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(54) **RADIATOR FOR SUPERCRITICAL VAPOR COMPRESSION TYPE REFRIGERATING CYCLE**

(76) Inventors: **Yasutaka Kuroda**, Anjo-city (JP); **Yoshitaka Tomatsu**, Chiryu-city (JP); **Nobuharu Kakehashi**, Toyoake-city (JP); **Motohiro Yamaguchi**, Hoi-gun (JP)

Correspondence Address:
HARNESS, DICKEY & PIERCE, P.L.C.
P.O. BOX 828
BLOOMFIELD HILLS, MI 48303 (US)

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(57) **ABSTRACT**

In a radiator for a supercritical cycle, a refrigerant outlet is provided at a position higher than that of a refrigerant inlet in a vertical direction such that refrigerant flows from a lower side to an upper side in the radiator. Accordingly, even when temperature of cool air to pass through the lower side of the radiator is high, the temperature of refrigerant flowing in the lower side is so high that a sufficient difference in temperature between cool air and refrigerant can be provided. As a result, a cooling efficiency of refrigerant can be improved.

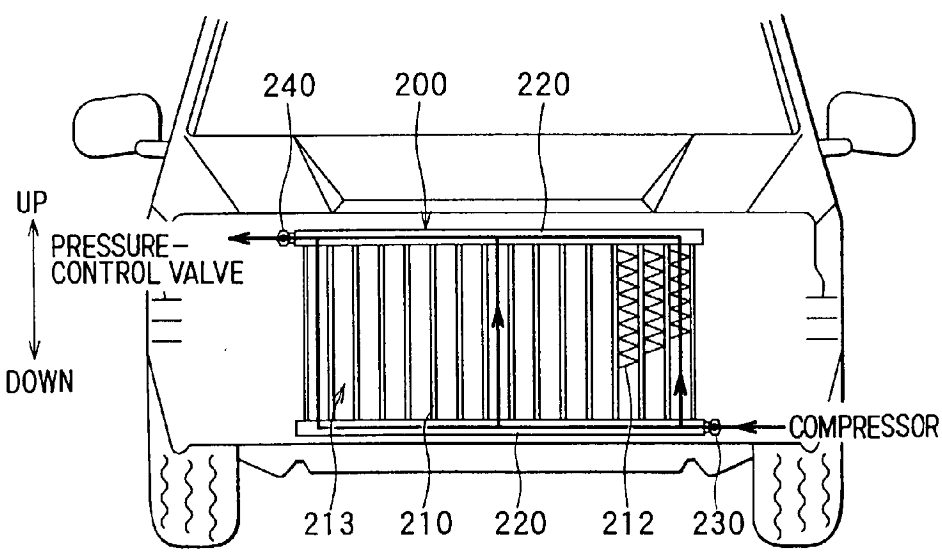


FIG. 1

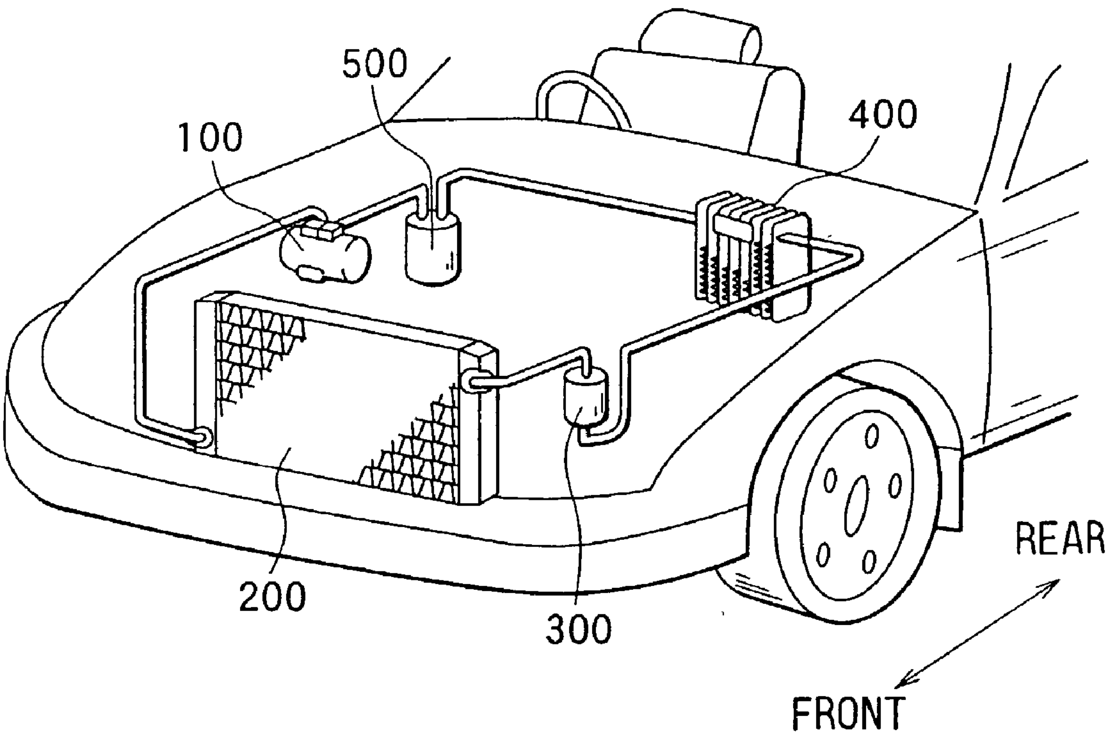


FIG. 2

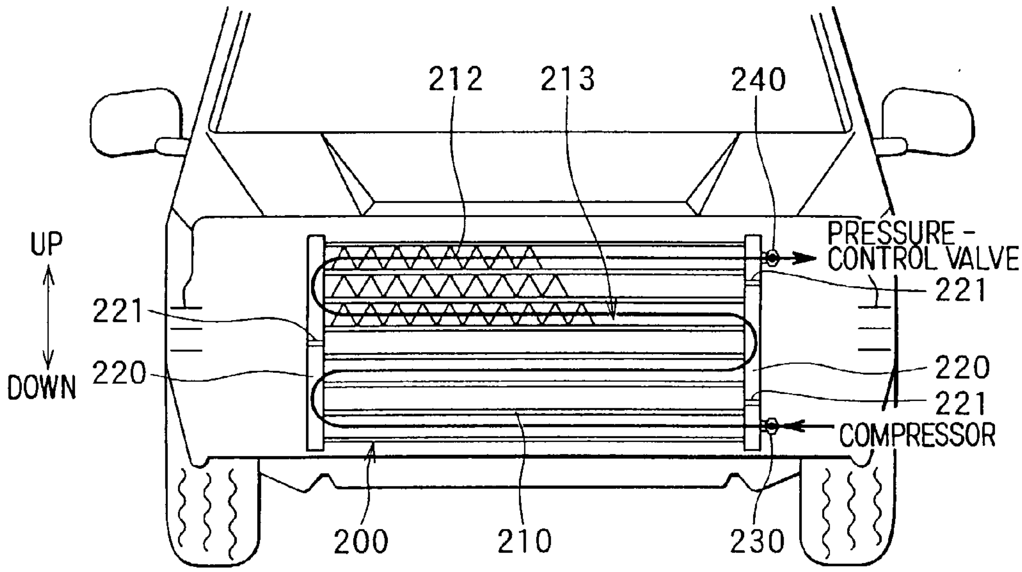

212
213
240
UP
DOWN
PRESSURE - CONTROL VALVE
221
221
220
220
221
COMPRESSOR
200
210
230

FIG. 3

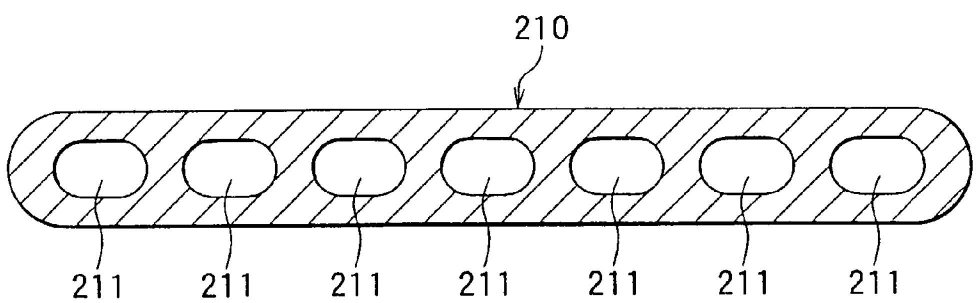

210
211
211
211
211
211
211
211

FIG. 4

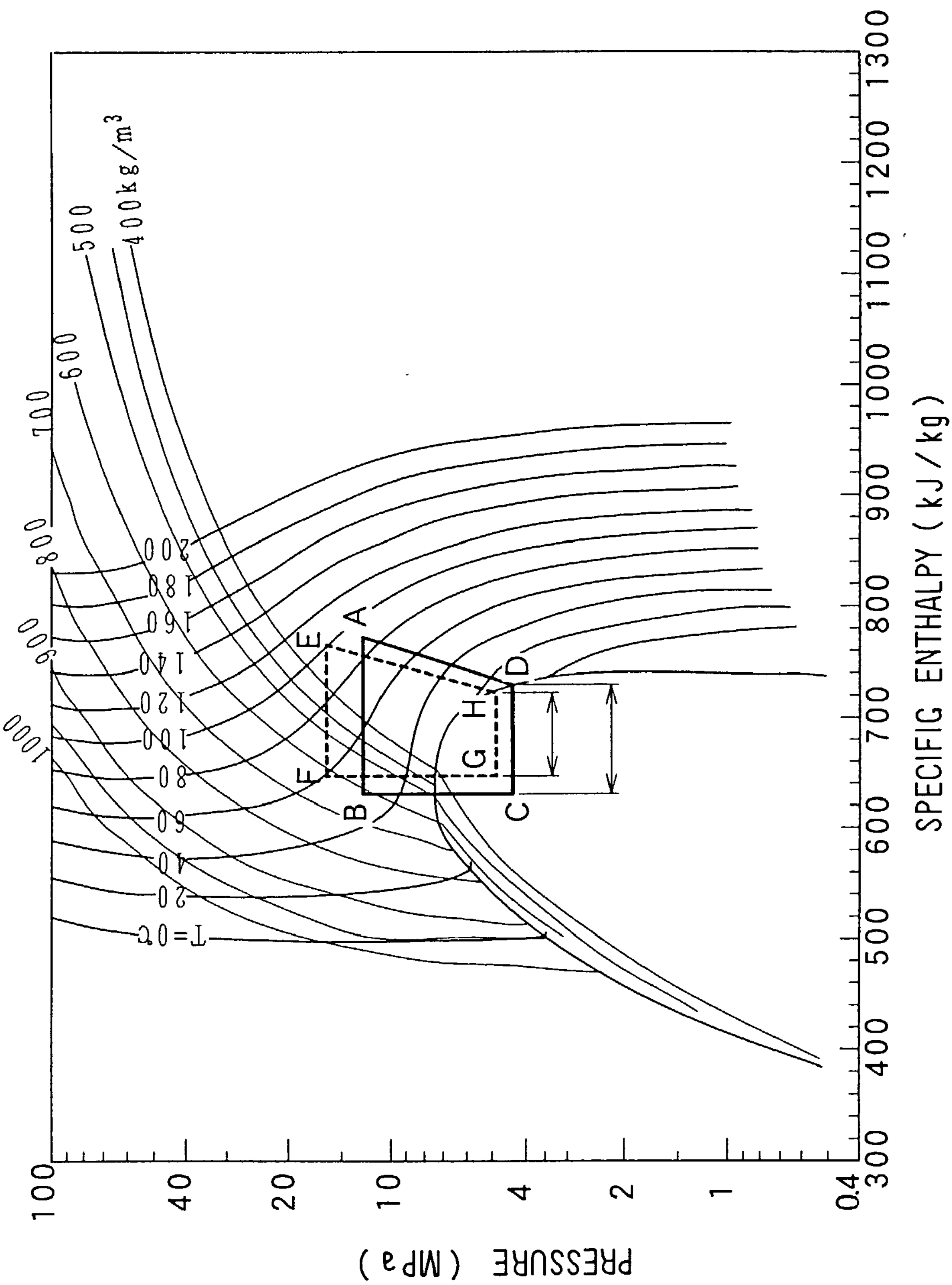

PRESSURE (MPa)
100
40
20
10
4
2
1
0.4
SPECIFIC ENTHALPY (kJ/kg)
300
400
500
600
700
800
900
1000
1100
1200
1300
T=0℃
20
40
60
80
100
120
140
160
180
200
1000
900
800
700
600
500
400kg/m3
A
B
C
D
E
F
G
H

FIG. 5

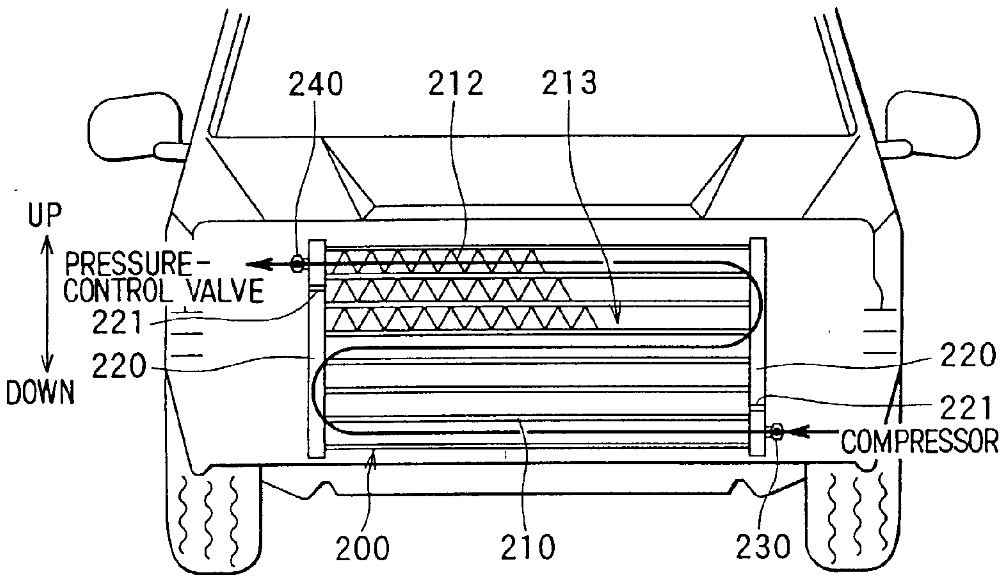

240
212
213
UP
PRESSURE-
CONTROL VALVE
221
220
DOWN
220
221
COMPRESSOR
200
210
230

FIG. 6

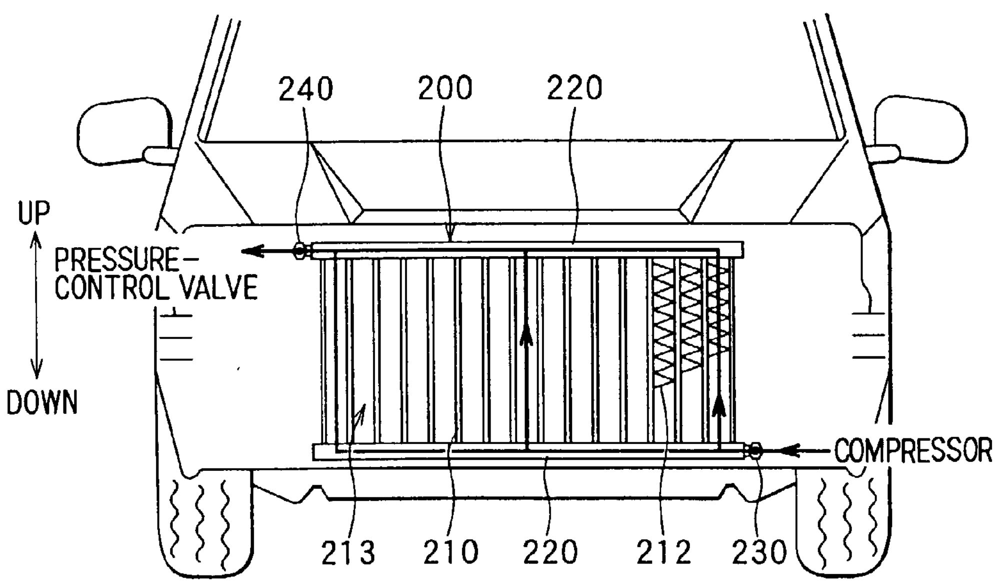

240
200
220
UP
PRESSURE-
CONTROL VALVE
DOWN
COMPRESSOR
213
210
220
212
230

FIG. 7

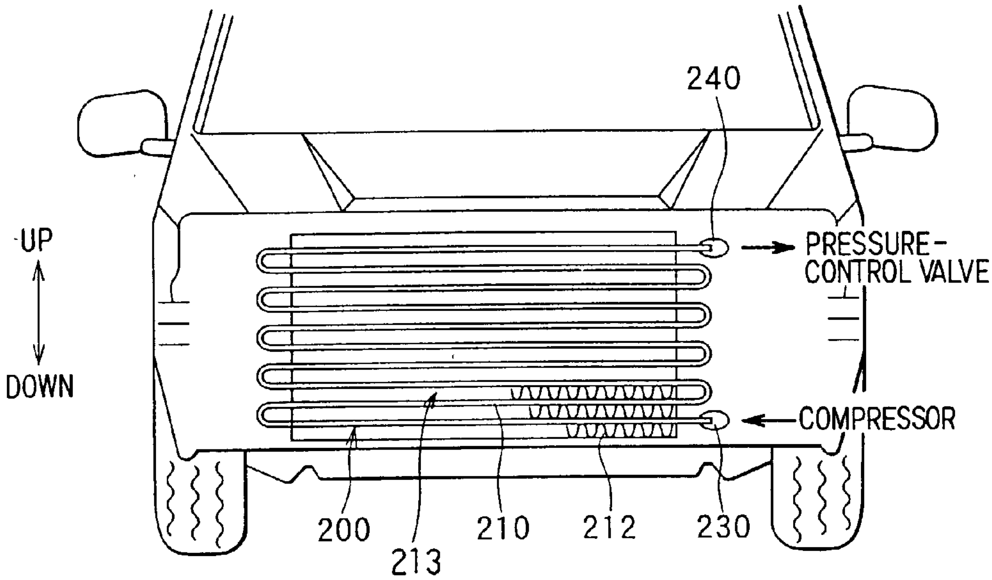

240
UP
DOWN
PRESSURE-
CONTROL VALVE
COMPRESSOR
200
213
210
212
230

FIG. 8

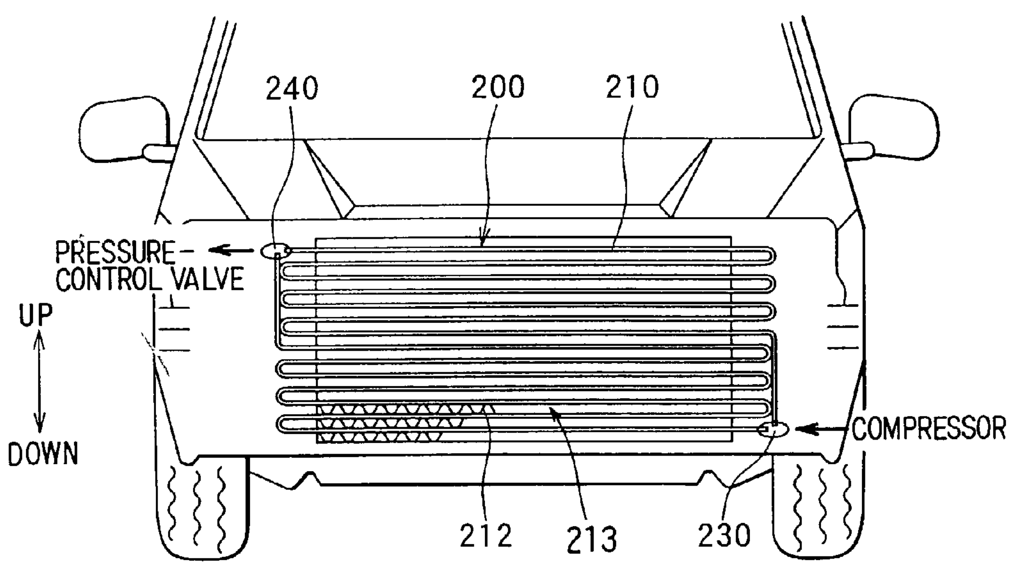

240
200
210
PRESSURE-
CONTROL VALVE
UP
DOWN
COMPRESSOR
212
213
230

FIG. 9

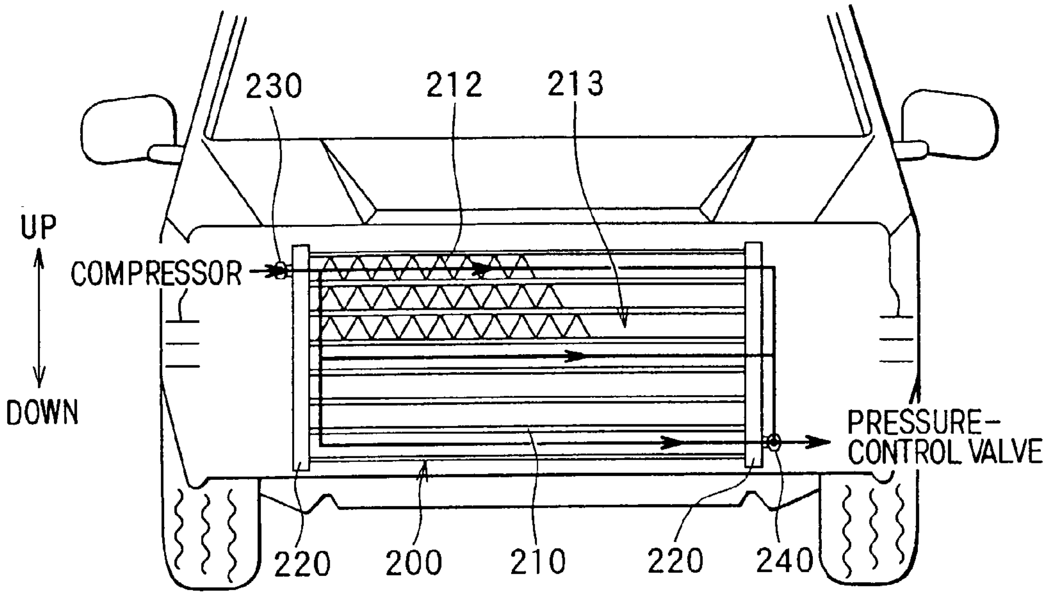
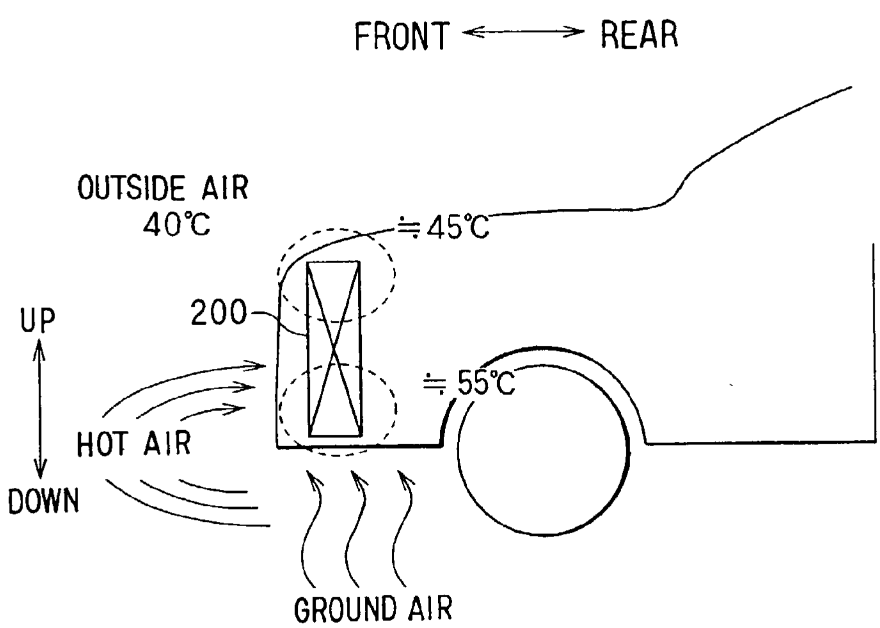

230
212
213
UP
COMPRESSOR
DOWN
PRESSURE-
CONTROL VALVE
220
200
210
220
240

FIG. 10


FRONT
REAR
OUTSIDE AIR
40℃
≒45℃
200
UP
≒55℃
HOT AIR
DOWN
GROUND AIR

RADIATOR FOR SUPERCRITICAL VAPOR COMPRESSION TYPE REFRIGERATING CYCLE

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is based upon and claims the benefit of Japanese Patent Application No. 11-276934 filed on Sep. 29, 1999, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates to a radiator (gas cooler) applied to a supercritical vapor compression type refrigerating cycle (hereinafter, referred to as a supercritical cycle) in which refrigerant pressure at a high-pressure side (discharge side) becomes a supercritical pressure of refrigerant or more.

[0004] 2. Description of the Related Art

[0005] In a supercritical cycle using fleon as refrigerant, since a pressure at a high-pressure side is smaller than a supercritical pressure of refrigerant, refrigerant changes its phase (condenses) in a condenser from a gaseous phase to a liquid phase while keeping its temperature approximately constant. A refrigerant density is increased in the condenser as it proceeds from a refrigerant inlet to a refrigerant outlet. Therefore, the position of the refrigerant inlet is generally higher than that of the refrigerant outlet. Meanwhile, a vehicle air conditioner is generally installed in a vehicle front part such that a cooling heat exchanger such as a condenser or a radiator can take cool air in easily.

SUMMARY OF THE INVENTION

[0006] In this connection, a temperature of cool air to pass through the cooling heat exchanger was measured to improve a cooling capability of the air conditioner when the vehicle was stopped. Accordingly, it was found that the temperature of cool air to pass through the lower side of the heat exchanger was higher than that of cool air to pass through the upper side of the heat exchanger.

[0007] That is, when the vehicle is stopped, as shown in **FIG. 10**, cool air to flow into the lower side of the heat exchanger **200** is heated by heat (ground heat), radiated from the ground, and hot air, discharged from an engine room, to have a temperature higher than that of cool air to flow into the upper side of the heat exchanger. Incidentally, it was experimentally confirmed that cool air of about 55° C. flew into the lower side while cool air of about 45° C. flew into the upper side when an outside air temperature was 40° C. As understood from this example, there arises a large difference in temperature of cool air between the lower side and the upper side of the heat exchanger for cooling.

[0008] The present invention has been made in view of the above problems. An object of the present invention is to improve a cooling efficiency of refrigerant in a radiator for a supercritical cycle.

[0009] According to a first aspect of the present invention, a refrigerant outlet is elevated from a refrigerant inlet in a vertical direction in a radiator. Accordingly, refrigerant flows into a lower side of the radiator with a temperature higher than that in an upper side of the radiator. Therefore, even when a temperature of cool air at the lower side is higher than that at the upper side, a sufficient difference in temperature between refrigerant and cool air can be provided, resulting in improvement of refrigerant cooling efficiency.

[0010] According to a second aspect of the present invention, a radiator includes a plurality of tubes each extending in a horizontal direction and defining therein a refrigerant passage in which refrigerant flows. In the plurality of tubes, a first one of the tubes, which is provided at a position higher than that of a second one of the tubes, has a cross-sectional area of the refrigerant passage larger than that of the second one of the tubes. Each of the plurality of tubes may have a plurality of refrigerant passages.

[0011] When each of the plurality of tubes has a plurality of refrigerant passages, a number of the plurality of refrigerant passages of a first one of the tubes, which is provided at a position higher than a second one of the tubes, can be larger than that of the second one of the tubes.

[0012] Accordingly, a large amount of refrigerant can flow in the upper portion of the radiator, through which cool air passes with a lower temperature, as compared to that of refrigerant flowing in the lower portion of the radiator. This also results in improved cooling efficiency. In these cases, it is preferable that a refrigerant inlet is elevated from a refrigerant outlet in the vertical direction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Other objects and features of the present invention will become more readily apparent from a better understanding of the preferred embodiments described below with reference to the following drawings, in which;

[0014] **FIG. 1** is a schematic diagram showing a vehicle installing therein a radiator according to a first preferred embodiment;

[0015] **FIG. 2** is a front view schematically showing the radiator installed in the vehicle in the first embodiment;

[0016] **FIG. 3** is a cross-sectional view showing a tube of the radiator;

[0017] **FIG. 4** is a p-h diagram of carbon dioxide;

[0018] **FIG. 5** is a front view schematically showing a modified radiator according to the first embodiment;

[0019] **FIG. 6** is a front view schematically showing a radiator according to a second preferred embodiment;

[0020] **FIG. 7** is a front view schematically showing a radiator according to a third preferred embodiment;

[0021] **FIG. 8** is a front view schematically showing a modified radiator according to the third embodiment;

[0022] **FIG. 9** is a front view schematically showing a radiator according to a fourth preferred embodiment; and

[0023] **FIG. 10** is an explanatory diagram for explaining problems to be solved by the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] Hereinafter, preferred embodiments are explained with reference to appended drawings through which the same parts and components are denoted with the same reference numerals.

[0025] (First Embodiment)

[0026] In a first preferred embodiment, a radiator for a supercritical cycle according to the present invention is applied to a vehicle air conditioner.

[0027] Referring to **FIG. 1** showing the supercritical cycle (vehicle air conditioner) installed in a vehicle, a compressor **100** sucks refrigerant (carbon dioxide in the present embodiment) and compresses it while receiving a drive power from a vehicle engine (not shown). High-pressure refrigerant discharged from the compressor **100** flows into a radiator **200** to exchange heat with air (cool air) to be cooled down. The radiator **200** is explained in detail later.

[0028] A pressure-control valve **300** decompresses refrigerant discharged from the radiator **200** while controlling a temperature of the refrigerant at the outlet side of the radiator **200** so that a coefficient of performance (COP) of the supercritical cycle is maximum. The pressure-control valve **300** has substantially the same functions as disclosed in JP-A-9-264622, and therefore is not explained in detail here.

[0029] An evaporator **400** evaporates refrigerant, decompressed by the pressure-controlled valve **300**, to exhibit a refrigerating capability (cooling capability). Refrigerant flowing out of the evaporator **400** flows into an accumulator (gas-liquid separator) **500**. The accumulator **500** separates the refrigerant into gaseous phase refrigerant and liquid phase refrigerant and send gaseous phase refrigerant toward the suction side of the compressor **100** while accumulating therein surplus refrigerant for the supercritical cycle.

[0030] Next, the radiator **200** according to the present embodiment is explained with reference to **FIG. 2**. The radiator **200** has plural tubes **210** in which refrigerant flows. The tubes **210** are arranged in parallel in a vertical direction and respectively extend in a horizontal direction. As shown in **FIG. 3**, each of the tubes **210** is formed by extruding or drawing to have plural refrigerant passages **211** therein. A corrugated fin **212** is provided between adjacent two of the tubes **210**, thereby constituting a heat exchange core **213** for cooling refrigerant.

[0031] Header tanks **220** are disposed at both ends in a longitudinal direction of the tubes **210**, and communicate with the tubes **210**. Each inside space of the header tanks **220** is divided into several spaces by partition plates (separators) **221**. A refrigerant inlet **230** is provided at the lower side of one of the header tanks **220**, i.e., at the lower side of the radiator **200**, to receive refrigerant discharged from the compressor **100**. On the other hand, a refrigerant outlet **240** is provided at the upper side of the one of the header tanks **220**, i.e., at the upper side of the radiator **200**, to discharge refrigerant that has been heat-exchanged in the radiator **200**. Accordingly, refrigerant flows in the radiator **200** from the lower side to the upper side while meandering in the radiator **200** as indicated by an arrow in **FIG. 2**.

[0032] Next, features of the present embodiment are described below According to the present embodiment, the refrigerant inlet **230** is provided at the lower side of the header tank **220** (radiator **200**), while the refrigerant outlet **240** is provided at the upper side of the header tank **220** (radiator **200**). That is, when the radiator **200** is installed in the vehicle, the refrigerant outlet **240** is elevated from the refrigerant inlet **230** in a vertical direction in the radiator **200**.

[0033] Further, in the supercritical cycle, high-pressure side refrigerant flows in the radiator **200** from the refrigerant inlet **230** toward the refrigerant outlet **240** while lowering its temperature. Therefore, the temperature of refrigerant at the refrigerant inlet **230** is higher than that at the refrigerant outlet **240**. On the other hand, the temperature of cool air is, as described above, high at the lower side of the radiator **200** as compared to that at the upper side. However, in the present embodiment, even when the temperature of cool air is high at the lower side, the temperature of refrigerant conducted into the radiator **200** from the lower side has so high that a sufficient difference in temperature between refrigerant and cool air can be provided at the lower side. As a result, the cooling efficiency of refrigerant can be improved in the radiator **200** of the supercritical cycle, resulting in improved cooling capability (refrigerating capability) of the air conditioner (supercritical cycle).

[0034] Incidentally, **FIG. 4** is a Mollier diagram in which solid lines A-B-C-D indicate the operation of the supercritical cycle according to the present embodiment, and broken lines E-F-G-H indicate an operation of a supercritical cycle in which refrigerant is made to flow from an upper side to a lower side in a radiator. As understood from the diagram, according to the present embodiment, the refrigerating capability (a difference in enthalpy between C and D) is increased at about 18% as compared to the conventional refrigerating capability (a difference in enthalpy between G and H).

[0035] The present embodiment is not limited to the radiator **200** shown in **FIG. 2**, but may be applied to the radiator **200** shown in **FIG. 5** in which the number of the partition plates (separators) **221** is decreased as compared to that in **FIG. 2** such that a turn number of refrigerant in the radiator **200** is decreased. The number of the partition plates **221** can also be increased as compared to that shown in **FIG. 2** to increase the turn number of refrigerant in the radiator **200**.

[0036] (Second Embodiment)

[0037] In the first embodiment, the tubes **210** are provided to extend in the horizontal direction. However, in a second preferred embodiment, as shown in **FIG. 6**, the tubes **210** may be arranged such that those longitudinal direction corresponds to a vertical direction and such that refrigerant flows therein from the lower side to the upper side.

[0038] (Third Embodiment)

[0039] In a third preferred embodiment, as shown in **FIGS. 7 and 8**, the tubes **210** meander and dispense with the header tanks **220** to constitute the heat exchange core **213**. In **FIG. 7**, only one tube **210** is made to meander from the refrigerant inlet **230** to the refrigerant outlet **240**. In **FIG. 8**, several (two in the figure) tubes **210** are made to meander from the refrigerant inlet **230** to the refrigerant outlet **240**.

[0040] (Fourth Embodiment)

[0041] In the first embodiment, refrigerant flows from the lower side to the upper side in the radiator **200** against gravity. This may deteriorate a flowing performance of refrigerant and a dividing performance for dividing refrigerant into the respective tubes **210** from the header tanks **220**.

[0042] In this connection, in a fourth preferred embodiment, as shown in **FIG. 9**, the refrigerant inlet **230** is provided at the upper side of the radiator **200** (one of the header tanks **220**), and the refrigerant outlet **240** is provided at the lower side of the radiator **200** (the other one of the header tanks **220**). Further, some of the tubes **210** arranged at the upper side respectively have a passage cross-sectional area (diameter of each refrigerant passage **211**) larger than that of the other tubes **210** arranged at the lower side.

[0043] Accordingly, refrigerant flows from the upper side to the lower side. Simultaneously, the upper side of the radiator **200**, through which cool air flows with a lower temperature, allows a large amount of refrigerant to flow therein as compared to the lower side, thereby providing a large difference in temperature between conditioning air and refrigerant. As a result, the radiator **200** in the supercritical cycle can improve the cooling efficiency and the dividing performance of refrigerant simultaneously.

[0044] In the present embodiment, the passage cross-sectional area of the tube positioned at the upper side is larger than that of the tube positioned at the lower side. However, the number of the refrigerant passages **211** in the tube positioned at the upper side may be increased as compared to that at the lower side. In such case, the same effects can be provided.

[0045] While the present invention has been shown and described with reference to the foregoing preferred embodiments, it will be apparent to those skilled in the art that changes in form and detail may be made therein without departing from the scope of the invention as defined in the appended claims.

[0046] For instance, although carbon dioxide is used as refrigerant in the supercritical cycle in the above embodiments, the present invention can be applied to other supercritical cycles using refrigerant other than carbon dioxide, such as ethylene, ethane, and nitrogen oxide.

What is claimed is:

1. A radiator for cooling refrigerant discharged from a compressor with a high pressure in a supercritical refrigerating cycle in which a pressure at a high-pressure side is a supercritical pressure of the refrigerant at least, the radiator comprising:

a heat exchange core portion defining therein a refrigerant passage in which refrigerant flows to be cooled, the heat exchange core portion having a refrigerant inlet for conducting the refrigerant into the refrigerant passage and a refrigerant outlet for discharging the refrigerant from the refrigerant passage;

wherein the refrigerant outlet is elevated from the refrigerant inlet in a vertical direction.

2. A radiator for cooling refrigerant discharged from a compressor with a high pressure in a supercritical refrigerating cycle in which a pressure at a high-pressure side is a supercritical pressure of the refrigerant at least, the radiator comprising:

a heat exchange core portion defining a refrigerant passage in which refrigerant flows to be cooled, the heat exchange core portion being constructed such that refrigerant flowing in an upper portion of the heat exchange core portion has a temperature lower than that of refrigerant flowing in a lower portion of the heat exchange core portion.

3. A radiator for cooling refrigerant discharged from a compressor with a high pressure in a supercritical refrigerating cycle in which a pressure at a high-pressure side is a supercritical pressure of the refrigerant at least, the radiator comprising:

a plurality of tubes extending in a horizontal direction in parallel with one another and each defining therein a refrigerant passage in which refrigerant flows; and

first and second header tanks respectively provided at both ends in a longitudinal direction of the plurality of tubes to communicate with the plurality of tubes,

wherein a first one of the plurality of tubes, a position of which is higher than that of a second one of the plurality of tubes, has a cross-sectional area of the refrigerant passage larger than that of the second one of the plurality of tubes.

4. The radiator of claim 3, wherein

the first one of the plurality of tubes is provided at an upper side of the plurality of tubes in a vertical direction; and

the second one of the plurality of tubes is provided at a lower side of the plurality of tubes in the vertical direction.

5. The radiator of claim 3, wherein:

the plurality of tubes has a first group of tubes positioned at an upper side of a center line thereof in a vertical direction, and a second group of tubes positioned at a lower side of the center line;

the first group of tubes includes the first one of the plurality of tubes; and

the second group of tubes includes the second one of the plurality of tubes.

6. The radiator of claim 3, wherein:

the first and second header thanks have a refrigerant inlet through which the refrigerant is conducted into the plurality of tubes and a refrigerant outlet from which the refrigerant is discharged from the plurality of tubes, the refrigerant inlet being elevated from the refrigerant outlet in a vertical direction.

7. A radiator for cooling refrigerant discharged from a compressor with a high pressure in a supercritical refrigerating cycle in which a pressure at a high-pressure side is a supercritical pressure of the refrigerant at least, the radiator comprising:

a plurality of tubes extending in a horizontal direction in parallel with one another and each defining therein a plurality of refrigerant passages in which refrigerant flows; and

first and second header tanks respectively provided at both ends in a longitudinal direction of the plurality of tubes to communicate with the plurality of tubes,

wherein a number of the plurality of refrigerant passages of a first one of the plurality of tubes, a position of which is higher than that of a second one of the plurality of tubes, is larger than that of the second one of the plurality of tubes.

8. The radiator of claim 7, wherein

the first one of the plurality of tubes is provided at an upper side of the plurality of tubes in a vertical direction; and

the second one of the plurality of tubes is provided at a lower side of the plurality of tubes in the vertical direction.

9. The radiator of claim 7, wherein:

the plurality of tubes has a first group of tubes positioned at an upper side of a center line thereof in a vertical direction, and a second group of tubes positioned at a lower side of the center line;

the first group of tubes include the first one of the plurality of tubes; and

the second group of tubes includes the second one of the plurality of tubes.

10. The radiator of claim 7, wherein:

the first and second header thanks have a refrigerant inlet through which the refrigerant is introduced into the plurality of tubes and a refrigerant outlet through which the refrigerant is discharged from the plurality of tubes, the refrigerant inlet being elevated from the refrigerant outlet in a vertical direction.

11. An on-vehicle structure of a radiator installed in a vehicle for cooling refrigerant discharged from a compressor with a high pressure equal to or larger than a supercritical pressure of the refrigerant in a supercritical cycle, the structure comprising:

a heat exchange core portion defining therein a refrigerant passage in which refrigerant flows to be cooled, the heat exchange core portion having a refrigerant inlet through which the refrigerant is conducted, and a refrigerant outlet through which the refrigerant is discharged, the refrigerant outlet being elevated from the refrigerant inlet in a vertical direction.

* * * * *