressor **21** based on the temperature of the evaporator **28**.

[0060] After that, the air volume ratio adjustment unit **65** of the controller **60** determines the air volume ratio of volume of the conditioned air blown out from each blowout port (step S**104**). In this connection, the decision of the air volume ratio will be described in detail later.

[0061] After the air volume ratio has been determined, the suction air ratio adjustment unit **66** of the controller **60** sets a suction ratio of the air, which is sucked from the operator cab, to the air which is sucked from the outside of the operator cab (step S**105**). The suction air ratio adjustment unit **66** controls the inside and outside air servo motor **36** and rotates the inside and outside air changeover door **35** so that the door **35** is opened by the degree of opening of the door **35** corresponding to the suction ratio.

[0062] Finally, the air volume setting unit **67** of the controller **60** sets an air volume blown out from the air conditioner **1** (step S**106**). Then, the air volume setting unit **67** decides a rotating speed of the blower **31** based on the air volume. After that, the controller **60** repeats the control of steps S**101** to S**106** at predetermined time intervals until operation of the air conditioner **1** is stopped.

[0063] FIG. **5** is a flow chart in which the process for determining the air volume ratio at step S**104** of FIG. **4** is shown in detail.

[0064] As shown in FIG. **5**, first, the load state judgment unit **64** judges whether the load state of the air conditioner **1** is a heating load or a cooling load (step S**201**). In the case where it is judged that the load state of the air conditioner **1** is a heating load, the air volume ratio adjustment unit **65** of the controller **60** judges whether or not the outside air temperature T_o is higher than 0° C. (step S**202**). In the case where the outside air temperature T_o is higher than 0° C. in step S**202**, the air volume ratio adjustment unit **65** closes the duct door **46** so that hot conditioned air can be blown out only from the foot blowout port **5** (step S**203**). On the other hand, in the case where it is judged at step S**202** that the outside air temperature T_o is less or equal 0° C., the air volume ratio adjustment unit **65** judges whether or not the windshield **9** or the door **13** is opened based on the open/close signal S_f of the windshield **9** and the open/close signal S_d of the door **13** (step S**204**).

[0065] In the case where S_d=0 and S_f=0 at step S**204**, that is, in the case where both the windshield **9** and the door **13** are closed, the air volume ratio adjustment unit **65** closes the duct door **46** so that hot conditioned air can be blown out only from the foot blowout port **5** as described above (step S**203**). On the other hand, in the case where S_d=1 or S_f=1 at step S**204**, that is, in the case where either the windshield **9** or the door **13** is opened, the air volume ratio adjustment unit **65** opens the duct door **46** so that hot conditioned air can be blown out from the face blowout port **6**, the rear blowout port **8** and the foot blowout port **5** (step S**205**). In this case, the air volume ratio adjustment unit **65** sets a ratio of the air volume blown out from the face blowout port **6** to the air volume blown out from the rear blowout port **8** to be 1 to 1.

[0066] At step **201**, in the case where the load state judgment unit **64** judges that the load state of the air conditioner **1** is the cooling load, the air volume ratio adjustment unit **65** judges whether or not the windshield **9** or the door **13** is opened based on the open/close signal S_f of the windshield **9** and the open/close signal S_d of the door **13** (step S**206**).

[0067] In the case where S_d=0 and S_f=0 at step S**206**, that is, in the case where both the windshield **9** and the door **13** are closed, the air volume ratio adjustment unit **65** opens the duct door **46** and closes the foot door **44** so that cold conditioned air can be blown out from the face blowout port **6** and the rear blowout port **8**. Further, the air volume ratio adjustment unit **65** rotates the front and rear air distribution adjusting door **47** so that the ratio of the volume of air blown out from the face blowout port **6** to the volume of air blown out from the rear blowout port **8** is 3 to 7 (step S**207**). On the other hand, in the case where S_d=1 or S_f=1 at step S**206**, that is, in the case where either the windshield **9** or the door **13** is opened, the air volume ratio adjustment unit **65** closes the foot door **44** and opens the duct door **46** in the same manner. Further, the air volume ratio adjustment unit **65** rotates the front and rear air distribution adjusting door **47** so that the ratio of the volume of air blown out from the face blowout port **6** to the volume of air blown out from the rear blowout port **8** is 7 to 3, so as to increase a volume of cold conditioned air blown out from the face blowout port **6** (step S**208**).

[0068] As described above, according to the air conditioner of one embodiment of the present invention, when it is detected that the windshield of the operator cab is opened, a ratio of the volume of the conditioned air blown out to the upper half of the operator's body, especially, a ratio of the volume of the conditioned air blown out from the front blowout port to the front face of the operator, is increased.

Therefore, the conditioned air can be supplied to and concentrated on the periphery of the operator. Accordingly, the air conditioner can effectively condition air in the operator cab, and thus, even if the windshield or the door of the operator cab is opened, the operator can comfortably work in the operator cab.

[0069] It should be noted that the present invention is not limited to the above specific embodiment. For example, a ratio of volume of the conditioned air blown out from each blowout port can be variously set according to the structure of the operator cab. For example, at steps S**205** and S**208** described above, the air volume ratio adjustment unit **65** may rotate the front and rear air distribution adjusting door **47** so that the ratio of the volume of air blown out from the face blowout port **6** to the volume of air blown out from the rear blowout port **8** is 10 to 0. In the case of a heating load, even if the operator cab is closed (at step **203**), the air volume ratio adjustment unit **65** may control the duct door **46** so that the conditioned air is also blown out from the face blowout port **6** and the rear blowout port **8**. Further, in the case where the operator cab is opened, the air volume ratio adjustment unit **65** may set the ratio of the air volume of the conditioned air blown out from the face blowout port **6** to the air volume of the conditioned air blown out from the rear blowout port **8** so that the air volume blown out from the face blowout port **6** is larger than the air volume blown out from the rear blowout port **8**.

[0070] In the embodiment described above, the controller **60** refers to the outside air temperature T_o in order to determine the ratio of the volume of the conditioned air blown out from each blowout port, only in the case of a heating load. However, in the case of a cooling load, the controller **60** may refer to the outside air temperature T_o or the inside air temperature T_i in order to determine the ratio. In this case, only when the operator cab is opened and the outside air temperature T_o or the inside air temperature T_i is not less than 30° C., the controller **60** may determine the ratio of the volume of the conditioned air blown out from the face blowout port **6** to be increased. Further, the controller **60** may refer to an amount of the sunlight L instead of the outside air temperature T_o or the inside air temperature T_i. Alternatively, the controller **60** may refer to an amount of sunlight L together with the outside air temperature T_o or inside air temperature T_i. For example, in the case where an amount of sunlight L exceeds 800 W/m^2, the controller **60** may reduce a volume of air blown out from the foot blowout port **5** and increase volumes of air blown out from the face blowout port **6** and the rear blowout port **8**.

[0071] Further, when the operator opens the door **13** and gets into the operator cab, in order to avoid feeling too hot or too cold, it is preferable that a volume of air blown out from the face blowout port **6** is not increased. Therefore, when the controller **60** continuously receives a signal (S_d=1), which indicates that the door **13** has been opened, from the open/close sensor **58**, for a predetermined period of time (for example, for 2 minutes), the air volume ratio adjustment unit **65** may control the mode servo motor **48** so that the volume of air blown out from the face blowout port **6** is increased.

[0072] In addition to the constitution of the present invention, when the operator cab is opened, the temperature adjustment unit **62** may control the compressor **21** so that a rotating speed of the compressor **21** is increased in order to enhance air conditioning power. The temperature adjustment unit **62** may also control the air mixing door **37** to change the degree of opening thereof. Further, when the operator cab is opened, the air volume setting unit **67** may control the blower **31** so that the rotating speed of the blower **31** is increased in order to increase the volume of air blown out from each blowout port.

[0073] Further, the air conditioning unit, which enhances the air conditioning power for the upper half of the operator body when the operator cab is opened, is not limited to the above specific embodiment. For example, a well known heater for heating the upper half of the operator's body may be attached to a pillar on the side of the operator cab. Only when the operator cab is opened, can the controller **60** operate the heater.

[0074] As described above, variations can be made within the scope of claim of the present invention.

What is claimed is:

1. An air conditioner for conditioning air in an operator cab of a vehicle, comprising:

a heating unit for heating an upper half of an operator's body;

an open/close sensor for detecting whether said operator cab is opened or closed; and

a controller for setting a heating power of said heating unit when said open/close sensor detects that said operator cab is opened, to be higher than the heating power of said heating unit when the operator cab is closed.

2. An air conditioner according to claim **1**, wherein

said heating unit comprises a front face heating unit for heating a front face of the operator, and

said controller sets a heating power of

said front face heating unit to be higher than the heating power of said front face heating unit when the operator cab is closed, in the case where said open/close sensor detects that said operator cab is opened.

3. An air conditioner according to claim **1**, wherein said vehicle is a construction vehicle.

4. An air conditioner for conditioning air in an operator cab of a vehicle, comprising:

an air conditioning unit for generating conditioned air;

at least one first blowout port for blowing out the conditioned air to an upper half of an operator's body;

a second blowout port for blowing out the conditioned air;

an open/close sensor for detecting whether said operator cab is opened or closed; and

a controller for setting a ratio of volume of the conditioned air, which is blown out from said at least one first blowout port, in the conditioned air, which is blown out from each blowout port when said open/close sensor detects that said operator cab is opened, to be higher than the ratio of volume of the conditioned air when said operator cab is closed.

5. An air conditioner according to claim **4**, wherein the conditioned air is heated.

6. An air conditioner according to claim **4**, wherein

said at least one first blowout port comprises a face blowout port for blowing out the conditioned air to the front face of the operator, and

said controller sets the ratio of volume of the conditioned air, which is blown out from said face blowout port, in the conditioned air, which is blown out from each blowout port, so that the ratio of volume of the conditioned air when said open/close sensor detects that said operator cab is opened, is higher than the ratio of volume of the conditioned air when said operator cab is closed.

7. An air conditioner according to claim **4**, wherein

said second blowout port is a blowout port arranged in a lower portion of a operator's seat, and

said controller sets the ratio of volume of the conditioned air so that, when said open/close sensor detects that said operator cab is opened, the conditioned air is blown out from both said at least one first blowout port and said second blowout port, and when said open/close sensor detects that said operator cab is closed, the conditioned air is only blown out from said second blowout port.

8. An air conditioner according to claim **4**, further comprising:

a temperature sensor for measuring a temperature of air in said operator cab or a temperature of air out said operator cab, wherein

said controller sets the ratio of volume of the conditioned air when said open/close sensor detects that said operator cab is opened and the measured temperature of the outside air or the inside air is not higher than a predetermined temperature, to be higher than the ratio of volume of the conditioned air when said operator cab is closed.

9. An air conditioner according to claim **4**, wherein said vehicle is a construction vehicle.

10. A method of controlling an air conditioner for conditioning air in an operator cab in a vehicle, the air conditioner comprising a heating unit for heating an upper half of an operator's body in said operator cab, comprising:

detecting whether said operator cab is opened or closed; and

setting a heating power of said heating unit when it is detected that said operator cab is opened, to be higher than the heating power of said heating unit when said operator cab is closed.

11. A method of controlling an air conditioner for conditioning air in an operator cab of a vehicle, the air conditioner comprising an air conditioning unit for generating conditioned air, at least one first blowout port for blowing out the conditioned air to an upper half of an operator's body and a second blowout port for blowing out the conditioned air,

the method comprising:

detecting whether said operator cab is opened or closed; and

setting a ratio of volume of the conditioned air, which is blown out from said first blowout port, in the conditioned air which is blown out from each blowout port, so that the ratio of volume of the conditioned air when it is detected that said operator cab is opened, is higher than the ratio of volume of the conditioned air when it is detected that said operator cab is closed.

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