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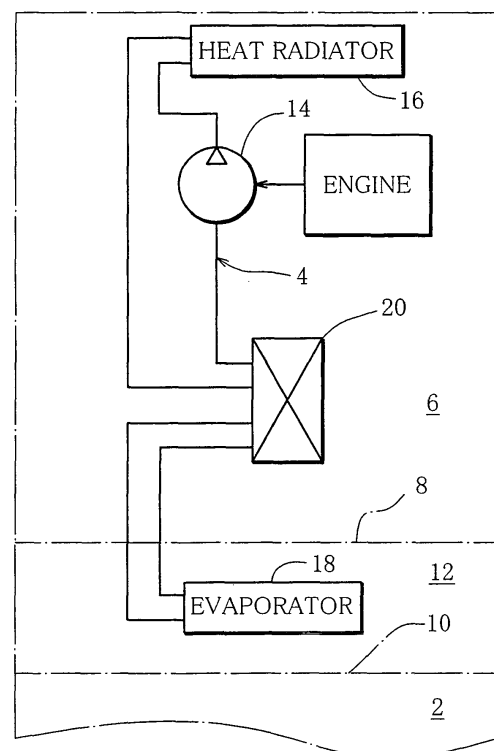
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(54) **Vapor compression refrigeration circuit and automotive air-conditioning system using same**

(57) A vapor compression refrigeration circuit comprises a compressor (14), a heat radiator (16), a high-temperature section (48) of an internal heat exchanger (28), a pressure reducer (22, 64, 68), an evaporator (18), an accumulator (24) and a low-temperature section (52) of the internal heat exchanger (28) disposed in this order in a circulation passage (4) through which a refrigerant circulates, when viewed along a direction of flow of the refrigerant. The pressure reducer (22, 64, 68), the accumulator (24) and the internal heat exchanger (28) are integrally formed.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] This invention relates to a vapor compression refrigeration circuit and an automotive air-conditioning system using this refrigeration circuit.

Description of the Related Art

[0002] The refrigeration circuit is used, for example in an automotive air-conditioning system, and has a circulation passage for circulating a refrigerant therethrough. In the circulation passage, generally, a compressor, a heat radiator (condenser or gas cooler), a pressure reducer (expansion valve) and an evaporator are inserted in this order when viewed along the direction of flow of the refrigerant. In the circulation passage, also a vapor-liquid separator for separating a vapor-phase component and a liquid-phase component of the refrigerant is disposed downstream of the heat radiator or downstream of the evaporator.

[0003] In recent years, out of consideration of environmental problems, the development of a refrigeration circuit using a refrigerant low in global warming potential (GWP) has been being advanced. As an example of such refrigerant, atoxic and noncombustible natural CO₂ (carbon dioxide) is proposed. Since the critical temperature of CO₂ is low, specifically about 31°C, the refrigeration circuit using CO₂ as a refrigerant is a transcritical cycle (supercritical cycle), and on the high-pressure side of the refrigeration circuit, the refrigerant comes into a supercritical state of about 7.4MPa in pressure, for example. In such refrigeration circuit, since CO₂ does not condense in the heat radiator, an accumulator as a vapor-liquid separator is disposed downstream of the evaporator in the circulation passage.

[0004] In addition, in some cases, in order to improve the coefficient of performance (COP), the refrigeration circuit using CO₂ also includes an internal heat exchanger disposed in the circulation passage, as disclosed in Unexamined Japanese Patent Publication No. H11-193967, for example. Specifically, the internal heat exchanger comprises a high-temperature section disposed between the heat radiator and the pressure reducer in the circulation passage and a low-temperature section disposed between the accumulator and the compressor in the circulation passage. In the internal heat exchanger, heat exchange takes place between a high-pressure refrigerant flowing in the high-temperature section and a low-pressure refrigerant flowing in the low-pressure section, so that the refrigerant has a decreased enthalpy at the inlet of the evaporator. Consequently, change in enthalpy of the refrigerant produced in the evaporator increases, so that the COP of the refrigeration circuit improves.

[0005] The conventional refrigeration circuit comprises, as major devices, a compressor, a heat radiator, a pressure reducer, an evaporator and an accumulator, and also comprises, as connecting parts for connecting an inlet and an outlet of such major devices, pipes disposed between such major devices and coupling members for coupling the devices and the pipes.

[0006] Thus, the refrigeration circuit is composed of a large number of major devices and connecting parts, so that assembling the refrigeration circuit, and particularly, installing the refrigeration circuit in a vehicle as a part of an automotive air-conditioning system is cumbersome work, especially because the engine room tends to be reduced in space.

[0007] Further, the refrigeration circuit using CO₂ as a refrigerant is higher in pressure on the high-pressure side, compared with the conventional refrigeration circuit using an HFC refrigerant. Thus, there is a concern about a leakage of the refrigerant around the coupling member.

[0008] Further, the use of the internal heat exchanger in the refrigeration circuit causes not only a decrease in ease of installation in the vehicle and an increase in concern about the refrigerant leakage, but also a rise in the refrigerant temperature at the inlet and outlet of the compressor and therefore a decrease in adiabatic efficiency (compression efficiency) of the compressor.

SUMMARY OF THE INVENTION

[0009] The primary object of the present invention is to provide a vapor compression refrigeration circuit which is composed of a reduced number of major devices and connecting parts so that the refrigerant leakage is prevented, and which is easy to assemble, and an automotive air-conditioning system using this refrigeration circuit.

[0010] In order to achieve this object, a vapor compression refrigeration circuit according to this invention comprises a compressor, a heat radiator, a high-temperature section of an internal heat exchanger, a pressure reducer, an evaporator, an accumulator and a low-temperature section of the internal heat exchanger disposed in this order in a circulation passage through which a refrigerant circulates, when viewed along a direction of flow of the refrigerant, wherein the pressure reducer, the accumulator and the internal heat exchanger are integrally formed.

[0011] In the vapor compression refrigeration circuit according to this invention, the pressure reducer, the accumulator and the internal heat exchanger are integrally formed. In other words, the pressure reducer, the accumulator and the internal heat exchanger form one module. Thus, the major devices constituting the refrigeration circuit are reduced in number, and also the connecting parts are reduced in number, since the pipes and coupling members used with the pipes for connecting the pressure reducer, the accumulator and the internal heat exchanger are reduced. Consequently, this vapor com-

pression refrigeration circuit is not only easy to assemble but also allows a reduction in size.

[0012] Further, the reduction in the number of coupling members in this vapor compression refrigeration circuit results in a reduction in the risk of the refrigerant leakage around the coupling members.

[0013] Desirably, the pressure reducer is adjacent to the accumulator. This allows a further reduction in size.

[0014] In addition, since heat exchange takes place between the pressure reducer and the accumulator, the heat transfer achieved in the internal heat exchanger is less needed. This allows a reduction in size of the internal heat exchanger and therefore allows a further reduction in size of the refrigeration circuit.

[0015] Desirably, the vapor compression refrigeration circuit further comprises a superheat reduction device for heat exchange between a liquid-phase component of the refrigerant accumulated in the accumulator and a vapor-phase component of the refrigerant exiting the low-temperature section of the internal heat exchanger.

[0016] In the desirable vapor compression refrigeration circuit, the refrigerant has a decreased temperature at the inlet of the compressor, which results in an increase in adiabatic efficiency (compression efficiency) of the compressor. In addition, since the degree of superheat of the refrigerant at the inlet of the compressor is decreased, the compression of the refrigerant requires less motive power. Consequently, this refrigeration circuit has an improved COP.

[0017] Desirably, the superheat reduction device has a pipe disposed in a part of the circulation passage between the low-temperature section of the internal heat exchanger and the compressor and the pipe passes across a bottom part of the accumulator.

[0018] In the desirable refrigeration circuit, the superheat reduction device has a simple structure which is constituted by the pipe and ensures that heat exchange takes place between the liquid-phase component of the refrigerant accumulated in the accumulator and the vapor-phase component of the refrigerant exiting the low-temperature section of the internal heat exchanger.

[0019] Desirably, the superheat reduction device further has surface irregularities formed on at least one of inner and outer peripheral surfaces of the pipe. Due to the surface irregularities, the pipe has an increased surface area, and therefore allows heat exchange to take place efficiently, so that the COP of the refrigeration circuit is further improved.

[0020] Desirably, the pipe has an oil return hole for drawing in a lubricating oil accumulated in the accumulator. The oil return hole ensures that the lubricating oil is returned to the compressor, thereby ensuring the durability of the compressor.

[0021] Desirably, the pipe have an inlet end and an outlet end each connected to an inner wall surface of the accumulator, where the outlet end is at a higher position than the inlet end and a surface of the liquid-phase component of the refrigerant accumulated in the accumulator.

[0022] In the desirable refrigeration circuit, the pipe extends also vertically within the accumulator, so that the liquid-phase component of the refrigerant accumulated in the accumulator contacts the pipe in a greater area. Thus, the pipe allows heat exchange to take place efficiently, so that the COP of the refrigeration circuit is further improved.

[0023] Further, the arrangement of the pipe with an outlet end at a higher position than an inlet end prevents the refrigerant in liquid form from exiting the accumulator, thereby preventing the occurrence of liquid compression in the compressor.

[0024] Desirably, the refrigerant is CO₂.

[0025] The desirable refrigeration circuit uses CO₂ as a refrigerant, and therefore is environmentally-friendly. In addition, although this refrigeration circuit uses CO₂ which becomes high in pressure as a refrigerant, the refrigerant leakage is prevented since the coupling members are reduced.

[0026] The present invention also provides an automotive air-conditioning system provided with any one of the preceding vapor compression refrigeration circuit.

[0027] Because of the use of the vapor compression refrigeration circuit in any one of the preceding vapor compression refrigeration circuit, the automotive air-conditioning system according to the present invention can be easily installed in a vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus, are not limitative of the present invention, and wherein:

FIG. 1 is a diagram showing the schematic structure of an embodiment of a refrigeration circuit of an automotive air-conditioning system according to the present invention,

FIG. 2 is a perspective view schematically showing a module applied to the refrigeration circuit of FIG. 1, FIG. 3A is a top view of the module of FIG. 2, FIG. 3B is a front view of the module of FIG. 2, FIG. 3C is a side view of the module of FIG. 2, FIG. 3D is a back view of the module of FIG. 2, FIG. 4 is a cross-sectional view along line IV-IV of FIG. 3A,

FIG. 5 is a diagram showing a heat exchange tube of the module of FIG. 2 with an adaptor joined thereto,

FIG. 6 is a cross-sectional view along line VI-VI of FIG. 3A,

FIG. 7 is a cross-sectional view along line VII-VII of FIG. 3C,

FIG. 8 is a partial cross-sectional view showing, in detail, a pipe used in the module of FIG. 2, in a straightened state,

FIG. 9 is a Mollier diagram for explaining the processes taking place in the refrigeration circuit of FIG. 1, and

FIG. 10 is a perspective view showing a variant of the heat exchange tube.

DETAILED DESCRIPTION

[0029] FIG. 1 shows an outline of an embodiment of a refrigeration circuit of an automotive air-conditioning system. The refrigeration circuit is a vapor compression type, and used to cool or dehumidify air sent to a vehicle compartment 2.

[0030] The refrigeration circuit has a circulation passage 4, and a CO₂ refrigerant (R-744), which is a natural refrigerant, with a small amount of lubricating oil contained as a refrigerating machine oil, circulates through the circulation passage 4. The circulation passage 4 extends from an engine room 6 to a front part of a vehicle compartment 2, through a partition wall 8. The front part of the vehicle compartment 2 is defined as a device space 12 by an instrument panel 10.

[0031] In the circulation passage 4, a compressor 14, a heat radiator 16 and an evaporator 18 are disposed, and also an internal heat exchanger module 20 is disposed. The module 20 has a structure in which a pressure reducer (expansion valve), an accumulator (vapor-liquid separator) and an internal heat exchanger are integrally formed. Thus, practically, in the circulation passage 14, the compressor 14, the heat radiator (gas cooler) 16, a high-temperature section (high-pressure section) of an internal heat exchanger, a pressure reducer, the evaporator 18, an accumulator, and a low-temperature section of the internal heat exchanger are disposed in this order.

[0032] Next, the module 20 will be described.

[0033] As shown in FIGS. 2, 3A, 3B, 3C and 3D, the module 20 includes a block 22 in a shape of a rectangular parallelepiped, and a box-shaped casing 24. The block 22 and the casing 24 are brazed together in a side-by-side arrangement. The block 22 and the casing 24 form a unit in a shape of a rectangular parallelepiped. In other words, the front face of the block 22 is flush with that of the casing 24, while the rear face of the block 22 is flush with that of the casing 24.

[0034] To the rear face of the unit formed by the joined block 22 and casing 24, two adapters 26, 26 are brazed. The two adapters 26, 26 are vertically spaced apart, and each adapter 26 has an oval shape with a determined thickness. To the outer surface of each adapter 26, each end of a U-shaped heat-exchange tube 28 is connected by brazing.

[0035] In the front face of the unit, four ports 30, 32, 34 and 36 are open. Two ports 30, 32 are formed in the block 22, vertically spaced apart, and the other two ports 34, 36 are formed in the casing 24, vertically spaced apart. Although not shown, a pipe extending from the outlet of the heat radiator 16 is connected to the lower one 32 of the two ports 30, 32 formed in the block 22, by

means of a coupling member, while a pipe extending from the inlet of the evaporator 18 is connected to the upper port 30 by means of a coupling member.

[0036] Further, a pipe extending from the inlet of the compressor 14 is connected to the lower one 36 of the two ports 34, 36 formed in the casing 24, by means of a coupling member, while a pipe extending from the outlet of the evaporator 18 is connected to the upper port 34 by means of a coupling member. It is to be noted that the upper port 30 in the block 22 and the upper port 34 in the casing 24 are located at the same height, and that the two pipes extending from the evaporator 18 are connected to the respective ports 30, 34, by means of one coupling member.

[0037] As shown in FIG. 4, in the block 22, a first internal flow passage 38 is formed to extend straight from the lower port 32 to the rear face. The first internal flow passage 38 has an end open at the rear face of the block 22, and this open end of the first internal flow passage 38 is covered with the lower adapter 26. In a surface (inner surface) of the lower adapter 26 located on the block 22 side, a groove (central groove) 40 is formed, and one end of the central groove 40 communicates with the first internal flow passage 38. The central groove 40 extends along the length of the adapter 26, and the other end of the central groove 40 communicate with a center hole 42 which passes through the center part of the adapter 26 in the thickness direction thereof. The center hole 42 has an end open at a surface (outer surface) of the adapter 26 opposite to the block 22.

[0038] As shown in FIG. 5, the heat exchange tube 28 has a coaxial double-tube structure and functions as an internal heat exchanger. Specifically, the heat exchange tube 28 includes a small-diameter tube 44, which is surrounded by a coaxial large-diameter tube 46. In the heat exchange tube 28, a flow passage (high-temperature section) 48 is defined inside the small-diameter tube 44, and this inner flow passage 48 communicates with the center hole 42 of each of the upper and lower adapters 26.

[0039] In the heat exchange tube 22, between the small-diameter tube 44 and the large-diameter tube 46, a cylindrical flow passage (low-temperature section) 52 approximately in the shape of a cylinder is defined by means of column-shaped parts 50 integrally connecting the small-diameter tube 44 and the large-diameter tube 46. Each adapter 26 has an upper hole 54 above the center hole 54 and a lower hole 56 below the center hole 42. Also the upper and lower holes 54, 56 pass through the adapter 26 in the thickness direction thereof. The respective ends of the upper and lower holes 54, 56 open at the outer surface of each of the upper and lower adapters 26 are connected to the cylindrical flow passage 52 of the heat exchange tube 28. Each adapter 26 has upper and lower grooves 58, 60 formed in the inner surface. When viewed along the length direction of the adapter 26, the upper and lower grooves 58, 60 extend from the upper and lower holes 54, 56 in the direction opposite to the central groove 40.

[0040] A second internal flow passage 62 formed in the block 22 communicates with an end of the central groove 40 formed in the inner surface of the upper adapter 26. The second internal flow passage 62 extends horizontally from the rear face of the block 22 toward the front face, halfway. The inner end of the second internal flow passage 62 communicates with the lower end of a valve hole 64 vertically extending in the block 22. The upper end of the valve hole 64 communicates the inner end of a third internal flow passage 66 which extends from the upper port 30 of the block 22 toward the rear face, halfway.

[0041] The upper end of the valve hole 64 is formed into a spherical valve seat. A valve ball 68 is seated on the spherical valve seat, from above. The block 22, the spherical valve seat of the valve hole 64 and the valve ball 68 constitute a pressure reducer. A helical compression spring 70 is loaded in contact with the upper side of the valve ball 68. The helical compression spring 70 always exerts a downward force on the valve ball 68. Meanwhile, a rod 72 which vertically extends in the block 22 is in contact with the lower side of the valve ball 68. The lower end of the rod 72 is located in the first internal flow passage 38. The rod 72 expands and contracts depending on the temperature of its lower end (thermal sensing part). Thus, the amount of lift of the valve ball 68 from the spherical valve seat, or in other words, the valve opening degree of the pressure reducer is determined such that the force exerted by the rod 72 balances the force exerted by the helical compression spring 70.

[0042] As shown in FIGS. 6 and 7, the casing 24 is in the shape of a box open to the block 22 side. The edge surrounding the opening of the casing 24 is brazed to the corresponding side face of the block 22.

[0043] In the rear wall of the casing 24, four connecting holes 72, 74, 76, 78 are formed, vertically spaced apart. The connecting holes 72, 74, 76, 78 each pass through the thickness of the rear wall of the casing 24, at the center of the width thereof. The connecting holes 72, 74 form a pair corresponding to the upper adapter 26, while the connecting holes 76, 78 form a pair corresponding to the lower adapter 26. The ends of each pair of the connecting holes 72, 74, 76, 78 which are open in the rear face of the casing 24 communicate with the ends of the upper and lower grooves 58, 60 formed in the inner surface of the corresponding adapter 26, respectively. Thus, the connecting holes 72, 74, 76, 78 each communicate with the cylindrical flow passage 52 of the heat exchange tube 28, through the adapter 26.

[0044] Inside the casing 24, a pipe (heat transfer pipe) 80 for heat exchange, also called a low-fin tube, is arranged. As shown in detail in FIG. 8, the pipe 80 has a helical ridge 82 formed integrally on the outer peripheral surface of the pipe 80, as a heat radiation fin. The outlet end of the pipe 80 is connected to the inner surface of the front wall of the casing 24 by brazing, and the lower port 36 is open within the region of the front wall surrounded by this outlet end. The inlet end of the pipe 80

is connected to the inner surface of the rear wall of the casing 24 by brazing, and the lower pair of the connecting holes 76, 78 are open within the region of the rear wall surrounded by this inlet end.

[0045] Although the pipe 80 extends in a bottom side part of the interior space 84 in a shape of a rectangular parallelepiped defined by the casing 42, the inlet end of the pipe 80 is located at a lower position than the outlet end. Thus, the pipe 80 extends not only horizontally but also vertically. Although the liquid-phase components of the refrigerant and the lubricating oil accumulate in the bottom side part of the interior space 84, the outlet end of the pipe 80 is located above the surface 86 of the liquid-phase components accumulated.

[0046] The pipe 80 has an oil return hole 88 passing through the peripheral wall thereof, at the bottom.

[0047] Referring to the Mollier diagram (p-h diagram) of FIG. 9, the processes taking place in the above-described refrigeration circuit will be described.

[0048] In this refrigeration circuit, the compressor 14 powered by the engine suctions a refrigerant in a vapor phase of a low temperature and pressure flowing from the port 36 of the module 20. Point a in FIG. 9 represents the state of the refrigerant at the inlet of the compressor 14.

[0049] The compressor 14 compresses the suctioned refrigerant into a supercritical state of a high temperature and pressure, and discharges it toward the heat radiator 16. In other words, the compressor 14 performs suction, compression and discharge of the refrigerant, so that the refrigerant is caused to circulate through the circulation passage 4. Point b represents the state of the refrigerant at the outlet of the compressor 14.

[0050] While passing through the heat radiator 16, the refrigerant flowing from the compressor 14 is cooled by air coming from ahead of the vehicle and from a fan, so that its temperature drops. Point c represents the state of the refrigerant at the outlet of the heat radiator 16.

[0051] The refrigerant that has exited the heat radiator 16 enters the module 20 through the port 32. The refrigerant entering the module 20 flows through the first internal flow passage 38 of the block 22, the central groove 40 and the center hall 42 of the lower adapter 26, successively, and then enters the inner flow passage 48 of the heat exchange tube 28. In the heat exchange tube 28, heat exchange takes place between the refrigerant flowing in the inner flow passage 48 and the refrigerant flowing in the cylindrical flow passage 52. Consequently, the refrigerant after exiting the inner flow passage 48 has an enthalpy decreased by Δh_2 , compared with before entering the inner flow passage 48. Point d represents the state of the refrigerant after exiting the inner flow passage 48.

[0052] The refrigerant that has passed through the inner flow passage 48 of the heat exchange tube 28 enters the second internal flow passage 62 of the block 22, through the center hole 42 and the central groove 40 of the upper adapter 26. Then, the refrigerant flows through

the valve hole 64 and the third internal flow passage 66, and once exits the module 30 through the port 30. Here, the valve hole 64 is decreased in flow-passage cross-sectional area at the upper end, due to the spherical valve seat and the valve ball 68 which constitute the pressure reducer. Thus, while passing through the upper end of the valve hole 64, the refrigerant expands. Due to this expansion, the pressure of the refrigerant drops to the critical pressure or below. At the port 30, the refrigerant is in the state of a vapor-liquid mixture, and point e represents this state.

[0053] While passing through the evaporator 18, the liquid-phase component of the refrigerant in the vapor-liquid mixture state evaporates by taking heat from the surroundings, so that the air flowing outside the evaporator 18 is cooled to become cold air. By this cold air entering the vehicle compartment 2, the vehicle compartment 2 is cooled or dehumidified. Point f represents the state of the refrigerant at the outlet of the evaporator 18.

[0054] The refrigerant, of which the liquid-phase component has almost completely evaporated in the evaporator 18, enters the casing 24 of the module 20, through the port 34. The refrigerant entering the casing 24 flows across the interior space 84 and enters the connecting holes 72, 74, where the liquid-phase component remaining in the refrigerant only in a very small amount does not enter the connecting holes 72, 74 but collides against and adheres to the inner surface of the casing 24. The liquid-phase component of the refrigerant that has adhered then flows downward along the inner surface and accumulates in the bottom side part of the interior space 84. Thus, the casing 24 functions as an accumulator.

[0055] The vapor-phase component of the refrigerant that has passed through the interior space 84 enters the cylindrical flow passage 52 of the heat exchange tube 28, through the upper and lower grooves 58, 60 and the upper and lower holes 54, 56 of the upper adapter 26. As mentioned above, the refrigerant flowing in the cylindrical flow passage 52 is heated by heat exchange with the refrigerant flowing in the inner flow passage 52, so that its enthalpy is increased by Δh_1 . Point g represents the state of the refrigerant at the inlet of the pipe 80 after passing through the cylindrical flow passage 52. According to the first law of thermodynamic, $\Delta h_1 \approx \Delta h_2$.

[0056] The refrigerant that has passed through the cylindrical flow passage 52 enters the pipe 80, through the upper and lower holes 54, 56 of the lower adapter 26, the upper and lower grooves 58, 60 and the connecting holes 76, 78. Heat exchange takes place also between the refrigerant flowing through the pipe 80 and the liquid-phase component of the refrigerant in contact with the outer peripheral surface of the pipe 80, so that the enthalpy of the refrigerant is decreased by Δh_3 . Point a represents the state of the refrigerant at the port 36 after passing through the pipe 80.

[0057] The refrigerant that has passed through the pipe 80 exits the module 20 through the port 36 and is again suctioned by the compressor 14. It is to be noted

that with the refrigerant flowing through the pipe 80, the lubricating oil accumulated in the bottom side part of the interior space 84 is drawn into the pipe 80 through the oil return hole 88. Thus, also the lubricating oil is returned to the compressor 14 with the refrigerant.

[0058] In the described refrigeration circuit, the pressure reducer, the accumulator and the internal heat exchanger are integrated to the module 20 in an inseparable manner. Consequently, the major devices constituting the refrigeration circuit are reduced in number, and also the connecting parts are reduced in number, since the pipes and coupling members used with the pipes for connecting the pressure reducer, the accumulator and the internal heat exchanger are reduced. Consequently, this refrigeration circuit is not only easy to assemble but also allows a reduction in size, so that the automotive air-conditioning system using this refrigeration circuit is easy to install in the vehicle.

[0059] Further, in this refrigeration circuit, the risk of the refrigerant leakage around the coupling members is reduced, since the coupling members are reduced.

[0060] Further, the module 20 used in this refrigeration circuit has a lateral two-layer structure in which the block 22 including the pressure reducer and the casing 24 forming the accumulator are adjacent with their side faces against each other (in plane contact with each other), which allows a further reduction in size.

[0061] Further, since the module 20 used in this refrigeration circuit is designed such that heat exchange takes place between the pressure reducer and the accumulator, the heat transfer achieved in the internal heat exchanger is less need. This allows a reduction in size of the heat exchange tube 28 as the internal heat exchanger, and therefore allows a further reduction in size of the refrigeration circuit. It is desirable to arrange such that, in the heat exchange tube 28, the direction of the refrigerant flowing through the inner flow passage 48 is opposite to the direction of the refrigerant flowing through the cylindrical flow passage 52. Such arrangement can provide a greater temperature difference between the refrigerant in the inner flow passage 48 and the refrigerant in the cylindrical flow passage 52, which results in an increase in heat exchange efficiency.

[0062] Further, the module 20 used in this refrigeration circuit includes the pipe 80 as a superheat reduction device. The pipe 80 allows heat exchange to take place between the liquid-phase component of the refrigerant accumulated in the accumulator and the vapor-phase component of the refrigerant exiting the low-temperature section of the internal heat exchanger. Consequently, the refrigerant has a decreased temperature at the inlet of the compressor 14, which results in an increase in adiabatic efficiency (compression efficiency) of the compressor 14 and a decrease in motive power required for compression of the refrigerant. Specifically, in isentropic change in the compressor, when the degree of superheat of the refrigerant is smaller, the gradient $\Delta P/\Delta h$ in the Mollier diagram is greater and the motive power required

for the compressor is smaller. Also for this reason, this refrigeration circuit has an improved COP.

[0063] Although the superheat reduction device is not limited to a particular structure, it is desirable to use the pipe 80, since the simple structure constituted by the pipe 80 can ensure that heat exchange takes place between the liquid-phase component of the refrigerant accumulated in the accumulator and the vapor-phase component of the refrigerant exiting the low-temperature section of the internal heat exchanger.

[0064] Desirably, the superheat reduction device has surface irregularities such as the ridge 82 on at least one of the inner and outer peripheral surfaces of the pipe 80. With the greater surface area, the pipe 80 enables efficient heat exchange, so that the COP of the refrigeration circuit is further improved.

[0065] Desirably, the pipe 80 has the oil return hole 88. Such arrangement ensures that the lubricating oil is returned to the compressor 14, thereby ensuring the durability of the compressor 14.

[0066] Desirably, the pipe 80 has the outlet end at a higher position than the inlet end. Such arrangement allows the pipe 80 to extend also vertically within the accumulator, thereby allowing the liquid-phase component of the refrigerant accumulated in the accumulator to contact the pipe in a greater area. Thus, the pipe 80 allows heat exchange to take place efficiently, so that the COP of the refrigeration circuit is further improved.

[0067] Further, the arrangement of the pipe 80 with the outlet end at a higher position than the inlet end prevents the refrigerant in liquid form from exiting the accumulator, thereby preventing the occurrence of liquid compression in the compressor 14.

[0068] This refrigeration circuit uses CO₂ as a refrigerant, and therefore is environmentally-friendly. In addition, although this refrigeration circuit uses CO₂ which becomes high in pressure as a refrigerant, the refrigerant leakage is prevented since the coupling members are reduced.

[0069] The present invention is not limited to the above-described embodiment but can be modified in various ways. For example, the refrigerant is not limited to CO₂.

[0070] In the described embodiment, although the material for each of the components constituting the module 20 is not limited to a particular one, it is desirable to use a metal high in thermal conductivity, such as copper or aluminum, in order to improve the efficiency of heat exchange between the pressure reducer and the accumulator.

[0071] Although in the described embodiment, the heat exchange tube 28 having a double-tube structure is used, there can be used a heat exchange tube 94 as shown in FIG. 9, which consists of three flat tubes 92 with a plurality of minute holes 90 stacked in layers. With the flat tubes stacked such that the high-pressure side and the lower-pressure side alternate, the heat exchange tube 92 enables an improvement in heat exchange efficiency.

ciency.

[0072] Although in the described embodiment, the pressure reducer of the module 20 consists of a thermal expansion valve which varies in valve opening degree depending on temperature, it can consist of a variable orifice which varies in valve opening degree depending on the flow rate of the refrigerant.

[0073] The invention thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

Claims

1. A vapor compression refrigeration circuit, comprising:

a compressor (14), a heat radiator (16), a high-temperature section (48) of an internal heat exchanger (28), a pressure reducer (22, 64, 68), an evaporator (18), an accumulator (24) and a low-temperature section (52) of the internal heat exchanger (28) disposed in this order in a circulation passage (4) through which a refrigerant circulates, when viewed along a direction of flow of the refrigerant, **characterized in that** the pressure reducer (22, 64, 68), the accumulator (24) and the internal heat exchanger (28) are integrally formed.

2. The vapor compression refrigeration circuit according to claim 1, wherein the pressure reducer (22, 64, 68) is adjacent to the accumulator (24).
3. The vapor compression refrigeration circuit according to claim 1 or 2, further comprising a superheat reduction device for heat exchange between a liquid-phase component of the refrigerant accumulated in the accumulator (24) and a vapor-phase component of the refrigerant exiting the low-temperature section (52) of the internal heat exchanger (28).
4. The vapor compression refrigeration circuit according to any one of claims 1, 2 and 3, wherein the superheat reduction device includes a pipe (80) disposed in a part of the circulation passage (4) between the low-temperature section (52) of the internal heat exchanger (28) and the compressor (14), the pipe passing across a bottom side part of the accumulator (24).
5. The vapor compression refrigeration circuit according to claim 4, wherein

the superheat reduction device further includes surface irregularities (82) formed on at least one of inner and outer peripheral surfaces of the pipe (80).

6. The vapor compression refrigeration circuit according to claim 4 or 5, wherein the pipe (80) has an oil return hole (88) for drawing in a lubricating oil accumulated in the accumulator (24). 5
7. The vapor compression refrigeration circuit according to any one of claims 4, 5 and 6, wherein the pipe (80) has an inlet end and an outlet end each connected to an inner wall surface of the accumulator (24), where the outlet end is at a higher position than the inlet end and a surface (86) of the liquid-phase component of the refrigerant accumulated in the accumulator (24). 10 15
8. The vapor compression refrigeration circuit according to any one of preceding claims, wherein the refrigerant is CO₂. 20
9. An automotive air-conditioning system, comprising a vapor compression refrigeration circuit according to any one of claims 1 to 8. 25

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FIG. 1

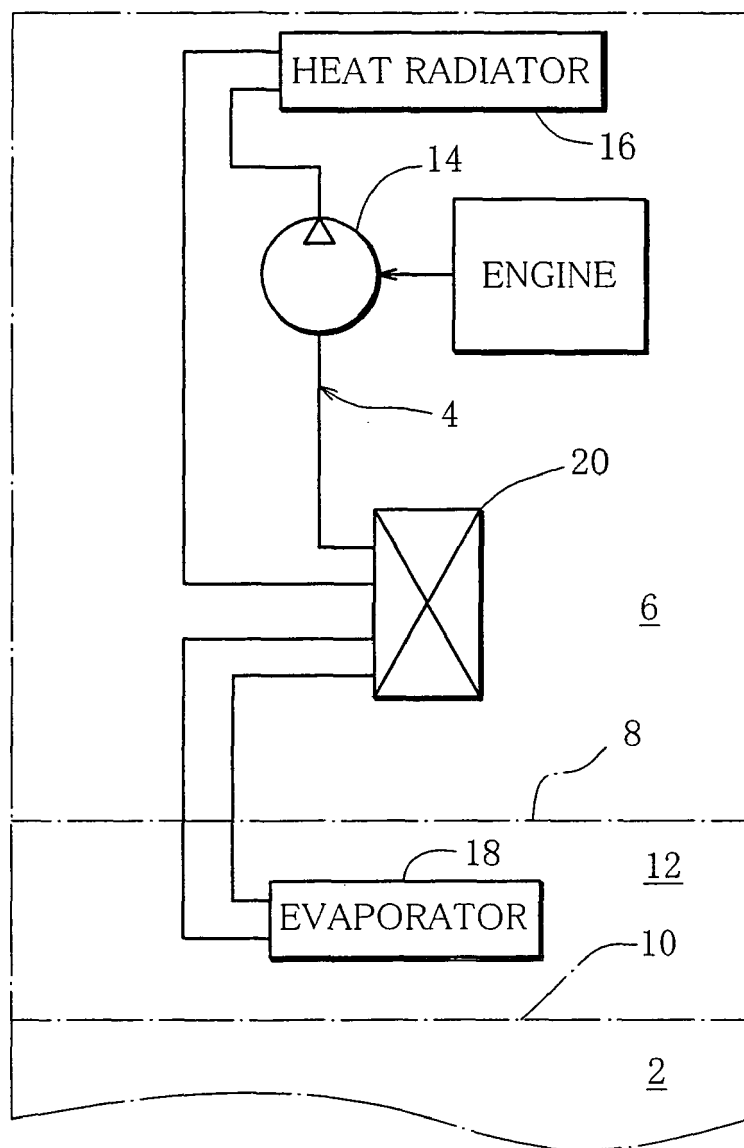


FIG. 2

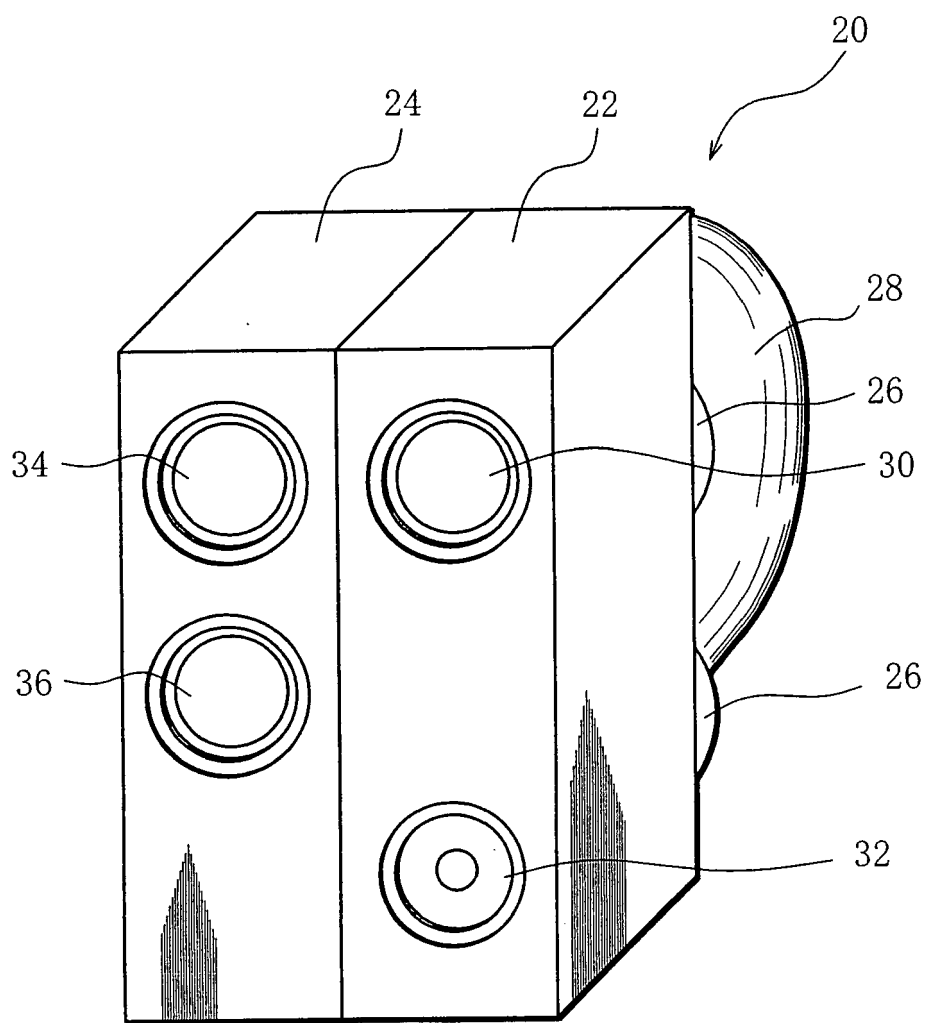


FIG. 3A

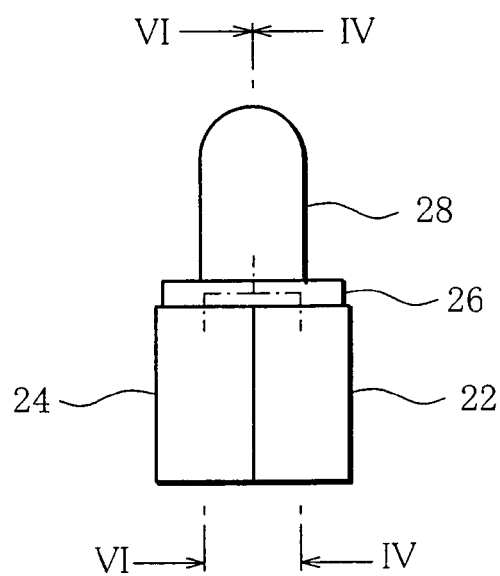


FIG. 3B

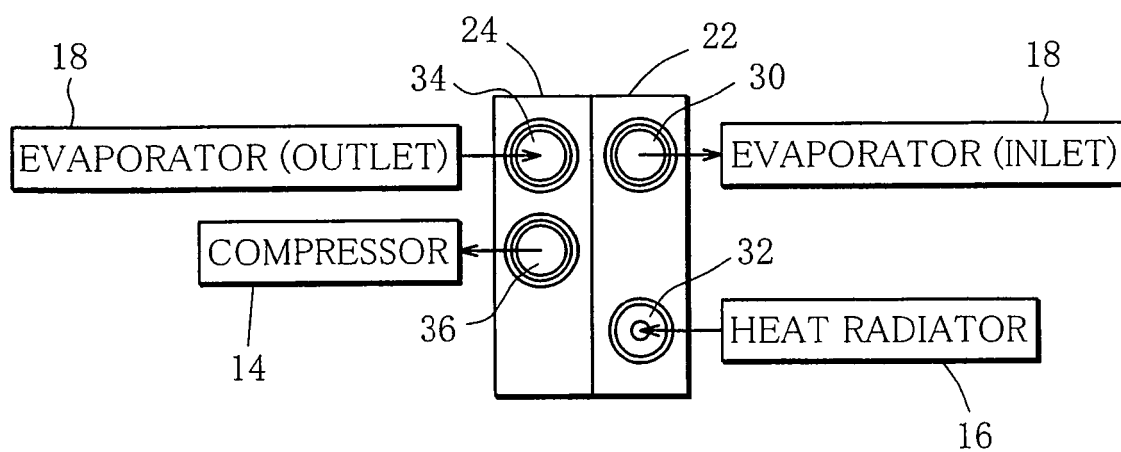


FIG. 3C

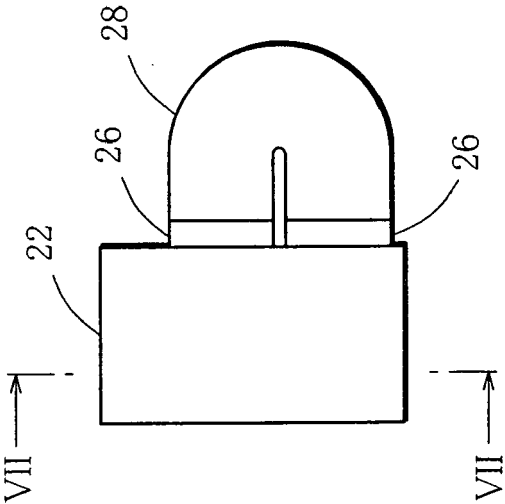


FIG. 3D

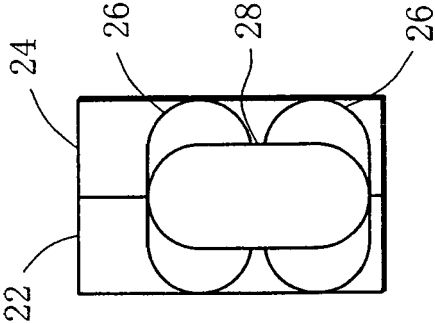


FIG. 4

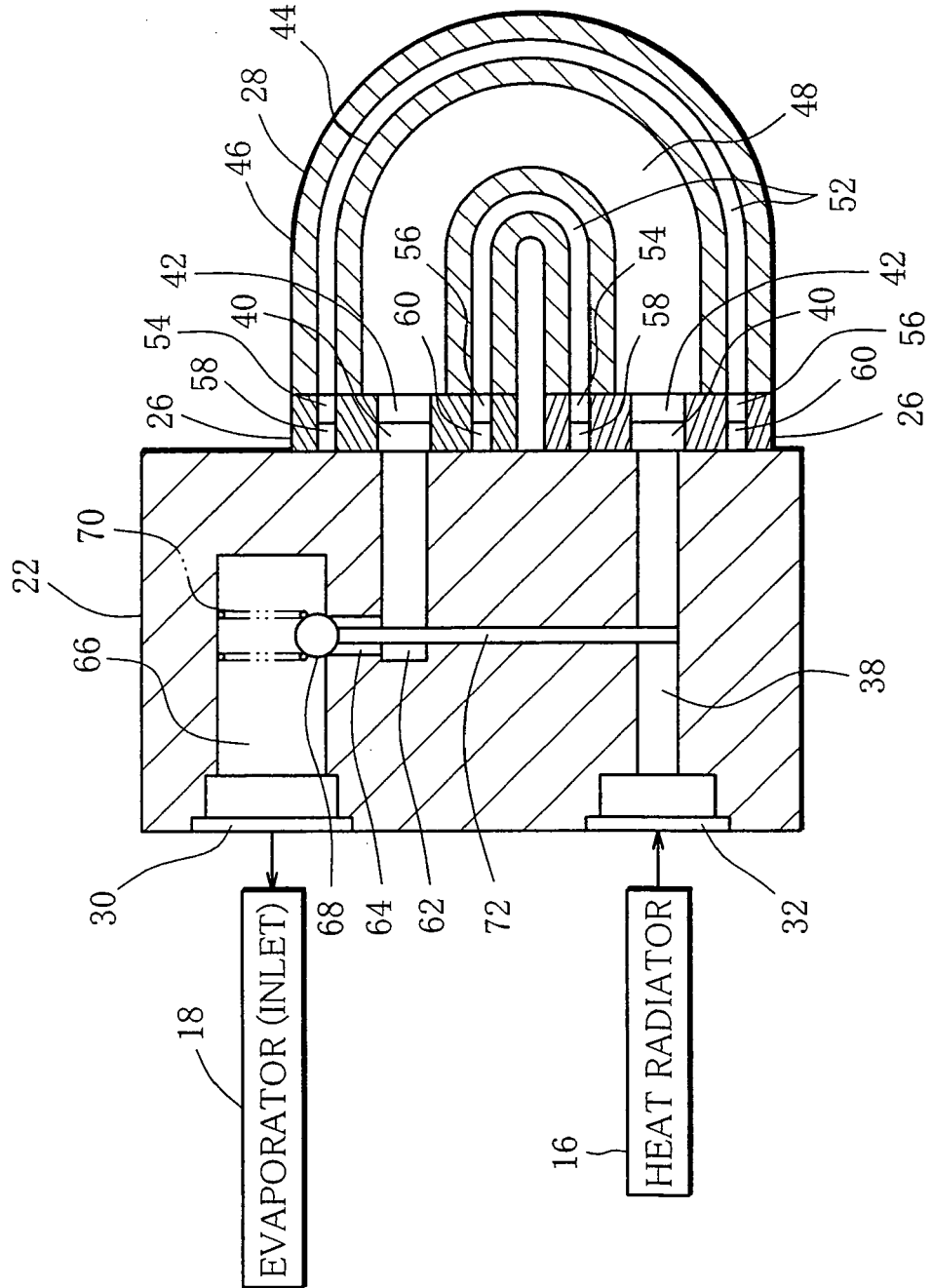


FIG. 5

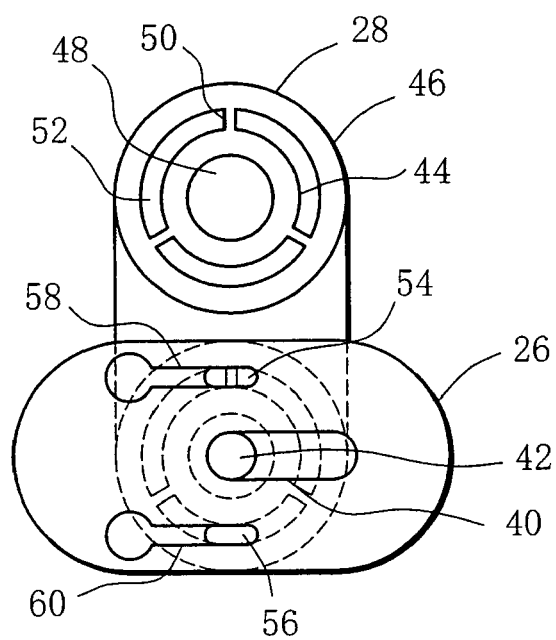


FIG. 6

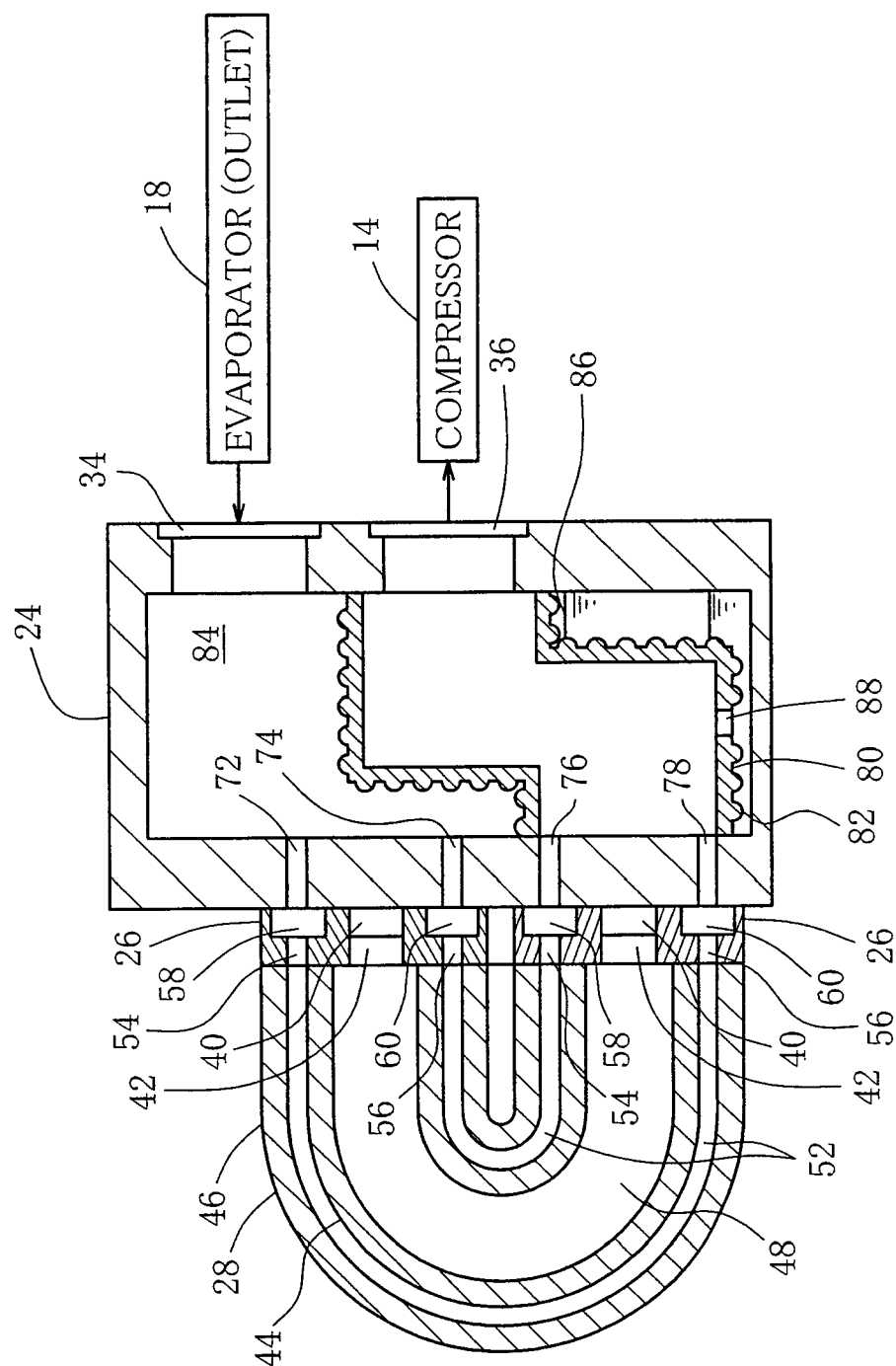


FIG. 7

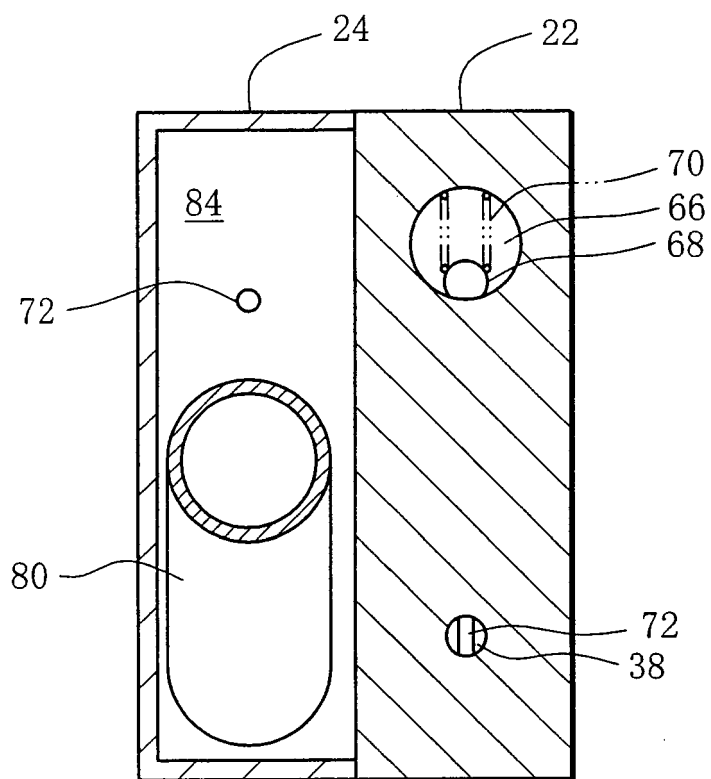


FIG. 8

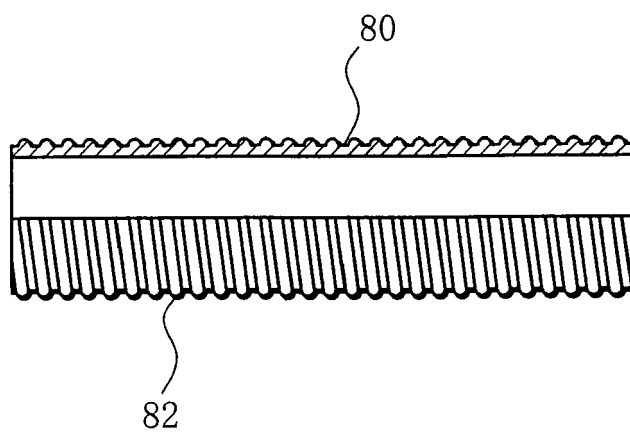


FIG. 9

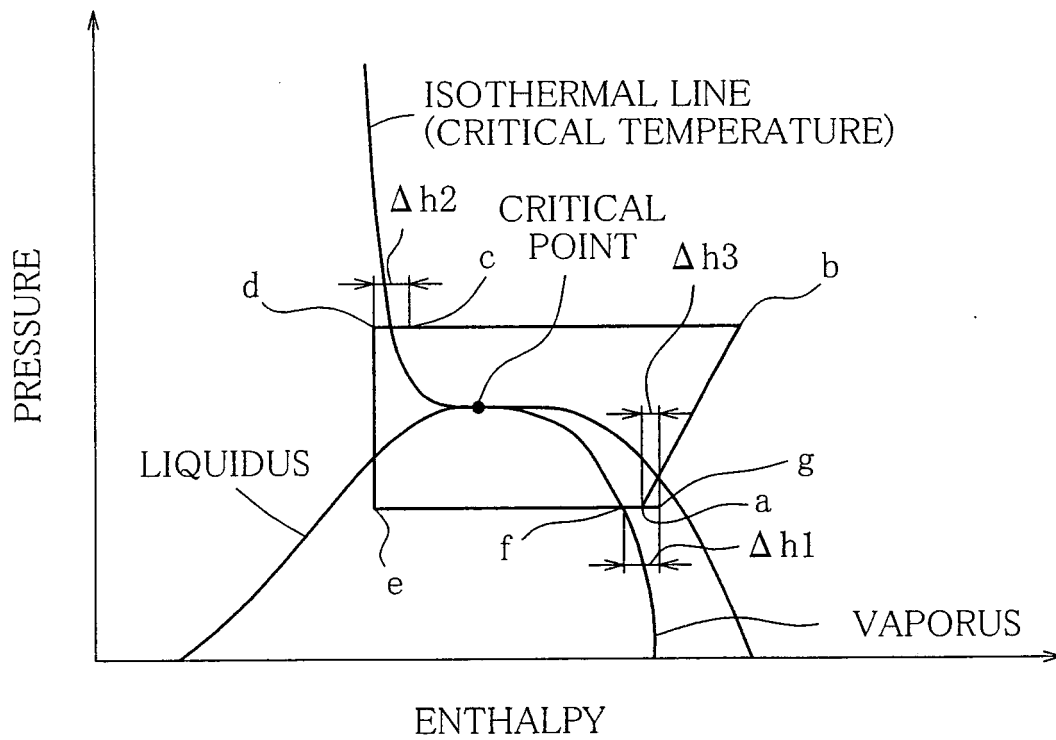
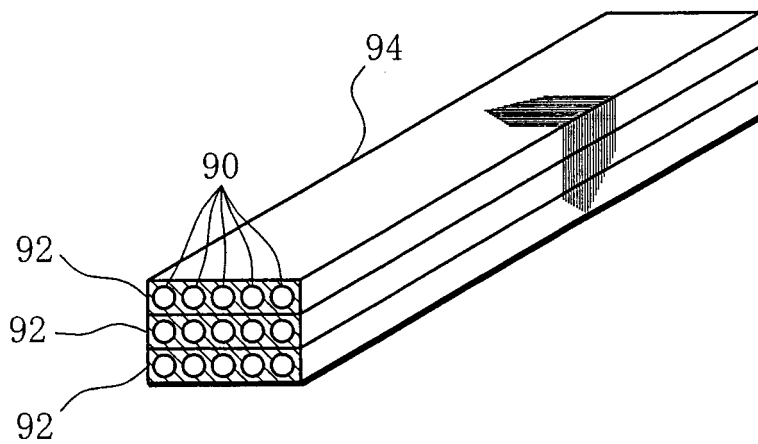


FIG. 10





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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 4 October 2007	Examiner de Graaf, Jan Douwe
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EUROPEAN SEARCH REPORT

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Place of search The Hague		Date of completion of the search 4 October 2007	Examiner de Graaf, Jan Douwe
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