A double-wall pipe includes an outer pipe provided with first and second openings, respectively, at first and second end parts of the outer pipe in a pipe longitudinal direction, and an inner pipe inserted in the outer pipe to define a passage between the outer pipe and the inner pipe. An inlet portion is connected to the outer pipe to communicate with the passage through the first opening, and an outlet portion is connected to the outer pipe to communicate with the passage through the second opening. In the double-wall pipe, the outer pipe and the inner pipe can be disposed to define an expanded portion having an expanded sectional area in the first passage, and the expanded portion can be provided at least at a portion near the inlet portion and the outer portion. The inner pipe can be provided with plural grooves in the double-wall pipe.
DOUBLE-WALL PIPE AND REFRIGERANT CYCLE DEVICE USING THE SAME

CROSS REFERENCE TO RELATED APPLICATION


FIELD OF THE INVENTION

[0002] The present invention relates to a double-wall pipe constructed with an inner pipe defining an inner passage and an outer pipe enveloping the inner pipe so as to define an outer passage between the outer pipe and the inner pipe. The double-wall pipe can be suitably used for a refrigerant cycle device, for example.

BACKGROUND OF THE INVENTION

[0003] A double-wall pipe is used in a refrigerant cycle device for a vehicle air conditioning system, for example.

[0004] A double-wall pipe disclosed in, for example, JP-A-2001-277842 is formed by combining a high-pressure refrigerant pipe extending between a compressor and a condenser and between the condenser and an evaporator, and a low-pressure refrigerant pipe extending between the evaporator and the compressor. The double-wall pipe has at least a double-wall section formed by enveloping the low-pressure refrigerant pipe (or the high-pressure refrigerant pipe) by the high-pressure refrigerant pipe (or the low-pressure refrigerant pipe).

[0005] Heat of the high-temperature high-pressure refrigerant can be transferred to the low-temperature low-pressure refrigerant in the double-wall section. Thus, the high-pressure refrigerant is supercooled (subcooled) by the low-pressure refrigerant and, consequently, the refrigerant having an increased liquid refrigerant amount flows into the evaporator. Resistance of the evaporator against the flow of the refrigerant decreases with the increase of the liquid refrigerant amount of the refrigerant. Consequently, the cooling ability of a cooling system including the evaporator is enhanced. The low-pressure refrigerant discharged from the evaporator is superheated by the heat of the high-pressure refrigerant to prevent the liquid compression in the compressor.

[0006] A double-wall pipe disclosed in JP-A-2003-329376 is formed by combining an inner pipe of a first diameter and an outer pipe of a second diameter. This double-wall pipe is fabricated by inserting the inner pipe into the outer pipe, and twisting the inner pipe so that a screw thread formed by twisting the inner pipe is pressed against the inside surface of the outer pipe.

[0007] A first fluid flows through the inner pipe and a second fluid flows through a helical passage defined by the screw thread of the inner pipe and the outer pipe.

[0008] The double-wall pipe disclosed in JP-A-2001-277842 enables heat transfer from the high-pressure refrigerant to the low-pressure refrigerant. However, nothing about heat transfer efficiency is described in JP-A-2001-277842. Heat transfer efficiency can be increased by increasing the outside diameter of the inner pipe close to the inside diameter of the outer pipe to increase the area of the heat transfer surface.

[0009] However, when the outside diameter of the inner pipe is close to the inside diameter of the outer pipe, an annular passage formed between the inner and the outer pipe is very narrow and exerts high resistance against the flow of the refrigerant. Moreover, an inlet and an outlet formed at opposite end parts of the outer pipe, or an inlet or an outlet formed at one end part of the outer pipe increases resistance against the flow of the refrigerant flowing in the vicinity of the inlet and the outlet or in the vicinity of the inlet or the outlet.

[0010] Since the inner pipe has a small surface area, heat cannot be efficiently transferred from one to the other of the fluids respectively flowing through the inner pipe and through the passage between the inner and the outer pipe.

[0011] The double-wall pipe disclosed in JP-A-2003-329376 connects headers respectively to an inlet and an outlet opening into the helical passage and formed respectively in opposite end parts of the outer pipe. Thus, the double-wall pipe needs additional parts.

SUMMARY OF THE INVENTION

[0012] A first object of the present invention is to provide an improved double-wall pipe.

[0013] A second object of the present invention is to provide a double-wall pipe having an outer pipe and an inner pipe connected to the outer pipe to form a passage between the outer pipe and the inner pipe, and facilitating connection of pipes to the passage.

[0014] A third object of the present invention is to provide a double-wall pipe having an outer pipe and an inner pipe connected to the outer pipe to form a passage between the outer pipe and the inner pipe, and provided with joints with a low resistance on a fluid flowing therethrough.

[0015] A fourth object of the present invention is to provide a double-wall pipe capable of efficiently transferring heat from one fluid to another.

[0016] A fifth object of the present invention is to provide a double-wall pipe capable of efficiently transferring heat between a high-temperature high-pressure refrigerant and a low-temperature low-pressure refrigerant in a refrigerant cycle device.

[0017] A sixth object of the present invention is to provide a refrigerant cycle device having a double-wall pipe.

[0018] According to an aspect of the present invention, a double-wall pipe includes an outer pipe provided with first and second openings, respectively, at first and second end parts of the outer pipe in a pipe longitudinal direction, an inner pipe inserted in the outer pipe to define a passage between the outer pipe and the inner pipe, an inlet portion connected to the outer pipe to communicate with the passage through the first opening, and an outlet portion connected to the outer pipe to communicate with the passage through the second opening.
In the double-wall pipe, the outer pipe and the inner pipe are disposed to define an expanded portion having an expanded sectional area in the passage between the outer pipe and the inner pipe, and the expanded portion is provided at least at a portion near the inlet portion and the outer portion. Accordingly, the double-wall pipe can be formed into a simple structure, and the expanded portion reduces resistance against the flow of a fluid flowing in the vicinity of the inlet portion and the outlet portion. Consequently, the fluid is able to flow at high-flow rates through the passage between the inner pipe and the outer pipe, and heat can be efficiently transferred between a fluid flowing in the inner pipe and a fluid flowing through the passage between the inner pipe and the outer pipe.

The expanded portion can be provided by expanding at least at a part of a circumferential portion of the outer pipe in a circumferential direction, or can be provided by reducing at least at a part of a circumferential portion of the inner pipe in a circumferential direction, at least at a portion near the inlet portion and the outlet portion.

According to another aspect of the present invention, in a double-wall pipe constructed with an outer pipe and an inner pipe inserted into the outer pipe, a surface of the inner pipe is provided with a plurality of grooves. For example, the grooves are straight grooves extending in a longitudinal direction of the inner pipe, or helical grooves winding around the inner pipe and extending in the longitudinal direction of the inner pipe. Alternatively, the grooves can include straight grooves extending in the longitudinal direction of the inner pipe, and helical grooves winding around the inner pipe and extending in the longitudinal direction of the inner pipe. Furthermore, the helical grooves can include first helical grooves winding in a first direction around the inner pipe, and second helical grooves winding in a second direction opposite the first direction around the inner pipe.

Accordingly, a turbulent flow of the fluid can be easily generated in the passage between the inner pipe and the outer pipe, and the turbulent flow of the fluid enhances the heat transfer efficiency. Consequently, heat can be efficiently transferred between the fluid flowing through the inner pipe and the fluid flowing through the passage between the inner pipe and the outer pipe.

According to another aspect of the present invention, in a double-wall pipe constructed with an outer pipe and an inner pipe inserted into the outer pipe, the inner pipe is provided in its wall with a groove portion extending from a first end part to a second end part of the inner pipe, the outer pipe has a first joining part joined airtight to the inner pipe at the first end part, and the outer pipe has a first connecting hole which is opened in a radial direction to directly communicate with the groove portion at the first end part. In this case, the double-wall pipe can be easily formed with a simple structure. The outer pipe can be provided with a second joining part joined airtight to the inner pipe at the second end part, and a second connecting hole can be opened in the outer pipe in the radial direction to directly communicate with the groove at the second end part.

For example, the groove portion has a groove extending in a circumferential direction at least in a part corresponding to the connecting hole of the outer pipe. In this case, the groove can extend in a complete circle in the circumferential direction at least in the part corresponding to the connecting hole of the outer pipe. Furthermore, the groove portion can include a helical groove extending helically, or a straight groove extending from the first end part to the second end part.

The inner pipe can be provided with cylindrical end parts respectively formed in first and second end parts thereof, the outer pipe can be provided with cylindrical end parts formed at first and second end parts thereof. In this case, the outer pipe has an inside diameter slightly greater than an outside diameter of the cylindrical end parts of the inner pipe, and the cylindrical end parts of the outer pipe are directly airtightly joined to the cylindrical end parts of the inner pipe, respectively, to form joints. Furthermore, the outer pipe including the cylindrical end parts can have a fixed inside diameter. Alternatively, parts, forming the joints, of the cylindrical end parts of the outer pipe can be radially reduced so as to tightly contact the inner pipe.

The double-wall pipe can be used in a refrigerant cycle device including a compressor, a condenser, a pressure-reducing device and an evaporator. In this case, the passage between the outer pipe and the inner pipe, and a passage inside the inner pipe can be used, respectively, as at least a part of a high-pressure passage connecting the condenser and the pressure-reducing device to carry a high-pressure refrigerant, and as at least a part of a low-pressure passage connecting the evaporator and the compressor to carry a low-pressure refrigerant. That is, the outer pipe and the inner pipe of the double-wall pipe can be used for a refrigerant cycle device such that a high-pressure refrigerant before being decompressed in the pressure-reducing unit flows through the passage between the outer pipe and the inner pipe, and a low-pressure refrigerant after being decompressed in the pressure-reducing unit flows in the inner pipe.

In a double-wall pipe, an uneven portion including at least a groove can be provided in the inner pipe. For example, the uneven portion includes ridges and grooves relative to an outer surface of the inner pipe, edges of the ridges of the uneven portion of the inner pipe are rounded in a radius smaller than an inner radius of the outer pipe, and a passage can be defined by the outer pipe and the grooves of the inner pipe and by the outer pipe and the ridges of the inner pipe. The inner pipe can be provided with an inner cylindrical end part without having the uneven portion, at one end part of the inner pipe, and the outer pipe can be provided with an outer cylindrical end part at a part corresponding to the inner cylindrical end part of the inner pipe. In this case, an inside diameter of the outer pipe can be set slightly greater than an outside diameter of the inner cylindrical end part of the inner pipe, and the outer cylindrical end part of the outer pipe and the inner cylindrical end part of the inner pipe can be directly airtightly joined to form a joint. Therefore, the joint can be easily formed.

In the present invention, the double-wall pipe can be suitably used for a refrigerant cycle device, and the refrigerant cycle device having a double-wall pipe can be suitably used for an air conditioner for a vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent
from the following detailed description of preferred embodiments made with reference to the accompanying drawings, in which:

[0030] FIG. 1 is a schematic view of an automotive air conditioning system;

[0031] FIG. 2 is a schematic perspective view of a refrigerant cycle device mounted on a vehicle;

[0032] FIG. 3 is a partly sectional plan view of a double-wall pipe in a first embodiment according to the present invention;

[0033] FIG. 4 is a sectional view taken on the line IV-IV in FIG. 3;

[0034] FIG. 5 is a Mollier diagram for explaining a phenomenon that occurs in a double-wall pipe;

[0035] FIG. 6 is a partly sectional plan view of a double-wall pipe in a second embodiment according to the present invention;

[0036] FIG. 7 is a partly cutaway perspective view of a double-wall pipe in a third embodiment according to the present invention;

[0037] FIG. 8 is a partly cutaway perspective view of a double-wall pipe in a fourth embodiment according to the present invention;

[0038] FIG. 9 is a side view of an inner pipe included in a double-wall pipe in a fifth embodiment according to the present invention;

[0039] FIG. 10 is a sectional view taken on the line X-X in FIG. 9;

[0040] FIG. 11 is a partly sectional plan view of a double-wall pipe in a sixth embodiment according to the present invention; and

[0041] FIG. 12 is a sectional view showing a double-wall pipe according to a modification of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

[0042] In this embodiment, a double-wall pipe 160 for carrying a refrigerant is typically used for a refrigerant cycle device 100A for a vehicle air conditioning system 100. The double-wall pipe 160 will be described with reference to FIGS. 1 to 4.

[0043] A vehicle has an engine room 1 holding an engine 10 therein and a passenger compartment 2 separated from the engine room 1 by a dash panel 3. The air conditioning system 100 has the refrigerant cycle device 100A including an expansion valve 130 and an evaporator 140, and an interior unit 100B. Components of the refrigerant cycle device 100A excluding the expansion valve 130 and the evaporator 140 are disposed in a predetermined mounting space of the engine room 1. The interior unit 1003 is arranged in an instrument panel placed in the passenger compartment 2.

[0044] The interior unit 100B has components including a blower 102, the evaporator 140 and a heater 103, and an air conditioner case 101 housing the components of the interior unit 100B. The blower 102 takes in outside air or inside air selectively and sends air to the evaporator 140 and the heater 103. The evaporator 140 is a cooling heat exchanger that evaporates a refrigerant, that is, a fluid, used for a refrigeration cycle to make the evaporating refrigerant absorb latent heat of vaporization from air so as to cool the air. The heater 103 uses hot water (engine-cooling water) for cooling the engine 10 as a heat source to heat air to be blown into the passenger compartment 2.

[0045] An air mixing door 104 is disposed near the heater 103 in the air conditioner case 101. The air mixing door 104 is operated to adjust the mixing ratio between cool air cooled by the evaporator 140 and hot air heated by the heater 103 so that air having a desired temperature is sent into the passenger compartment 2.

[0046] The refrigerant cycle device 100A includes a compressor 110, a condenser 120, the expansion valve 130 and the evaporator 140. Pipes 150 connect those components of the refrigerant cycle device 100A to form a closed circuit. A double-wall pipe 160 of the present invention is placed in the pipes 150, for example.

[0047] The compressor 110 is driven by the engine 10 to compress a low-pressure refrigerant vapor to provide a high-temperature high-pressure refrigerant vapor. A pulley 111 is attached to the drive shaft of the compressor 110. A drive belt 12 is extended between the pulley 111 and a crankshaft pulley 11 to drive the compressor 110 by the engine 10. The pulley 111 is linked to the drive shaft of the compressor 110 by an electromagnetic clutch (not shown). The electromagnetic clutch connects the pulley 111 to or disconnects the pulley 111 from the drive shaft of the compressor 110. The condenser 120 is connected to a discharge side of the compressor 110. The condenser 120 is a heat exchanger (refrigerant radiator) that cools the refrigerant vapor by fresh air (outside air) to condense the refrigerant vapor into liquid refrigerant.

[0048] The expansion valve 130 reduces the pressure of the refrigerant (e.g., liquid refrigerant) discharged from the condenser 120 and makes the refrigerant expand. The expansion valve 130 is a pressure-reducing valve capable of reducing the pressure of the refrigerant in an isentropic state. The expansion valve 130 is placed near the evaporator 140 in the passenger compartment 2. The expansion valve 130 is a temperature-controlled expansion valve having a variable orifice and is capable of controlling the flow of the refrigerant so that the refrigerant is heated at a predetermined degree of superheat. The expansion valve 130 controls the expansion of the refrigerant so that the degree of superheat of the refrigerant in the evaporator 140 is, for example, 5° C. or below, more specifically, in the range of 0° C. to 3° C. As described above, the evaporator 140 is a cooling heat exchanger for cooling air to be blown into the passenger compartment. The discharge side of the evaporator 140 is connected to a suction side of the compressor 110.

[0049] The double-wall pipe 160 is placed in the pipe 150 extending between the condenser 120 and the expansion valve 130. The double-wall pipe 160 constructs a part of a high-pressure pipe 151 for carrying the high-pressure refrigerant discharged from the condenser 110, and a part of a low-pressure pipe 152 for carrying the low-pressure refrigerant from the evaporator 140 to the compressor 110.
The double-wall pipe 160 has a length in the range of 700 to 900 mm. As shown in FIG. 2, the double-wall pipe 160 has a plurality of bend portions 160c and is extended in the engine room 1 so that the double-wall pipe 160 may not touch the engine 10 and other devices and the body of the vehicle.

Referring to FIGS. 3 and 4, the double-wall pipe 160 has an outer pipe 161 and an inner pipe 162. The inner pipe 162 is extended in the outer pipe 161 to penetrate through the outer pipe 161. The outer pipe 161 is, for example, a 5/8 inch aluminum pipe having an outside diameter of 19.05 mm and an inside diameter of 16.65 mm. Longitudinal end parts of the outer pipe 161 are reduced to form reduced joining parts 161b. The reduced joining parts 161b of the outer pipe 161 are welded to the inner pipe 162 in a liquid-tight or air-tight state. Thus, the outer pipe 161 and the inner pipe 162 define a passage 160a therebetween.

An inlet pipe 163 (i.e., an inlet portion) and an outlet pipe 164 (i.e., an outlet portion) are welded to end parts of the outer pipe 161, respectively. The refrigerant flows through the inlet pipe 164 into the passage 160a and flows out of the passage 160a through the outlet pipe 164. The inlet pipe 163 and the outlet pipe 164 extend perpendicularly to the longitudinal direction of the outer pipe 161 and serve as connecting pipes. Joints 163a and 164a are attached to the inlet pipe 163 and the outlet pipe 164, respectively. The joint 163a connects the inlet pipe 163 and the high-pressure pipe 151 connected to the condenser 110. The joint 164a connects the outlet pipe 164 to the high-pressure pipe 151 connected to the expansion valve 130. Therefore, the high-pressure refrigerant flows through the passage 160a.

Parts corresponding to the inlet pipe 163 and the outlet pipe 164 of the outer pipe 161 are expanded to form expanded parts 161a. The expanded parts 161a form expanded passages 160b having an increased sectional area in the passage 160a.

The inner pipe 162 is, for example, a 5/8 inch aluminum pipe having an outside diameter of 15.88 mm and an inside diameter of 13.48 mm. The outside diameter of the inner pipe 162 is determined so that the passage 160a has a sectional area large enough to pass the high-pressure refrigerant, and the outer surface of the inner pipe 162 is as close to the inner surface of the outer pipe 161 as possible. Thus, the heat transfer surface area of the inner pipe 162 can be effectively increased.

Joints 162e are attached to the opposite longitudinal ends of the inner pipe 162, respectively. The low-pressure pipe 152 connected to the evaporator 140 is connected to the joint 162e on the right side, as viewed in FIG. 3, and the low-pressure pipe 152 connected to the compressor 110 is connected to the joint 162e on the left side, as viewed in FIG. 3. The low-pressure refrigerant flows through the inner pipe 162 as in the arrow in FIG. 3.

Three longitudinal straight grooves 162b are formed on the surface of a part, corresponding to the range where the passage 160a is formed, of the inner pipe 162 as shown in FIG. 4. Thus, the straight grooves 162b and longitudinal straight ridges protruding outside are arranged alternately in the circumferential direction. The straight grooves 162b form longitudinal straight inner ridges protruding inside the inner pipe 162. The straight grooves 162b and the straight ridges each of which extends in the pipe longitudinal direction are arranged alternately in the circumferential direction. In FIG. 4, three straight grooves 162b and straight ridges are provided as an example.

The operation and functional effect of the double-wall pipe 160 will be described in connection with a Mollier diagram shown in FIG. 5.

When the passenger requests to operate the air conditioning system 100 for a cooling operation, the electromagnetic clutch is engaged to drive the compressor 110 by the engine 10. Then, the compressor 110 draws the refrigerant discharged from the evaporator 140, compresses the drawn refrigerant and discharges high-temperature high-pressure refrigerant toward the condenser 120. The condenser 120 cools the high-temperature high-pressure refrigerant into the liquid refrigerant in a substantially totally liquid phase, for example. The liquid refrigerant flows through the passage 160a into the expansion valve 130. The expansion valve 130 reduces the pressure of the liquid refrigerant and expands the liquid refrigerant. The evaporator 140 evaporates the liquid refrigerant into a gaseous refrigerant of a substantially saturated gas having a degree of superheat in the range of 0°C to 5°C. The refrigerant evaporated by the evaporator 140 absorbs heat from air flowing through the evaporator 140 so that the air is cooled. The saturated gaseous refrigerant evaporated by the evaporator 140, having a low-temperature low-pressure, flows through the inner pipe 162, and returns to the compressor 110.

Heat is transferred from the high-temperature high-pressure refrigerant flowing through the passage 160a to the low-temperature low-pressure refrigerant flowing through the inner pipe 162 by performing heat exchange therebetween. Consequently, the high-temperature high-pressure refrigerant is cooled and the low-temperature low-pressure refrigerant is superheated as shown in FIG. 5. Thus, the liquid-phase refrigerant discharged from the condenser 120 is super-cooled (sub-cooled) and the temperature thereof drops while the high-pressure refrigerant from the condenser 120 is flowing through the double-wall pipe 160 (sub-cooling). The saturated gaseous refrigerant (low-pressure refrigerant) discharged from the evaporator 140 is superheated to a gaseous refrigerant having a degree of superheat (superheating).

The parts of the outer pipe 161 of the double-wall pipe 160 in this embodiment are expanded to form the expanded parts 160b. Therefore, the inlet pipe 163 and the outlet pipe 164 can be simply connected to the outer pipe 161 so as to communicate with the passage 160a.

Since the outside diameter of the inner pipe (e.g., 5/8 in. pipe) 162 is determined so that the passage 160a has a sectional area large enough to pass the high-pressure liquid-phase refrigerant, and the outer surface of the inner pipe 162 is as close to the inner surface of the outer pipe (e.g., 5/8 in. pipe) 161 as possible, the inner pipe 162 has a large heat transfer surface area. Consequently, heat can be efficiently transferred from the high-temperature refrigerant to the low-temperature refrigerant.

The expanded parts 161a formed in the outer pipe 161 form the expanded passages 160a, respectively, and the
inlet pipe 163 and the outlet pipe 164 are connected to the expanded parts 161a, respectively. Therefore, impact exerted on the inner pipe 162 by the high-pressure refrigerant flowing from the inlet pipe 163 into the passage 160a, resistance against the circumferential flow of the refrigerant flowing around the inner pipe 162, and resistance against the flow of the refrigerant deflecting from a longitudinal direction to a circumferential direction and flowing into the outlet pipe 164 can be reduced. Consequently, the high-pressure refrigerant can flow at a high flow rate through the passage 160a, and the heat can be efficiently transferred from the high-temperature refrigerant (i.e., high-pressure refrigerant) to the low-temperature refrigerant (i.e., low-pressure refrigerant).

Further, in this embodiment, the high-temperature high-pressure refrigerant flows through the passage 160a between the outer pipe 161 and the inner pipe 162. Therefore, it can restrict a heat loss due to a heat exchange between high-temperature air in the engine room 1 and the low-temperature low-pressure refrigerant inside the inner pipe 162. Accordingly, heat transmitting performance between the high-pressure high-temperature refrigerant and the low-temperature low-pressure refrigerant can be effectively improved. As a result, it is unnecessary to provide an insulating material on the outer surface of the outer pipe 161, for insulating a heat exchange between the low-temperature low-pressure refrigerant and high-temperature air in the engine room 1.

The hardness of the inner pipe 162 can be increased by work hardening when the straight grooves 162b are formed, and the bending rigidity (the section modulus) of the inner pipe 162 can be increased by the longitudinal ribs formed when the straight grooves 162b are formed. Consequently, the sectional deformation of the inner pipe 162 when the bend portion 160c is formed in the double-wall pipe 160, and the resulting narrowing of the passage 160a can be suppressed. Since the straight grooves 162b increase the sectional area of the passage 160a, the flow resistance of the high-pressure refrigerant can be reduced. Therefore, the flow rate of the high-pressure refrigerant flowing through the passage 160a can be increased and the efficiency of heat transfer from the high-temperature refrigerant (i.e., high-pressure refrigerant) to the low-temperature refrigerant (i.e., low-pressure refrigerant) can be improved.

The straight grooves 162b increase the area of the surface of the inner pipe 162 serving as a heat transfer surface for transferring heat from the high-temperature high-pressure refrigerant flowing through the passage 160a to the low-temperature low-pressure refrigerant flowing through the inner pipe 162. Consequently, the efficiency of heat transfer from the high-temperature refrigerant to the low-temperature refrigerant can be improved. The straight grooves 162b form the longitudinal straight inner ridges inside the inner pipe 162, and the straight grooves 162b and the protruding portions are arranged circumferentially alternately on the outer surface of the inner pipe 162. Therefore, heat can be satisfactorily transferred from the high-temperature refrigerant flowing through the passage 160a through the inner pipe 162 to the low-temperature refrigerant flowing through the inner pipe 162.

The high-temperature high-pressure refrigerant flows through the passage 160a and the low-pressure refrigerant flows through the inner pipe 162. Therefore, heat loss between high-temperature air in the engine room 1 and the low-pressure refrigerant can be prevented, and the heat can be efficiently transferred from the high-temperature refrigerant to the low-temperature refrigerant.

When the outer pipe 161 and the inner pipe 162 of the double-wall pipe 160 are formed integrally by an extrusion process, plural longitudinal extending ribs are formed between the outer pipe 161 and the inner pipe 162 in a circumferential arrangement, and the longitudinal extending ribs divide the passage 160a into a plurality of divisional passages. In this case, the longitudinal extending ribs exert resistance against the flow of the refrigerant in the passage 160a. When a part, facing one of the divisional passages, of the outer pipe 161 is brought into contact with a part, facing the divisional passage, of the inner pipe 162 when the bend portion 160c is formed in the double-wall pipe 160, the divisional passage is closed and, consequently, resistance against the flow of the refrigerant increases. In the first embodiment, the outer pipe 161 and the inner pipe 162 are produced separately and are combined to form the double-wall pipe 160, the foregoing problem does not arise in the double-wall pipe 160.

Normally, the temperature difference between air and the refrigerant is small and the heat exchanging performance (cooling ability) reduces when the refrigerant flowing into the evaporator 140 has a superheating degree. The double-wall pipe 160 in this embodiment can give a degree of super heat to the refrigerant discharged from the evaporator 140 and hence it is unnecessary to have a degree of super heat to the refrigerant (saturated gas) flowing into the evaporator 140. Therefore, the evaporator 140 is able to exercise a high heat exchanging performance (cooling ability), and the double-wall pipe 160 gives a degree of super heat to the refrigerant discharged from the evaporator 140 to convert the refrigerant into a perfectly gaseous refrigerant (gas-phase refrigerant). Consequently, it is possible to prevent the compression of the liquid-phase refrigerant by the compressor 110.

The expanded parts 161a may be formed in circumferential parts, near the inlet pipe 163 and the outlet pipe 164, of the outer pipe 161, depending on resistance against the flow of the high-pressure refrigerant in the vicinity of the inlet pipe 163 and the outlet pipe 164.

Second Embodiment

FIG. 6 shows a part of a double-wall pipe 160 of the second embodiment.

Referring to FIG. 6, the double-wall pipe 160 in the second embodiment according to the present invention has expanded passages 160b formed in longitudinal end parts thereof and different from those of the double-wall pipe 160 in the first embodiment.

Since the expanded passages 160b formed near an inlet pipe 163 and an outlet pipe 164 in the longitudinal end parts of the double-wall pipe 160, respectively, are the same in shape, only the expanded passage 160b formed near an inlet pipe 163 will be described. A depression 162a (recess portion) is formed in an inner pipe 162 by radially depressing a circumferential part of the inner pipe 162 to define the
expanded passage 160b. Because the depression 162a is formed in the inner pipe 162, a narrow part is formed in the inner pipe 162 due to the depression 162a. The expanded passages 160b at the junction between the inlet pipe 163 and a passage 160a defined by the outer pipe 161 and the inner part 162 at and the junction between the outlet pipe 164 and the passage 160a can be formed by forming the depressions 162a in the inner pipe 162 without diameerally expanding the end parts of the outer pipe 161. The depressions 162a are formed in the circumferential parts of the inner part 162 in a circumferential range. The depressions 162a may be annular grooves formed in the end parts of the inner pipe 162. The depression 162a at the junction of the inlet pipe 163 and the passage 160a guides the refrigerant having passed through the inlet pipe 163 into grooves 162a. The depression 162a at the junction of the outlet pipe 164 and the passage 160a guides the refrigerant having passed through the passage 160a into outlet pipe 164. Thus, in the second embodiment, the effect of the double-wall pipe 160 similarly to that of the double-wall pipe 160 in the first embodiment can be obtained.

[0073] The depressions 162a may be annular grooves in parts, near the inlet pipe 163 and the outlet pipe 164, of the inner pipe 162, depending on resistance against the flow of the high-pressure refrigerant in the vicinity of the inlet pipe 163 and the outlet pipe 164.

[0074] In the second embodiment, the other parts can be made similar to those of the above-described first embodiment.

Third Embodiment

[0075] FIG. 7 shows an inner pipe 160 and an outer pipe 161 of the third embodiment. Referring to FIG. 7, a double-wall pipe 160 in the third embodiment according to the present invention has an inner pipe 162 provided with three helical grooves 162d formed in the shape of a three-thread screw instead of the straight grooves 162a of the inner pipe 162 of the double-wall pipe 160 in the first embodiment. Multiple helical grooves, that is, more than one helical groove, may be formed in the shape of a multithread screw and arranged at equal or predetermined pitches or a single helical groove may be formed in the inner pipe 162 instead of the three helical grooves 162d. The three helical grooves 162d are formed by deforming the wall of the inner pipe 162. The three helical grooves 162d form helical ridges inside the inner pipe 162. The three helical grooves 162d are parallel to each other.

[0076] The three helical grooves 162d winding around the inner pipe 162 increase the bending rigidity (the section modulus) of the inner pipe 162 and prevent an undesirable deformation in the section of the inner pipe 162 when a bend portion 160c (FIG. 2) is formed in the double-wall pipe 160.

[0077] Turbulence can be caused in the refrigerant flowing through a passage 160a due to the spiral grooves 162d, thereby enhancing heat transfer efficiency. Consequently, heat can be efficiently transferred between a fluid (e.g., low-pressure refrigerant) inside the inner pipe 162 and a fluid (e.g., high-pressure refrigerant) in the passage 160a.

[0078] In the third embodiment, the other parts can be made similar to those of the above-described first or second embodiment.

Fourth Embodiment

[0079] Referring to FIG. 8, an inner pipe 162 included in a double-wall pipe 160 in the fourth embodiment is provided with straight grooves 162d and helical grooves 162f. That is, the fourth embodiment is a combination between the third embodiment and the first embodiment, in the structure of the inner pipe 162. In the fourth embodiment, the other parts can be formed similar to the first embodiment or the second embodiment.

Fifth Embodiment

[0080] The inner pipe 162 of the double-wall pipe 160 in the third embodiment is provided with the helical grooves 162f parallel to each other. The inner pipe 162 may be provided with helical grooves respectively having different helix angles and intersecting each other. When the inner pipe 162 is provided with such helical grooves intersecting each other, turbulent streams of the refrigerant can be produced in the passage 160a and in the inner pipe 162 to promote heat transfer. The inner pipe 162 may be provided with a plurality of helical grooves respectively having positive and negative helix angles. For example, one of two helical grooves may be a right-hand helical groove and the other may be a left-hand helical groove, or some of a plurality of helical grooves may be right-hand helical grooves and the rest may be left-hand helical grooves. The inner pipe 162 may be provided with a plurality of parallel right-hand helical grooves and a plurality of parallel left-hand helical grooves. FIGS. 9 and 10 show an inner pipe 162 included in a double-wall pipe 160 in the fifth embodiment according to the present invention in a side elevation and a cross-sectional view, respectively. In FIG. 9, broken lines indicate center lines of two first helical grooves 162e, that is, right-hand helical grooves 162e, and two second helical grooves 162f, that is, left-hand helical grooves 162f, formed in the inner pipe 162. The numbers, widths, depths, helix angles and pitches of the first helical grooves 162e and the second helical grooves 162f may be determined on the basis of the sectoral area of the passage 160a, the resistance of the passage 160a on the flow of the refrigerant and the flexibility of the inner pipe 162. The inner pipe 162 may be provided with straight grooves in combination with the helical grooves 162e and 162f.

[0081] When the right-hand helical grooves 162e and the left-hand helical grooves 162f are formed by deforming the wall of the inner pipe 162, the inner pipe 162 assumes the shape of a bellows and the inner pipe 162 can be easily bent in any directions. The grooves formed in the inner pipe 162 form a plurality of ridges and recesses inside the inner pipe 162. Consequently, heat transfer between a fluid (refrigerant) inside the inner pipe 162 and the fluid (refrigerant) flowing through outside the inner pipe 162 can be promoted. The inner pipe 162 has the plurality of grooves and a plurality of protrusions in an alternate arrangement. Consequently, heat transfer between the fluid flowing through the passage 160a and the fluid inside the inner pipe 162 can be promoted. In the double-wall pipe 160 in the fifth embodiment, the helical grooves 162e and 162f formed in the inner pipe 162 form a plurality of junctions and a plurality of rhombic protruding portions on the surface of the inner pipe 162. The rhombic protruding portions are in contact with the inside surface of an outer pipe 161. Thus, the passage 160 can be surely formed between the outer pipe 161 and the inner pipe 162.
As shown in FIG. 10, the edges of the ridges each formed between the helical grooves 162e and 162f are rounded in a radius of a circle smaller than the radius of a circle enveloping the inner pipe 162 in a state before the helical grooves 162e and 162f are formed. Thus, the area of contact between the outer pipe 161 and the inner pipe 162 can be made small.

Sixth Embodiment

FIG. 11 shows a double-wall pipe 160 in the sixth embodiment according to the present invention. This double-wall pipe 160 can be intended for carrying a refrigerant in a refrigerant cycle device for an automotive air conditioning system. The double-wall pipe 160 can be used as an internal heat exchanger for transferring heat from a high-temperature high-pressure refrigerant to a low-temperature low-pressure refrigerant. The double-wall pipe 160 in the sixth embodiment differs from the double-wall pipe 160 in the first embodiment principally in an outer pipe 161 of a shape different from that of the outer pipe 161 of the first embodiment and an inner pipe 162 provided with grooves of a shape different from that of the grooves 162b of the inner pipe 162 of the second embodiment.

The outer pipe 161 has a fixed inside diameter slightly greater than the outside diameter of the inner pipe 162. End parts of the outer pipe 161 are airtight joined to end parts of the inner pipe 162 by airtight joints 161b. Each of the airtight joints 161b is formed by connecting a cylindrical end part 161c of the outer pipe 161 and a cylindrical end part 162b of the inner pipe 162. The cylindrical end parts 161c of the outer pipe 161 are put on and joined by brazing or welding to the cylindrical end parts 162b of the inner pipe 162, respectively, to form the airtight joints 161b. The radial dimensions of the cylindrical end parts 161c of the outer pipe 161 are reduced by pressing so that the cylindrical end parts 162b of the inner pipe 162 can be closely fitted to the cylindrical end parts 161c, respectively.

The airtight joint 161b may be formed in one end part of the outer pipe 161 and one end part of the inner pipe 162, and the other ends of the outer pipe 161 and the inner pipe 162 may be connected by a joining means other than the airtight joint 161b. For example, a rubber O-ring may be squeezed between the other end parts of the outer pipe 161 and the inner pipe 162, or the other ends of the outer pipe 161 and the inner pipe 162 may be connected by a pipe joint.

Burring holes to be used as connecting holes are formed in the end parts of the outer pipe 161 at positions at a predetermined distance from the ends of the outer pipe 161. The burring holes are provided to correspond to radial side portions of ends of a helical groove 162d formed in the inner pipe 162 or annular grooves 162g formed in the end parts of the inner pipe 162, respectively. Burrs extend radially outward from the edges of the burring holes, respectively. A flange inlet pipe 163b and a flange outlet pipe 164b are joined to the burring holes, respectively. The flange inlet pipe 163b and the flange outlet pipe 164b open into the interior of the outer pipe 161. In this embodiment, the burring holes and the pipes 163b, 164b construct communication parts communicating with components in the refrigerant cycle.

The inner pipe 162 has a fixed inside diameter. The inner pipe 162 has cylindrical end parts of a predetermined length. The inner pipe 162 is a wave pipe (corrugated pipe) having outer ridges, outer grooves, inner ridges and inner grooves. The ridges and the grooves are formed circumferentially alternately. The ridges and the grooves may be defined by grooves longitudinally separated from each other with respect to the length of the inner pipe 162. The plurality of grooves may intersect each other or may be parallel to each other. The grooves may be straight grooves extending parallel to the axis of the inner pipe 162 or may be helical grooves winding around the inner pipe 162.

In the double-wall pipe 160 of the sixth embodiment, the inner pipe 162 is provided with annular grooves 162g and multiple helical grooves 162d (e.g., three helical grooves). The edges of the ridges each formed between the adjacent helical grooves 162d are close to the inner surface of the outer pipe 161. The diameter of a cylinder enveloping the ridges of the inner pipe 162 is smaller than the inside diameter of the outer pipe 161. Thus, passages are defined by the helical grooves 162d of the inner pipe 162 and the outer pipe 161, and by the ridges of the inner pipe 162 and the outer pipe 161. The ridges of the inner pipe 162 are partially in contact with the outer pipe 161. Consequently, the passage defined by the ridges of the inner pipe 162 and the outer pipe 161 can be partially narrowed or partially blocked.

The annular grooves 162g are provided to extend along the circumferential direction of the inner pipe 162 at positions corresponding to the inlet pipe 163b and the outlet pipe 164b, respectively. The annular grooves 162g are provided to extend and wind entirely around the inner pipe 162.

The helical grooves 162d extend continuously between the two annular grooves 162g. For example, the helical grooves 162d extend from one of the annular grooves 162g to the other one of the annular grooves 162g. Thus, the helical grooves 162d form a longitudinal passage extend to the annular grooves 162g. The helical grooves 162d extend continuously between the opposite annular grooves 162g.

Accordingly, the inlet pipe 163b and the outlet pipe 164b communicate directly with the annular grooves 162g, respectively. In this embodiment, the annular grooves 162g and the helical grooves 162d form a passage 160a between the outer pipe 161 and the inner pipe 162.

The inlet pipe 163b and the outlet pipe 164b radially communicate with the annular grooves 162g of the inner pipe 162, respectively. Consequently, the high-pressure refrigerant is able to flow smoothly into and out of the passage 160a.

Since the annular grooves 162g are provided to correspond to the inlet pipe 163b and the outlet pipe 164b, respectively, the circumferential positioning of the inner pipe 162 relative to the inlet pipe 163b and the outlet pipe 164b attached to the outer pipe 162 is not necessary. Thus, the annular grooves 162g and the helical grooves 162d can be easily connected to the inlet pipe 163b and the outlet pipe 164b.

The inside diameter of the outer pipe 162 is made slightly greater than the outside diameter of the inner pipe 162, the respective opposite end parts of the outer pipe 161 and the inner pipe 162 are joined together, and the outer pipe 161 including the cylindrical end parts 161c has a fixed inside diameter. Therefore, the outer pipe 161 and the inner pipe 162 can be easily connected. Further, the passage 160a
can communicate with the inlet pipe 163b and the outlet pipe 164b without partly expanding the outer pipe 161.

[0094] In the double-wall pipe 160 of the sixth embodiment, the high-temperature high-pressure refrigerant flows from a condenser through the passage 160a to an evaporator, and the low-temperature low-pressure refrigerant flows from the evaporator through the inner pipe 162 to a compressor. The temperature of the high-temperature high-pressure refrigerant is higher than that of the low-temperature low-pressure refrigerant and that of the atmosphere surrounding the outer pipe 161, and, the high-temperature high-pressure refrigerant needs cooling in a refrigerant cycle device. Therefore, the high-temperature high-pressure refrigerant can be effectively cooled by the atmosphere in addition to being cooled by heat transfer from the high-temperature high-pressure refrigerant to the low-temperature low-pressure refrigerant flowing through the inner pipe 162. Since the grooves 162d may be high pressure, the inner pipe 162 may be provided with the substantially annular passage 160a defined by heat transfer surfaces of a large area, heat transferred efficiently from the high-temperature high-pressure refrigerant to the low-temperature low-pressure refrigerant. The helical grooves 162d of the inner pipe 162 generate a turbulent stream in the passage 160a, which promotes heat transfer.

[0095] The double-wall pipe 160 can be mounted to a vehicle. Bend portions can be formed in the double-wall pipe 160 to locate the double-wall pipe 160 at a suitable position of the vehicle. Since the helical grooves 162d are extended in the substantially whole inner pipe 162 excluding the end parts, the passage 160a maintains a necessary sectional area even when the double-wall pipe 160 is bent. For example, the helical grooves 162d prevent the excessive deformation of the inner pipe 162. The helical grooves 162d provide the passage 160a even when the outer pipe 161 and the inner pipe 162 are deformed when the double-wall pipe 160 is bent. Since the inner pipe 162 provided with the helical grooves 162d functions like a bellows, the inner pipe 162 can be easily bent. Therefore, it is preferable that the inner pipe 162 is provided with the helical grooves 162d at least in parts thereof to be bent.

[0096] The inner pipe 162 of the double-wall pipe 160 in the sixth embodiment may be provided with straight grooves like the straight grooves 162i of the inner pipe 162 of the double-wall pipe 160 in the first embodiment instead of the helical grooves 162d or may be provided with the helical grooves 162d and the straight grooves 162b in combination. The helical grooves 162d may be partly broken with respect to the length of the inner pipe 162. The plurality of helical grooves 162d may be provided with circumferential grooves having the shape of a broken ring instead of the annular grooves 162g. The annular grooves 162g may be replaced with helical grooves of very small pitches having very narrow helical ridges. The annular grooves 162g may be omitted and the helical grooves 162d and the straight grooves 162b may be extended between parts connected to the pipes 163b, 164b.

Other Embodiments

[0097] Although the present invention has been described in connection with some preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications will become apparent to those skilled in the art.

[0098] For example, the grooves (162b, 162d, 162e, 162f) of the foregoing embodiments may extend continuously over the entire length of the inner pipe 162. Alternatively, the grooves (162b, 162d, 162e, 162f) may be longitudinally divided into a plurality of separated sections. When the helical grooves (162d, 162e, 162f) are formed so as to intersect each other, the helical grooves may be joined at the intersections of the helical grooves (162d, 162e, 162f), and the passage 160a can be surely secured.

[0099] The grooves (162b, 162d, 162e, 162f) of the foregoing embodiments are formed by deforming the wall of the inner pipe 162 so that the grooves and the ridges are formed inside and outside the inner pipe 162. Grooves may be formed only in the outer surface of the inner pipe 162. The outer pipe 161 may be provided with grooves. For example, the outer pipe 161 may be provided with a plurality of intersecting helical grooves.

[0100] In the above-described first embodiment, as shown in FIG. 4, the outside wall surface of the inner pipe 162 does not contact the inside wall surface of the outer pipe 161. However, the outside wall surface of the inner pipe 162 can be made to partially contact the inside wall surface of the outer pipe 161, as shown in FIG. 12. Even in this case, because the groove 162b is formed, a deformation of the inner pipe 162 due to the outer pipe 161 can be restricted when the bend portions 160c is formed. Furthermore, the passage 160a can be easily formed in the bend portion 160c by the groove 162b.

[0101] Refrigerants (fluids) respectively having different physical properties may flow through the double-wall pipe. Refrigerants flowing respectively in different directions, refrigerants respectively having different temperatures or refrigerants respectively having different pressures may be used in the double-wall pipe. For example, a combination of a high-pressure refrigerant and a low-pressure refrigerant on the inlet and the outlet side of the expansion valve, a combination of a high-pressure refrigerant and a low-pressure refrigerant on the suction and the discharge sides of the compressor, or a combination of a high-temperature refrigerant on the inlet side of the condenser and a low-temperature refrigerant on the outlet side of the evaporator may be used. The double-wall pipe of the present invention can be used to supply and return lines connecting the interior and the exterior unit of a refrigerant cycle device. The double-wall pipe of the present invention can be applied to lines connecting the components of an interior unit and those of an exterior unit of a refrigerant cycle device.

[0102] The % in. pipe as the outer pipe 161 and the % in. pipe as the inner pipe 162 are only examples, and the outer pipe 161 and the inner pipe 162 may be pipes of other sizes. For example, the inner pipe 162 may be a % in. pipe and the outer pipe 161 may be a % in. diameter pipe having an inside diameter of 19.6 mm, the outer pipe 161 may be a % in. pipe and the inner pipe 162 may be a 12.7 mm diameter pipe having an inside diameter of 10.3 mm.

[0103] The double-wall pipe 160 does not need to be provided with the expanded parts 160b and the grooves 162b, 162d, 162e and 162f and may be provided with some of those.
0104 Although the double-wall pipe 160 of the invention has been described as used for a refrigerant cycle device 100A of an automotive air conditioning system 100, the present invention is not limited thereto in its practical application. The double-wall pipe 160 may be applied to domestic air conditioners. When the double-wall pipe 160 is used for a domestic air conditioner, the temperature of the atmosphere around the outer pipe 161 is lower than that of air in the engine room 1. Therefore, the low-pressure refrigerant may be passed through the passage 160a and the high-pressure refrigerant may be passed through the inner pipe 162 when the mode of heat transfer from the high-pressure refrigerant to the low-pressure refrigerant permits.

0105 Although the double-wall pipes in the foregoing embodiments have been described as heat exchangers for transferring heat from the refrigerant in one condition to the refrigerant in another condition, the double-wall pipes can be applied to heat exchange between different fluids (e.g., water and a refrigerant). For example, water and the refrigerant may be passed through the inner pipe and the passage between the outer and the inner pipes, respectively, or the refrigerant and water may be passed through the passage and the inner pipe, respectively. A fluid to be passed through the passage between the outer pipe and the inner pipe can be selectively determined taking into consideration whether or not the fluid needs to exchange heat with the atmosphere and/or the flow rate of the fluid.

0106 While the invention has been described with reference to preferred embodiments thereof, it is to be understood that the invention is not limited to the preferred embodiments and constructions. The invention is intended to cover various modifications and equivalent arrangements. Further, while the various elements of the embodiments are shown in various combinations, which are preferred, other combinations and configuration, including more, less or only a single element, are also within the spirit and scope of the invention.

What is claimed is:

1. A double-wall pipe comprising:
   an outer pipe provided with first and second openings, respectively, at first and second end parts of the outer pipe in a pipe longitudinal direction;
   an inner pipe inserted in the outer pipe to define a passage between the outer pipe and the inner pipe;
   an inlet portion connected to the outer pipe to communicate with the passage through the first opening; and
   an outlet portion connected to the outer pipe to communicate with the passage through the second opening, wherein:
   the outer pipe and the inner pipe are disposed to define an expanded portion having an expanded sectional area in the passage; and
   the expanded portion is provided at least at a portion near the inlet portion and the outer portion.

2. The double-wall pipe according to claim 1, wherein the expanded portion is provided by expanding at least a part of a circumferential portion of the outer pipe in a circumferential direction, at least at a portion near the inlet portion and the outlet portion.

3. The double-wall pipe according to claim 1, wherein the expanded portion is provided by reducing at least a part of a circumferential portion of the inner pipe in a circumferential direction, at least at a portion near the inlet portion and the outlet portion.

4. The double-wall pipe according to claim 1, wherein the inner pipe has therein a passage through which a fluid different from a fluid of the passage between the inner pipe and the outer pipe flows.

5. The double-wall pipe according to claim 1, wherein a surface of the inner pipe has a plurality of grooves.

6. The double-wall pipe according to claim 5, wherein the grooves are straight grooves extending in a longitudinal direction of the inner pipe.

7. The double-wall pipe according to claim 5, wherein the grooves are helical grooves winding around the inner pipe and extending in a longitudinal direction of the inner pipe.

8. The double-wall pipe according to claim 5, wherein the grooves include straight grooves extending in a longitudinal direction of the inner pipe, and helical grooves winding around the inner pipe and extending in a longitudinal direction of the inner pipe.

9. The double-wall pipe according to claim 7, wherein the helical grooves include first helical grooves winding in a first direction around the inner pipe, and second helical grooves winding in a second direction opposite the first direction around the inner pipe.

10. A double-wall pipe comprising:
    an outer pipe; and
    an inner pipe inserted in the outer pipe to define a passage between the outer pipe and the inner pipe,
    wherein a surface of the inner pipe has a plurality of grooves.

11. The double-wall pipe according to claim 10, wherein the grooves are straight grooves extending in a longitudinal direction of the inner pipe.

12. The double-wall pipe according to claim 10, wherein the grooves are helical grooves winding around the inner pipe and extending in a longitudinal direction of the inner pipe.

13. The double-wall pipe according to claim 10, wherein the grooves include straight grooves extending in a longitudinal direction of the inner pipe, and helical grooves winding around the inner pipe and extending in the longitudinal direction of the inner pipe.

14. The double-wall pipe according to claim 12, wherein the helical grooves include first helical grooves winding in a first direction around the inner pipe, and second helical grooves winding in a second direction opposite the first direction around the inner pipe.

15. A double-wall pipe comprising:
    an inner pipe in which a fluid flows; and
    an outer pipe disposed at an outer side of the inner pipe to define a passage between the inner pipe and outer pipe, through which a fluid flows, wherein:
    the inner pipe is provided in its wall with a groove portion extending from a first end part to a second end part of the inner pipe;
    the outer pipe has a first joining part joined airtight to the inner pipe at the first end part; and
the outer pipe has a first connecting hole which is opened in a radial direction to directly communicate with the groove portion at the first end part.

16. The double-wall pipe according to claim 15, wherein the outer pipe has a second joining part joined airtightly to the inner pipe at the second end part; and

the outer pipe has a second connecting hole which is opened in the radial direction to directly communicate with the groove at the second end part.

17. The double-wall pipe according to claim 15, wherein the groove portion has a groove extending in a circumferential direction at least in a part corresponding to the connecting hole of the outer pipe.

18. The double-wall pipe according to claim 17, wherein the groove extends in a complete circle in the circumferential direction at least in the part corresponding to the connecting hole of the outer pipe.

19. The double-wall pipe according to claim 15, wherein the groove portion includes a helical groove extending helically.

20. The double-wall pipe according to claim 19, wherein the groove portion further includes a straight groove extending from the first end part to the second end part.

21. The double-wall pipe according to claim 15, wherein:

the inner pipe has cylindrical end parts respectively formed in the first and second end parts thereof;

the outer pipe has cylindrical end parts formed at first and second end parts thereof and having an inside diameter slightly greater than an outside diameter of the cylindrical end parts of the inner pipe; and

the cylindrical end parts of the outer pipe are directly airtightly joined to the cylindrical end parts of the inner pipe, respectively, to form joints.

22. The double-wall pipe according to claim 21, wherein the outer pipe including the cylindrical end parts has a fixed inside diameter.

23. The double-wall pipe according to claim 21, wherein:

the outer pipe including the cylindrical end parts has a fixed inside diameter; and

parts, forming the joints, of the cylindrical end parts of the outer pipe are radially reduced so as to tightly contact the inner pipe.

24. The double-wall pipe according to claim 10, wherein the outer pipe and the inner pipe have a bend portion which is bent in a predetermined shape in accordance with a mounting space.

25. The double-wall pipe according to claim 1, wherein the double-wall pipe is used in a refrigerant cycle device including a compressor, a condenser, a pressure-reducing device, an evaporator, wherein:

the passage between the outer pipe and the inner pipe, and a passage inside the inner pipe are used, respectively, as at least a part of a high-pressure passage connecting the condenser and the pressure-reducing device to carry a high-pressure refrigerant, and as at least a part of a low-pressure passage connecting the evaporator and the compressor to carry a low-pressure refrigerant.

26. The double-wall pipe according to claim 10, wherein the outer pipe and the inner pipe are used for a refrigerant cycle device such that a high-pressure refrigerant flows through the passage between the outer pipe and the inner pipe, and a low-pressure refrigerant flows in the inner pipe.

27. The double-wall pipe according to claim 1, wherein the outer pipe and the inner pipe are formed separately.

28. A double-wall pipe for a refrigerant cycle device, comprising:

an inner pipe for carrying a low-pressure refrigerant after decompressed in the refrigerant cycle device flows, the inner pipe having an uneven portion provided in its wall; and

an outer pipe disposed at an outer side of the inner pipe to define a passage between the inner pipe and the outer pipe, through which a high-pressure refrigerant before being decompressed in the refrigerant cycle device flows.

29. The double-wall pipe according to claim 28, wherein the uneven portion includes at least a groove extending in a longitudinal direction of the inner pipe.

30. The double-wall pipe according to claim 29, wherein the groove is a helical groove.

31. The double-wall pipe according to claim 28, wherein:

the uneven portion includes ridges and grooves relative to an outer surface of the inner pipe;

edges of the ridges of the uneven portion of the inner pipe are rounded in a radius smaller than an inner radius of the outer pipe; and

the passage for the high-pressure refrigerant is defined by the outer pipe and the grooves of the inner pipe and by the outer pipe and the ridges of the inner pipe.

32. The double-wall pipe according to claim 28, wherein:

the inner pipe has an inner cylindrical end part without having the uneven portion, at one end part of the inner pipe;

the outer pipe has an outer cylindrical end part at a part corresponding to the inner cylindrical end part of the inner pipe and having an inside diameter slightly greater than an outside diameter of the inner cylindrical end part of the inner pipe; and

the outer cylindrical end part of the outer pipe and the inner cylindrical end part of the inner pipe are directly airtightly joined to form a joint.

33. The double-wall pipe according to claim 1, wherein the double-wall pipe is used for an air conditioner for a vehicle.

34. A refrigerant cycle device comprising:

a compressor which compresses refrigerant;

a refrigerant radiator which cools high-pressure refrigerant from the compressor;

a pressure-reducing unit which decompresses the high-pressure refrigerant to be a low-pressure refrigerant;

an evaporator in which the low-pressure refrigerant after decompressed in the pressure-reducing unit is evaporated; and

a double-wall pipe including an outer pipe and an inner pipe, wherein the inner pipe is inserted into the outer pipe to define a first passage between the outer pipe and the inner pipe, and has therein a second passage, wherein:
the first passage is used as at least a part of a high-pressure passage through which the high-pressure refrigerant from the refrigerant radiator to the pressure-reducing unit flows;

the second passage is used at least a part of a low-pressure passage through which the low-pressure refrigerant from the evaporator to the compressor flows;

the outer pipe has first and second openings, respectively, in circumferential wall portions of first and second end parts of the outer pipe in a pipe longitudinal direction;

the outer pipe is connected to an inlet portion from which the high-pressure refrigerant flows into the first passage, and is connected to an outlet portion from which the high-pressure refrigerant in the first passage flows out;

the outer pipe and the inner pipe are disposed to define an expanded portion having an expanded sectional area in the first passage; and

the expanded portion is provided at least at a portion near the inlet portion and the outer portion.

35. The refrigerant cycle device according to claim 34, wherein the expanded portion is provided by expanding at least a part of a circumferential portion of the outer pipe in a circumferential direction, at least in a portion near the inlet portion and the outlet portion.

36. The refrigerant cycle device according to claim 34, wherein the expanded portion is provided by reducing at least a part of a circumferential portion of the inner pipe in a circumferential direction, at least in a portion near the inlet portion and the outlet portion.

37. A refrigerant cycle device comprising:

a compressor which compresses refrigerant;

a refrigerant radiator which cools high-pressure refrigerant from the compressor;

a pressure-reducing unit which decompresses the high-pressure refrigerant to be a low-pressure refrigerant;

an evaporator in which the low-pressure refrigerant after decompressed in the pressure-reducing unit is evaporated; and

a double-wall pipe including an outer pipe and an inner pipe, wherein the inner pipe is inserted into the outer pipe to define a first passage between the outer pipe and the inner pipe, and has therein a second passage, wherein:

the first passage is used as at least a part of a high-pressure passage through which the high-pressure refrigerant from the refrigerant radiator to the pressure-reducing unit flows;

the second passage is used at least a part of a low-pressure passage through which the low-pressure refrigerant from the evaporator to the compressor flows; and

a surface of the inner pipe has a plurality of grooves.

38. The refrigerant cycle device according to claim 37, wherein the double-wall pipe is bent in accordance with a mounting space to have a bend portion.

39. The refrigerant cycle device according to claim 37, wherein the grooves are straight grooves extending in a longitudinal direction of the inner pipe.

40. The refrigerant cycle device according to claim 37, wherein the grooves are helical grooves winding around the inner pipe and extending in a longitudinal direction of the inner pipe.

41. The refrigerant cycle device according to claim 37, wherein the grooves include straight grooves extending in a longitudinal direction of the inner pipe, and helical grooves winding around the inner pipe and extending in the longitudinal direction of the inner pipe.

42. The refrigerant cycle device according to claim 34, wherein the low-pressure refrigerant at a refrigerant outlet of the evaporator has a superheat degree that is lower than a predetermined value.