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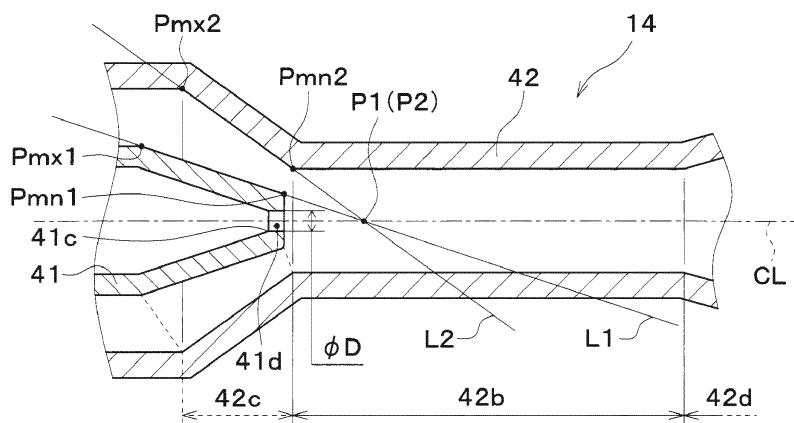
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(54) **EJECTOR**

(57) An ejector includes a nozzle (41) configured to decompress a fluid and eject the fluid from a fluid injection port (41e), and a body (42). The body has a fluid suction port (42a), a mixing portion (42b), and a pressure increase portion (42d). A suction passage (42c) through which a suction fluid flows is defined between an outer surface of the nozzle and an inner surface of the body. The mixing portion is located coaxially with a central axis (CL) of the nozzle. A nozzle passage in the nozzle includes a converging portion (41b) and a throat portion (41c). A length of a part of the nozzle passage extending

from the throat portion to the fluid injection port in a direction along the central axis is equal to or less than twice a diameter (ϕD) of an opening of the fluid injection port. In a reference cross-section, a nozzle outer periphery intersection point (P1) is an intersection point of the central axis (CL) and a nozzle outer periphery line (L1) passing through a largest diameter point (Pmx1) and a smallest diameter point (Pmn1) of a part of the outer surface of the nozzle defining the suction passage. The nozzle outer periphery intersection is located inside the mixing portion.

FIG. 3



Description**PRIOR ART DOCUMENT****CROSS REFERENCE TO RELATED APPLICATION****PATENT DOCUMENT**

[0001] This application is based on Japanese Patent Application No. 2018-009477 filed on January 24, 2018, the disclosure of which is incorporated herein by reference.

5 **[0008]**

Patent Literature 1: JP 2004-270460 A
Patent Literature 2: US Patent Application Publication No. 2016/0187037

TECHNICAL FIELD

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SUMMARY OF THE INVENTION

[0002] The present disclosure relates to an ejector configured to draw a fluid by an entrainment effect of a high-speed fluid ejected from a nozzle.

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[0009] Since the suction passage is defined between the outer surface of the nozzle and the inner surface of the body, the flow directions of the suction fluid and the jet fluid may not be appropriately aligned with each other if the outer surface of the nozzle is not formed in an appropriate shape even if the part of the body defining the suction passage is the curved surface as in Patent Literature 2.

BACKGROUND ART

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[0010] In view of this point, since a Laval nozzle is used as the nozzle in Patent Literature 2, the outer surface of the nozzle can be easily formed into an appropriate shape.

[0003] Conventionally, a general ejector is configured to draw a fluid through a fluid suction port formed in a body by an entrainment effect of a high-speed fluid ejected from a nozzle. In this type of ejector, energy loss caused when a refrigerant is decompressed by the nozzle is recovered by drawing the fluid from the outside. A pressure of a mixture of the jet fluid and a suction fluid is increased by converting the recovered energy into a pressure energy by a diffuser portion (i.e. pressure increase portion).

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[0011] A nozzle passage defined in the Laval nozzle includes: a converging portion that decreases the passage cross-sectional area toward the downstream side of the fluid flow; a throat portion provided at the most downstream part of the converging portion in the fluid flow, the passage cross-sectional area at the throat portion being the smallest in the nozzle; and a diverging portion that increases the passage cross-sectional area from the throat portion toward the fluid injection port. Accordingly, since the length of the nozzle in a direction along the central axis is relatively long, the shape of the outer surface of the nozzle can be easily processed into a desired shape such that the suction fluid flows along the central axis.

[0004] For example, Patent Literature 1 discloses an ejector used in a supercritical refrigeration cycle in which carbon dioxide is used as a refrigerant and the pressure of the refrigerant on a high-pressure side of the cycle exceeds a critical pressure of the refrigerant. The ejector functions as a refrigerant decompressor.

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[0005] The ejector of Patent Literature 1 includes a plug nozzle as a nozzle. The plug nozzle is a nozzle used with a needle that is disposed in a nozzle passage defined in the nozzle such that the fluid is ejected along the needle. In the ejector of Patent Literature 1, by adopting the plug nozzle, it is attempted to improve the energy conversion efficiency in the nozzle by bringing the expansion form of the jet fluid close to the proper form regardless of the pressure fluctuation of the refrigerant flowing into the nozzle.

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[0012] In the plug nozzle, the throat portion is located at the most downstream portion of the nozzle passage to bring the expansion form of the jet fluid close to the proper expansion. Accordingly, the nozzle passage of an ideal plug nozzle may not have a passage corresponding to the diverging portion of the Laval nozzle.

[0006] Patent Literature 2 discloses an ejector including a suction passage to reduce the energy loss of the fluid flowing through the ejector.

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[0013] Even if a fluid passage is formed at a part located downstream of the throat portion for the convenience of manufacturing, the length of the fluid passage in the direction along the central axis may be equal to or shorter than twice a diameter of an opening of the fluid injection port. Further, the inventors have confirmed through tests and studies that, by forming the nozzle such that the length of the fluid passage in the direction along the central axis is equal to or shorter than twice the diameter of the opening of the injection port, the energy conversion efficiency by the nozzle is equal to or higher than that by an ideal nozzle.

[0007] In a general ejector, a suction passage is defined between an outer surface of a nozzle and an inner surface of a cylindrical body to which the nozzle is fixed. In the ejector of Patent Literature 2, a part of the body defining the suction passage is a curved surface such that the flow directions of the suction fluid and the jet fluid are aligned with each other. As a result, according to the ejector of Patent Literature 2, it is attempted to reduce the energy loss (i.e. mixing loss) caused when the suction fluid and the jet fluid are mixed.

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[0014] In the ejector having the plug nozzle as in Patent Literature 1, it may be difficult to process the outer surface

of the downstream part of the nozzle into an appropriate shape, and accordingly it may be difficult to form the suction passage to decrease the energy loss. It may be conceivable that the size of the nozzle is increased to process the shape of the outer surface of the nozzle into an appropriate shape. However, this may lead to an increase of the size of the ejector.

[0015] In view of the above points, it is an object of the present disclosure to provide an ejector including a nozzle having a throat portion at most downstream part of a nozzle passage which can reduce energy loss caused in a fluid flowing through the ejector without increasing a size of the ejector.

[0016] An ejector according to a first aspect of the present disclosure includes a body and a nozzle configured to decompress a fluid and eject the fluid from a fluid injection port. The body has a fluid suction port, a mixing portion, and a pressure increase portion. The fluid is drawn into the body through the fluid suction port by an entrainment effect of a jet fluid ejected from the fluid injection port. The jet fluid and a suction fluid drawn through the fluid suction port is mixed in the mixing portion. The pressure increase portion is configured to convert a velocity energy of the mixed fluid flowing out of the mixing portion into a pressure energy. At least a part of the nozzle is housed in the body. A suction passage through which the suction fluid flows is defined between an outer surface of the nozzle and an inner surface of the body. The mixing portion has a shape of a solid of revolution about a central axis of the nozzle. A nozzle passage defined in the nozzle includes: a converging portion decreasing a passage cross-sectional area toward a downstream side of a fluid flow; and a throat portion located at most downstream part of the converging portion, the passage cross-sectional area at the throat portion being smallest in the nozzle passage. A length of a part of the nozzle passage extending from the throat portion to the fluid injection port in a direction along the central axis is equal to or less than twice a diameter of an opening of the fluid injection port. A reference cross-section is a cross-section including the central axis. In the reference cross-section, a part of the outer surface of the nozzle defining the suction passage approaches the central axis toward the downstream side of the fluid flow. In the reference cross-section, a nozzle outer periphery intersection point is an intersection point of the central axis and a nozzle outer periphery line passing through a largest diameter point and a smallest diameter point of the part of the outer surface of the nozzle defining the suction passage, a diameter of the part of the outer surface of the nozzle being largest at the largest diameter point and being smallest at the smallest diameter point. The nozzle outer periphery intersection point is located inside the mixing portion.

[0017] According to this, in the reference cross-section of the ejector having the nozzle in which the length of the fluid passage from the throat portion to the fluid injection port is equal to or less than twice the diameter of the opening of the fluid injection port, i.e. in the reference

cross-section of the ejector having the nozzle in which the throat portion is located at the most downstream part of the nozzle passage, the nozzle outer periphery intersection point is located inside the mixing portion.

[0018] Accordingly, the suction fluid flowing along the outer surface of the nozzle can be guided to the inside of the mixing portion to merge with the jet fluid inside the mixing portion. As a result, the energy loss caused when the suction fluid and the jet fluid are mixed can be suppressed.

[0019] Further, the length of the part of the outer surface of the nozzle defining the suction passage in the direction along the central axis can be short compared with a case where the nozzle outer periphery intersection point is located downstream of the mixing portion.

[0020] That is, according to the ejector of the first aspect, in the ejector having the nozzle in which the throat portion is located at the most downstream part of the nozzle passage, the energy loss caused in the fluid flowing through the ejector can be suppressed.

[0021] The sentence "the length of the fluid passage extending from the throat portion to the fluid injection port in the direction along the central axis is equal to or less than twice the diameter of the opening of the fluid injection port" includes a meaning that the length of the fluid passage in the direction along the central axis is 0, i.e. the fluid passage extending from the throat portion to the fluid injection portion is not defined. However, when a diverging portion is provided as the fluid passage extending from the throat portion to the fluid injection port, a length of the diverging portion in the direction along the central axis is greater than 0.

[0022] An ejector according to a second aspect of the present disclosure includes a body and a nozzle configured to decompress a fluid and eject the fluid from a fluid injection port. The body has a fluid suction port, a mixing portion, and a pressure increase portion. The fluid is drawn into the body through the fluid suction port by an entrainment effect of a jet fluid ejected from the fluid injection port. The jet fluid and a suction fluid drawn through the fluid suction port is mixed in the mixing portion. The pressure increase portion is configured to convert a velocity energy of the mixed fluid flowing out of the mixing portion into a pressure energy. At least a part of the nozzle is housed in the body. A suction passage through which the suction fluid flows is defined between an outer surface of the nozzle and an inner surface of the body. The mixing portion has a shape of a solid of revolution about a central axis of the nozzle. A nozzle passage defined in the nozzle includes: a converging portion decreasing a passage cross-sectional area toward a downstream side of a fluid flow; a throat portion located at most downstream part of the converging portion, the passage cross-sectional area at the throat portion being smallest in the nozzle passage; and a diverging portion increasing the passage cross-sectional area from the throat portion to the fluid injection port. A length of the diverging portion in a direction along the central axis is equal to or less than twice a diameter

of an opening of the fluid injection port. A reference cross-section is a cross-section including the central axis. In the reference cross-section, a nozzle inner periphery line passes through a smallest diameter point of the diverging portion at which a diameter of the diverging portion is smallest and a largest diameter point of the diverging portion at which the diameter of the diverging portion is largest, and the nozzle inner periphery line intersects with the mixing portion of the body.

[0023] According to this, in the reference cross-section of the ejector having the nozzle in which the length of the diverging portion in the direction along the central axis is equal to or less than twice the diameter of the opening of the fluid injection port, i.e. in the reference cross-section of the ejector having the nozzle in which the throat portion is located at the most downstream part of the nozzle passage, the nozzle inner periphery line intersects with the mixing portion of the body.

[0024] Accordingly, the jet fluid flowing along the inner surface of the diverging portion can be guided to the inside of the mixing portion to merge with the jet fluid inside the mixing portion. As a result, the energy loss caused when the suction fluid and the jet fluid are mixed can be suppressed.

[0025] Further, since the length of the diverging portion in the direction along the central axis is equal to or less than the diameter of the opening of the fluid injection port, the length of the part of the outer surface of the nozzle defining the suction passage in the direction along the central axis can be limited from increasing.

[0026] That is, according to the ejector of the second aspect, in the ejector having the nozzle in which the throat portion is located at the most downstream part of the nozzle passage, the energy loss caused in the fluid flowing through the ejector can be suppressed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027]

FIG. 1 is a diagram illustrating an ejector refrigeration circuit as a whole in a first embodiment.

FIG. 2 is a cross-sectional diagram of the ejector taken along an axial direction according to the first embodiment.

FIG. 3 is a schematic enlarged view of a part III of FIG. 2.

FIG. 4 is a schematic enlarged cross-sectional diagram showing a modification example of the ejector according to the first embodiment.

FIG. 5 is a schematic enlarged cross-sectional diagram illustrating another modification example of the ejector according to the first embodiment.

FIG. 6 is a schematic enlarged cross-sectional diagram illustrating an ejector according to a second embodiment.

FIG. 7 is a diagram of an ejector refrigeration circuit as a whole in another embodiment.

EMBODIMENTS FOR EXPLOITATION OF THE INVENTION

[0028] Hereinafter, embodiments for implementing the present disclosure will be described referring to drawings. In each embodiment, portions corresponding to the elements described in the preceding embodiments are denoted by the same reference numerals, and redundant explanation may be omitted. When only a part of a configuration is described in an embodiment, another preceding embodiment may be applied to the other parts of the configuration. The present disclosure is not limited to combinations of embodiments which combine parts that are explicitly described as being combinable. As long as no problem is present, the various embodiments may be partially combined with each other even if not explicitly described.

(First embodiment)

[0029] A first embodiment of the present disclosure will be described with reference to FIGS. 1 to 5. As shown in FIG. 1, an ejector 14 according to the present embodiment is applied to an ejector refrigeration cycle 10 which is a vapor compression type refrigeration cycle device. The ejector refrigeration cycle 10 has a function of heating the water in a heat pump for supplying the water stored in a tank to a kitchen, bath, or the like as residential water.

[0030] Accordingly, the water is a heat exchange target fluid of the ejector refrigeration cycle 10. The fluid to be ejected, suctioned, or increased in pressure by the ejector 14 is a refrigerant of the ejector refrigeration cycle 10.

[0031] The refrigerant of the ejector refrigeration cycle 10 is carbon dioxide. The ejector refrigeration cycle 10 constitutes a supercritical refrigeration cycle in which the pressure of the refrigerant discharged from a compressor 11 (i.e. the refrigerant on the high-pressure side in the cycle) is equal to or higher than the critical pressure of the refrigerant. Accordingly, the ejector refrigeration cycle 10 can heat the water such that the temperature of the water is equal to or higher than 90 degrees Celsius.

[0032] The compressor 11 of the ejector refrigeration cycle 10 is configured to draw the refrigerant, pressurize the refrigerant to be high-pressure refrigerant, and discharge the refrigerant. In the present embodiment, the compressor 11 is an electric compressor in which a fixed displacement compression mechanism whose discharge capacity is fixed is driven by an electric motor. The rotation speed (i.e. the refrigerant discharge capacity) of the compressor 11 is controlled according to a control signal output from a controller (not shown).

[0033] A refrigerant inlet side of a water-refrigerant heat exchanger 12 is connected to a refrigerant discharge port of the compressor 11. The water-refrigerant heat exchanger 12 is a radiator configured to radiate heat of the high-pressure refrigerant discharged from the compressor 11 to the water circulating in a water circulating

cycle 20. The water-refrigerant heat exchanger 12 serves as a heating heat exchanger for heating the water. A water pump for pumping the water, a tank for storing the heated water (not shown), and the like are disposed in the water circulating cycle 20.

[0034] An outlet side of the water-refrigerant heat exchanger 12 is connected to an inlet side of an electric expansion valve 13. The electric expansion valve 13 is a variable throttle mechanism configured to decompress the high-pressure refrigerant flowing out of the water-refrigerant heat exchanger 12 to be an intermediate-pressure refrigerant. The electric expansion valve 13 also functions as a flow rate adjuster for adjusting the flow rate of the refrigerant flowing to the downstream side. The throttle degree of the electric expansion valve 13 is controlled according to a control signal output from the controller.

[0035] An outlet of the electric expansion valve 13 is connected to an inlet side of a nozzle 41 of the ejector 14. The ejector 14 is a refrigerant decompressor configured to decompress the intermediate-pressure refrigerant flowing out of the electric expansion valve 13 to a low-pressure refrigerant. Further, the ejector 14 functions as a refrigerant transport device that draws and transports the refrigerant that has flowed out of an evaporator 16, which will be described later, by the entrainment effect of the jet refrigerant ejected from the nozzle 41 at a high speed.

[0036] The detailed configuration of the ejector 14 will be described with reference to FIGS. 2 and 3. The ejector 14 has the nozzle 41 and a body 42.

[0037] The nozzle 41 is configured to convert the pressure energy of the refrigerant flowing therein from an inlet 41a into a velocity energy. The nozzle 41 is configured to decompress the refrigerant flowing therein from the inlet 41a in an isentropic manner, and effect the refrigerant from a refrigerant injection port 41e located at the most downstream part in the refrigerant flow. The nozzle 41 is made of a substantially cylindrical metal (in the present embodiment, a stainless steel alloy) whose tip portion tapers in the flow direction of the refrigerant.

[0038] A nozzle passage defined in the nozzle 41 has a converging portion 41b, a throat portion 41c, and the like. The cross-sectional area of the converging portion 41b decreases from the inlet 41a side toward the downstream side of the refrigerant flow. The throat portion 41c is formed at the most downstream part of the converging portion 41b in the refrigerant flow. The passage cross-sectional area is the smallest at the throat portion 41c. Further, in the nozzle 41, a refrigerant passage 41d is defined between the throat portion 41c and the refrigerant injection port 41e for convenience in manufacturing.

[0039] The cross-sectional area of the refrigerant passage 41d is equal to that of the throat portion 41c. Therefore, the energy loss due to friction generated when the refrigerant flows through the refrigerant passage 41d tends to be relatively large. Accordingly, in an ideal nozzle 41, it is desirable that the throat portion 41c and the re-

frigerant injection port 41e coincide with each other without forming the refrigerant passage 41d. However, forming the throat portion 41c and the refrigerant injection port 41e to coincide with each other with high accuracy may cause an increase in manufacturing cost, for example.

[0040] Thus, although the nozzle 41 of the present embodiment has the refrigerant passage 41d, an outer peripheral portion of the refrigerant injection port 41e of the nozzle 41 (that is, the tip of the nozzle 41) is chamfered, for example. A length of the refrigerant passage 41d in a direction along a central axis CL of the nozzle 41 is equal to or less than twice a diameter ϕD of an opening of the refrigerant injection port 41e. Accordingly, the nozzle 41 of the present embodiment has the throat portion 41c at the most downstream part of the nozzle passage.

[0041] The inventors have confirmed through tests and studies that, by forming the nozzle 41 such that the length of the refrigerant passage 41d in the axial direction is equal to or less than twice the diameter of the refrigerant injection port, the energy conversion efficiency by the nozzle 41 is equal to or higher than that by an ideal nozzle in which the throat portion 41c and the refrigerant injection port 41e coincide with each other.

[0042] That is, by forming the nozzle 41 such that the length of the part defining the refrigerant passage 41d in the direction along the central axis CL is equal to or less than twice the diameter ϕD of the opening of the refrigerant injection port 41e, the shape of the nozzle 41 can be close to an ideal shape as much as possible.

[0043] Further, a chamfered part of the tip portion of the nozzle 41 is so small that the chamfered part does not affect the performance of the ejector 14. Accordingly, the chamfered part of the tip portion of the nozzle 41 is not included in a part of the outer peripheral surface of the nozzle 41 defining the suction passage 42c.

[0044] The body 42 is made of a substantially cylindrical metal (aluminum in the present embodiment). The body 42 functions as a fixation member for supporting the nozzle 41 and forms a framework of the ejector 14. Specifically, the nozzle 41 is fixed by press-fitting or the like so as to be accommodated inside the one end side in the longitudinal direction of the body 42.

[0045] A refrigerant suction port 42a is provided in a portion of the outer peripheral surface of the body 42 on the outer peripheral side of the nozzle 41 so as to penetrate the inside and the outside of the portion and communicate with the refrigerant injection port 41e of the nozzle 41. The refrigerant suction port 42a is a through-hole that draws in the refrigerant flowing out of the evaporator 16 into the ejector 14 by using entrainment effect of the jet refrigerant discharged from the refrigerant injection port 41e of the nozzle 41.

[0046] Further, a mixing portion 42b, the suction passage 42c, and a diffuser portion 42d are formed in the body 34. The mixing portion 42b defines a space for mixing the jet refrigerant ejected from the refrigerant injection port 41e with the suction refrigerant drawn from the re-

frigerant suction port 42a. The mixing portion 42b has a circular column shape of a solid of revolution. The mixing portion 42b is located downstream of the nozzle 41 in the refrigerant flow. The center axis of the mixing portion 42b is disposed coaxially with the central axis CL of the nozzle 41.

[0047] The suction passage 42c is a refrigerant passage for guiding the suction refrigerant drawn from the refrigerant suction port 42a to the mixing portion 42b. The suction passage 42c is a space defined by the outer surface of the tapered tip portion of the nozzle 41 and the inner surface of the body 42. Accordingly, the cross-section of the suction passage 42c taken along a plane perpendicular to the central axis CL has an annular shape. Further, the refrigerant outlet of the suction passage 42c has an annular shape surrounding the refrigerant injection port 41e.

[0048] The diffuser portion 42d defines a space for converting the velocity energy of the mixed refrigerant of the jet refrigerant and the suction refrigerant into the pressure energy. That is, the diffuser portion 42d is a pressure increase portion that slows down the flow speed of the mixed refrigerant to increase the pressure of the mixed refrigerant.

[0049] The diffuser portion 42d defines a space that continues from the outlet of the mixing portion 42b and increases the passage cross-sectional area toward the downstream side of the refrigerant flow. The diffuser portion 42d is formed in a substantially truncated conical shape of revolution. The center axis of the diffuser portion 42d is disposed coaxially with the central axis CL of the nozzle 41.

[0050] Next, the detailed shapes of the nozzle 41 and the body 42 of the ejector 14 will be described with reference to FIG. 3. First, a cross-section of the nozzle including the central axis CL is defined as a reference cross-section. Accordingly, FIGS. 2, 3 are cross-sectional diagrams illustrating the reference cross-section of the ejector 14 taken along the axial direction.

[0051] As shown in FIG. 3, in the present embodiment, a line representing the outer surface of the nozzle 41 defining the suction passage 42c approaches the central axis CL toward the downstream side of the refrigerant flow. Further, a line representing the inner surface of the body 42 defining the suction passage 42c approaches the central axis CL toward the downstream of the refrigerant flow. Accordingly, the passage cross-sectional area of the suction passage 42c decreases toward the downstream side of the refrigerant flow.

[0052] A line passing through a largest diameter point Pmx1 and a smallest diameter point Pmn1 is defined as a nozzle outer periphery line L1. The largest diameter point Pmx1 is a part of the outer surface of the nozzle 41 at which the diameter of the nozzle 41 is the largest in the part defining the suction passage 42c. The smallest diameter point Pmn1 is a part of the outer surface of the nozzle 41 at which the diameter of the nozzle 41 is the smallest in the part defining the suction passage 42c. An

intersection point at which the nozzle outer periphery line L1 intersects with the central axis CL is defined as a nozzle outer periphery intersection point P1.

[0053] In the present embodiment, in the reference cross-section, the nozzle outer periphery line L1 intersects with a line representing the mixing portion 42b. Further, in the reference cross-section, the nozzle outer periphery intersection point P1 is located inside the mixing portion 42b. That is, the nozzle outer periphery intersection point P1 is located downstream of an inlet portion of the mixing portion 42b in the refrigerant flow.

[0054] A line passing through a largest diameter point Pmx2 and a smallest diameter point Pmn2 is defined as a body inner periphery line L2. The largest diameter point Pmx2 is a part of the inner surface of the body 42 at which the diameter of the body 42 is the largest in the part defining the suction passage 42c. The smallest diameter point Pmn2 is a part of the inner surface of the body 42 at which the diameter of the body 42 is the smallest in the part defining the suction passage 42c. An intersection point at which the body inner periphery line L2 intersects with the nozzle outer periphery line L1 is defined as a suction passage intersection point P2.

[0055] In the present embodiment, in the reference cross-section, the suction passage intersection point P2 is located inside the mixing portion 42b and on the central axis CL. That is, the suction passage intersection point P2 is located on a part of the central axis CL that is located downstream of the inlet portion of the mixing portion 42b in the refrigerant flow. Accordingly, in the present embodiment, in the reference cross-section, the nozzle outer periphery intersection point P1 coincides with the suction passage intersection point P2.

[0056] As shown in FIG. 1, a refrigerant outlet of the diffuser portion 42d is connected to an inlet side of an accumulator 15. The accumulator 15 is a gas-liquid separation unit that separates gas and liquid of the refrigerant that has flowed out of the diffuser portion 42d from each other. The accumulator 15 according to the present embodiment also functions as a reservoir for storing a part of the separated liquid-phase refrigerant as an excess refrigerant in the cycle.

[0057] A gas-phase refrigerant outlet port of the accumulator 15 is connected to the intake port side of the compressor 11. On the other hand, the liquid-phase refrigerant outlet port of the accumulator 15 is connected to the refrigerant inlet side of the evaporator 16 through a fixed throttle 15a that is a decompression portion. As the fixed throttle 15a, an orifice, a capillary tube, or the like can be employed.

[0058] The evaporator 16 is a heat-absorbing heat exchanger that evaporates the low-pressure refrigerant and exerts a heat absorbing action by exchanging heat between the low-pressure refrigerant reduced in pressure by the fixed throttle 15a and the air blown from the outside fan 16a. The refrigerant outlet of the evaporator 16 is connected to the refrigerant suction port 42a of the ejector 14. The outside fan 16a is an electric blower whose ro-

tation speed (i.e., blowing capacity) is controlled by a control voltage output from the controller.

[0059] The controller (not shown) is configured by a well-known microcomputer including a CPU, a ROM, a RAM, and the like, and peripheral circuits of the microcomputer. The controller performs various calculations and processes based on a control program stored in the ROM. The controller controls the electric actuators 11, 13, 16a connected to the output side of the controller.

[0060] A sensor group including multiple control sensors such as an outside air temperature sensor, a high-pressure sensor, and a water temperature sensor is connected to the controller. The detection values of the sensors are input to the controller. Specifically, the outside air temperature sensor is an outside air temperature detection unit that detects the outside air temperature. The high-pressure sensor is a high-pressure refrigerant pressure detection unit configured to detect the pressure of the high-pressure refrigerant flowing out of the water-refrigerant heat exchanger 12. The tank temperature sensor is a water temperature detection unit configured to detect the temperature of the water stored in the tank.

[0061] Furthermore, an operation panel (not shown) located in the house is connected to the input side of the controller. Operation signals output from various operation switches on the operation panel are input to the controller. The operation switches on the operation panel includes an actuation switch for actuating the heat pump type water heater, a temperature adjustment switch for adjusting the temperature of the water stored in the tank, and the like.

[0062] The controller according to the present embodiment integrally includes control units that control operation of various control target devices connected to an output side of the controller. The controller includes a configuration (hardware and software) that controls operation of each of the control target devices and embodies a control unit of the corresponding control target device. For example, the configuration for controlling the refrigerant discharge capacity of the compressor 11 constitutes the discharge capacity control unit.

[0063] Next, the operation of the ejector refrigeration cycle 10 according to the present embodiment having the above-described configuration will be described. First, when the actuation switch on the operation panel is turned on, the controller actuates the compressor 11, the electric expansion valve 13, the outside fan 16a, and the like. As a result, the compressor 11 draws the refrigerant, compresses the refrigerant, and discharges the refrigerant.

[0064] The high-temperature high-pressure refrigerant discharged from the compressor 11 flows into the refrigerant passage in the water-refrigerant heat exchanger 12 and exchanges heat with the water circulating in the water circulating cycle 20. Thus, the water is heated. The heated water is stored in the tank connected to the water circulating cycle 20. At this time, the rotational speed (i.e. the refrigerant discharge capacity) of the compressor 11

is determined with reference to a control map preliminarily stored in the controller based on the detection value of the outside air temperature sensor.

[0065] The refrigerant flowing out of the refrigerant passage in the water-refrigerant heat exchanger 12 is decompressed by the electric expansion valve 13 to become the intermediate-pressure refrigerant. At this time, the throttle degree of the electric expansion valve 13 is determined with reference to a control map preliminarily stored in the controller based on the detection value of the high-pressure sensor and the like. In this control map, the throttle degree of the electric expansion valve 13 is determined such that the coefficient of performance (COP) of the cycle approaches the maximum value.

[0066] The intermediate-pressure refrigerant decompressed by the electric expansion valve 13 flows into the nozzle 41 of the ejector 14 through the inlet 41a. The refrigerant flowing into the nozzle 41 of the ejector 14 is isentropically decompressed and ejected from the refrigerant injection port 41e.

[0067] The refrigerant flowing out of the evaporator 16 is drawn from the refrigerant suction port 42a by the entrainment effect of the jet refrigerant ejected from the refrigerant injection port 41e of the nozzle 41. The suction refrigerant drawn from the refrigerant suction port 42a flows into the mixing portion 42b through the suction passage 42c and is mixed with the jet refrigerant.

[0068] The refrigerant mixed in the mixing portion 42b flows into the diffuser portion 42d. In the diffuser portion 42d, a kinetic energy of the mixed refrigerant is converted into a pressure energy since the passage cross-sectional area increases. As a result, the pressure of the mixture refrigerant rises. The refrigerant flowing out of the diffuser portion 42d flows into the accumulator 15 and is separated into gas and liquid.

[0069] The liquid-phase refrigerant separated by the accumulator 15 is reduced in pressure by the fixed throttle 15a and flows into the evaporator 16. The refrigerant flowing into the evaporator 16 absorbs heat from the outside air blown from the outside fan 16a and evaporates. The refrigerant flowing out of the evaporator 16 is drawn into the ejector 14 through the refrigerant suction port 42a. On the other hand, the gas-phase refrigerant separated by the accumulator 15 is drawn into the compressor 11 and compressed again.

[0070] The ejector refrigeration cycle 10 of the present embodiment operates as described above, and accordingly the water stored in the tank of the heat pump type water heater is heated.

[0071] At this time, in the ejector refrigeration cycle 10, the refrigerant increased in pressure by the diffuser portion 42d of the ejector 14 is drawn into the compressor 11. The ejector refrigeration cycle 10 can thus achieve reduction of power consumption of the compressor 11 and improvement in coefficient of performance (COP) of the cycle, in comparison with a general refrigeration cycle device having refrigerant evaporating pressure at an evaporator substantially equal to pressure of a refrigerant

drawn into a compressor.

[0072] Further, according to the ejector refrigeration cycle 10 of the present embodiment, in the reference cross-section of the ejector 14, the nozzle outer periphery intersection point P1 is located downstream of the inlet portion of the mixing portion 42b. Accordingly, the pressure increase amount in the diffuser portion 42d is greater than a general ejector, and the COP of the ejector refrigeration cycle 10 can be improved.

[0073] In the ejector 14 of the present embodiment, the nozzle outer periphery intersection point P1 is located inside the mixing portion 42b in the reference cross-section as shown in FIG. 3. Accordingly, an angle between the flow direction of the mainstream of the suction fluid and the flow direction of the mainstream of the jet fluid can be reduced without increase of the size of the ejector 14, and the energy loss can be reduced.

[0074] If the nozzle outer periphery intersection point P1 is located upstream of the mixing portion 42b in the refrigerant flow, the suction refrigerant and the jet refrigerant are mixed at a part located upstream of the mixing portion 42b. This may cause turbulence in the mixed refrigerant before flowing into the mixing portion 42b, and the turbulence may cause vortices. As a result, friction between the mixed refrigerant and the wall surface defining the suction passage 42c may cause an increase of the energy loss of the refrigerant.

[0075] Further, if the nozzle outer periphery intersection point P1 is located downstream of the mixing portion 42b in the refrigerant flow, the angle between the flow direction of the mainstream of the suction fluid and the flow direction of the mainstream of the jet fluid is decreased, and accordingly the energy loss can be reduced. However, a length of the part of the nozzle 41 defining the suction passage 42c is elongated in the direction along the central axis CL. Accordingly, this may result in increase of size of the ejector 14 as a whole.

[0076] In contrast, according to the ejector 14 of the present embodiment, since the nozzle outer periphery intersection point P1 is located inside the mixing portion 42b, the suction fluid flowing along the outer surface of the nozzle 41 can be guided to the inside of the mixing portion 42b such that the suction fluid is mixed with the jet fluid inside the mixing portion 42b. Accordingly, the increase of the energy loss due to mixing of the suction fluid and the jet fluid at the part located upstream of the mixing portion 42b can be suppressed. Further, the length of the nozzle 41 in the direction along the central axis CL does not unnecessarily increase.

[0077] That is, according to the ejector 14 of the present embodiment, the energy loss of the refrigerant flowing through the ejector 14 can be reduced without increasing the size of the ejector 14. As a result, the pressure increase amount by the ejector 14 can be increased, and the COP of the ejector refrigeration cycle 10 including the ejector 14 can be improved.

[0078] Moreover, in the ejector 14 of the present embodiment, the nozzle 41 has the throat portion 41c at the

most downstream part of the nozzle passage. Accordingly, the energy loss due to the friction caused when the refrigerant flows through the part located downstream of the throat portion 41c can be suppressed. As a result, the energy loss caused when the refrigerant flowing through the ejector can be further suppressed.

[0079] In the ejector 14 of the present embodiment, in the reference cross-section, the nozzle outer periphery line L1 intersects with a line representing the mixing portion 42b of the body 42. According to this, the nozzle outer periphery intersection point P1 is surely located inside the mixing portion 42b.

[0080] In the ejector 14 of the present embodiment, the suction passage intersection point P2 is located inside the mixing portion 42b and on the central axis CL. According to this, the suction fluid flowing along the inner surface of the body 42 can be guided to the inside of the mixing portion 42b to be mixed with the jet fluid inside the mixing portion 42b. As a result, the energy loss caused when the suction fluid and the jet fluid are mixed can be further suppressed.

[0081] In the present embodiment, in the reference cross-section, the suction passage intersection point P2 is located on the central axis CL and coincides with the nozzle outer periphery intersection point P1. However, the suction passage intersection point P2 may be modified to be located as shown in FIGS. 4, 5, as long as the suction passage intersection point P2 is located inside the mixing portion 42b. FIGS. 4, 5 are drawings corresponding to FIG. 3.

[0082] For example, in FIG. 4, the suction passage intersection point P2 is located inside the mixing portion 42b and over the central axis CL in the reference cross-section. That is, the suction passage intersection point P2 is located downstream of the intersection point of the body inner periphery line L2 and the central axis CL. According to this, the angle between the flow direction of the mainstream of the suction fluid and the flow direction of the mainstream of the jet fluid is decreased, and the energy loss can be suppressed.

[0083] For example, in FIG. 5, the suction passage intersection point P2 is located inside the mixing portion 42b and at a position that does not exceed the central axis CL in the reference cross-section. That is, the suction passage intersection point P2 is located upstream of the intersection point of the body inner periphery line L2 and the central axis CL. According to this, since the angle between the flow direction of the mainstream of the suction fluid and the flow direction of the mainstream of the jet fluid is increased, the mixability of the suction fluid and the jet fluid can be improved.

[0084] That is, the position of the suction passage intersection point P2 may be appropriately modified based on the priority of the effect of suppressing the energy loss and the effect of improving the mixability of the suction fluid and the jet fluid.

[0085] Further, the advantages of the ejector 14 of the present embodiment, i.e. the effect of reducing the en-

ergy loss of the refrigerant flowing through the ejector 14 without increasing the size, is effective in an ejector in which the shape of the outer surface of the nozzle 41 defining the suction passage 42c is likely to affect the flow direction of the suction fluid.

[0086] Such ejectors include, for example, a small ejector in which the passage cross-sectional area of the suction passage 42c or the passage cross-sectional area of the mixing portion 42b is relatively small, an ejector in which the outer diameter of the nozzle 41 is nearly equal to the inner diameter of the part of the body 42 defining the mixing portion 42b, and an ejector in which the length from the refrigerant injection port 41e to the inlet of the mixing portion 42b is relatively small (for example, the length is less than 5 times the inner diameter of the mixing portion 42b).

(Second Embodiment)

[0087] In the present embodiment, an example in which the nozzle 41 of the first embodiment is modified as shown in FIG. 6 will be described. FIG. 6 is a drawing corresponding to FIG. 3 described in the first embodiment. In FIG. 6, the same or equivalent parts as those of the first embodiment are denoted by the same reference numerals.

[0088] The nozzle passage of the present embodiment includes a diverging portion 41g in which the passage cross-sectional area increases from the throat portion 41c toward the refrigerant injection port 41e. Further, the length of the diverging portion 41g in the direction along the central axis CL is equal to or less than twice the diameter ϕD of the opening of the refrigerant injection port 41e. Accordingly, the nozzle 41 of the present embodiment has the throat portion 41c at the most downstream part of the nozzle passage.

[0089] In the reference cross-section, a line passing through a smallest diameter point Pmn3 and a largest diameter point Pmx3 is defined as a nozzle inner periphery line L3. The smallest diameter point Pmn3 is a part of the diverging portion 41g at which the diameter of the diverging portion 41g is the smallest. The largest diameter point Pmx3 is a part of the diverging portion 41g at which the diameter of the diverging portion 41g is the largest. A part at which the nozzle inner periphery line L3 intersects with the nozzle outer periphery line L1 is defined as a nozzle shape intersection point P3.

[0090] In the present embodiment, in the reference cross-section, the nozzle inner periphery line L3 intersects with the line representing the mixing portion 42b. Further, the nozzle shape intersection point P3 is located inside the mixing portion 42b. That is, the nozzle shape intersection point P3 is located downstream of an inlet portion of the mixing portion 42b in the refrigerant flow. Other configurations and operations of the ejector 14 and the ejector refrigeration cycle 10 are the same as those of the first embodiment.

[0091] Accordingly, the ejector refrigeration cycle 10

of the present embodiment can heat the water stored in the tank of the heat pump type water heater as in the first embodiment. Moreover, according to the ejector 14 of the present embodiment, the energy loss of the refrigerant flowing through the ejector 14 can be reduced without increasing the size of the ejector 14 as in the first embodiment.

[0092] As shown in FIG. 6, in the reference cross-section of the ejector 14 of the present embodiment, the nozzle inner periphery line L3 intersects with a line representing the mixing portion 42b of the body 42. According to this, since the jet fluid flowing along the inner surface of the diverging portion 41g can be guided to the inside of the mixing portion 42b to be mixed with the suction fluid inside the mixing portion 42b, the energy loss caused when the suction fluid and the jet fluid are mixed can be suppressed.

[0093] Further, since the length of the diverging portion 41g in the direction along the central axis CL is not longer than twice the diameter ϕD of the opening of the refrigerant injection port 41e, the length of the nozzle in the central axis CL is not unnecessarily increased.

[0094] Moreover, according to the ejector 14 of the present embodiment, since the nozzle shape intersection point P3 is located inside the mixing portion 42b, the suction fluid flowing along the inner surface of the body 42 can be guided to the inside of the mixing portion 42b such that the suction fluid is mixed with the jet fluid inside the mixing portion 42b. As a result, the energy loss caused when the suction fluid and the jet fluid are mixed can be further suppressed.

[0095] Further, the advantages of the shape of the diverging portion 41g of the ejector 14 according to the present embodiment, i.e. the effect of reducing the energy loss of the refrigerant flowing through the ejector 14 without increasing the size, is effective in an ejector in which the shape of the outer surface of the nozzle 41 defining the suction passage 42c is likely to affect the flow direction of the suction fluid.

[0096] Such ejectors include, for example, a small ejector in which the passage cross-sectional area of the suction passage 42c or the passage cross-sectional area of the mixing portion 42b is relatively small, and an ejector in which the length from the refrigerant injection port 41e to the inlet of the mixing portion 42b is relatively small (for example, the length is less than 5 times the inner diameter of the mixing portion 42b).

[0097] The present disclosure is not limited to the embodiments described above, and various modifications can be made as follows within a scope not departing from the spirit of the present disclosure.

[0098] In the above-described embodiments, the ejector 14 of the present disclosure is used in the ejector refrigeration cycle 10. However, the usage of the ejector 14 of the present disclosure is not limited to this. The ejector 14 may be used in devices other than the ejector refrigeration cycle.

[0099] Further, the usage of the ejector refrigeration

cycle 10 is not limited to the heat pump type water heater. The ejector refrigeration cycle 10 may be used for: an air-conditioning device for adjusting the temperature of the air that is a heat exchange target fluid and is conveyed to an air-conditioning target space; and a refrigeration container for cooling an air that is a heat exchange target fluid and circulating in a refrigeration space, for example.

[0100] The cycle configuration of the ejector refrigeration cycle to which the ejector 14 of the present disclosure is not limited to the above-described embodiments.

[0101] For example, as shown in FIG. 7, the ejector refrigeration cycle may include a branch portion 17 configured to branch the flow of the refrigerant flowing out of the refrigerant passage in the water-refrigerant heat exchanger 12, and a second evaporator 18 configured to evaporate the refrigerant flowing out of the ejector 14. In the ejector refrigeration cycle, one refrigerant outlet of the branch portion 17 may be connected to the inlet 41a of the ejector 14, the other one refrigerant outlet of the branch portion 17 may be connected to the refrigerant inlet side of the first evaporator 16 through the fixed throttle 15a, and the outlet of the diffuser portion 42d of the ejector 14 may be connected to the intake port side of the compressor 11 through the second evaporator 18.

[0102] The configuration of the ejector 14 is not limited to that disclosed in the embodiments described above.

[0103] For example, in the first embodiment, the refrigerant passage 41d is defined in the ejector 14. However, the ejector 14 may not have the refrigerant passage 41d and the chamfered portion of the tip portion of the nozzle 41 if it can be manufactured.

[0104] In the above-described embodiments, the line representing the outer surface of the nozzle 41 defining the suction passage 42c is a linear line. However, this line is not limited to be linear and may be a curved line. Similarly, in the above-described embodiments, the line representing the inner surface of the body 42 defining the suction passage 42c is a linear line. However, this line is not limited to be linear and may be a curved line.

[0105] In the above-described embodiments, the mixing portion 42b has a circular column shape. However, the mixing portion 42b may have a truncated conical shape increasing the passage cross-sectional area toward the downstream side of the refrigerant flow, like the diffuser portion 42d. In this case, a spread angle (that is, an increasing degree of the passage cross-sectional area) of the mixing portion 42b is set to be smaller than a spread angle (that is, an increasing degree of the passage cross-sectional area) of the diffuser portion 42d.

[0106] Further, the line representing the diffuser portion 42d of the body 42 in the reference cross-section may be a combination of multiple curves. For example, the increasing degree of the passage cross-sectional area of the diffuser portion 42d may decrease after gradually increasing along the flow direction of the fluid. Thus, the pressure of the fluid can be isentropically increased in the diffuser portion 42d.

[0107] In the above-described embodiments, the elec-

tric expansion valve 13 is used. However, the ejector 14 may further have a valuable mechanism for adjusting the flow rate. For example, a needle-shaped valve body may be disposed in the nozzle passage of the nozzle 41. A central axis of the valve body is disposed coaxially with the central axis CL of the nozzle 41. Further, an actuation device (e.g. stepper motor) for displacing the valve body in the direction along the central axis CL is disposed in the body 42.

[0108] According to this, the passage cross-sectional area at the throat portion 41c can be changed by moving the valve body using the actuation device. Further, the ejector 14 has a function of a flow rate adjuster.

[0109] The needle-shaped valve body may be arranged to stick out from the refrigerant injection port 41e toward the downstream side of the refrigerant flow regardless of the presence or absence of the actuation device. According to this, the expansion form of the jet refrigerant can be approximated to a proper expansion, and the energy conversion efficiency by the nozzle 41 that is a plug nozzle can be further improved.

[0110] The components described in each of the above embodiments may be appropriately combined to the extent practicable. For example, in the ejector 14 of the second embodiment, the position of the suction passage intersection point P2 may be changed as described in the modification example of the first embodiment.

[0111] It should be understood that the present disclosure described based on the embodiments is not limited to the embodiments or structures presented herein. To the contrary, the present disclosure is intended to cover various modification and equivalent arrangements. In addition, while the various elements are shown in various combinations and configurations, which are exemplary, other combinations and configurations, including more, less or only a single element, are also within the spirit and scope of the present disclosure.

Claims

1. An ejector comprising:

a nozzle (41) configured to decompress a fluid and eject the fluid from a fluid injection port (41e); and
a body (42) that has

a fluid suction port (42a) through which the fluid is drawn in the body by an entrainment effect of a jet fluid ejected from the fluid injection port,
a mixing portion (42b) in which the jet fluid and a suction fluid drawn through the fluid suction port are mixed, and
a pressure increase portion (42d) configured to convert a velocity energy of the mixed fluid flowing out of the mixing portion

into a pressure energy, wherein

at least a part of the nozzle is housed in the body,
a suction passage (42c) through which the suction fluid flows is defined between an outer surface of the nozzle and an inner surface of the body,
the mixing portion has a shape of a solid of revolution about a central axis (CL) of the nozzle,
the nozzle defines therein a nozzle passage that includes

a converging portion (41b) decreasing a passage cross-sectional area toward a downstream side of a fluid flow, and
a throat portion (41c) located at most downstream part of the converging portion, the passage cross-sectional area at the throat portion being smallest in the nozzle passage,

a length of a part of the nozzle passage extending from the throat portion to the fluid injection port in a direction along the central axis (CL) is equal to or less than twice a diameter (φD) of an opening of the fluid injection port,
a reference cross-section is a cross-section including the central axis (CL),
in the reference cross-section, a part of the outer surface of the nozzle defining the suction passage approaches the central axis (CL) toward the downstream side of the fluid flow,
in the reference cross-section, a nozzle outer periphery intersection point (P1) is an intersection point of the central axis (CL) and a nozzle outer periphery line (L1) passing through a largest diameter point (Pmx1) and a smallest diameter point (Pmn1) of the part of the outer surface of the nozzle defining the suction passage, a diameter of the part of the outer surface of the nozzle being largest at the largest diameter point (Pmx1) and being smallest at the smallest diameter point (Pmn1), and
the nozzle outer periphery intersection point (P1) is located inside the mixing portion.

2. The ejector according to claim 1, wherein in the reference cross-section, the nozzle outer periphery line (L1) intersects with the mixing portion of the body.
3. The ejector according to claim 1 or 2, wherein in the reference cross-section, a part of the inner surface of the body defining the suction passage approaches the central axis (CL) toward the downstream side of the fluid flow,
in the reference cross-section, a suction passage intersection point (P2) is an intersection point of the

nozzle outer periphery line (L1) and a body inner periphery line (L2) passing through a largest diameter point (Pmx2) and a smallest diameter point (Pmn2) of the part of the inner surface of the body defining the suction passage, a diameter of the part of the inner surface of the body being largest at the largest diameter point (Pmx2) and being smallest at the smallest diameter point (Pmn2), and
the suction passage intersection point (P2) is located inside the mixing portion.

4. The ejector according to any one of claims 1 to 3, wherein
the nozzle passage includes a diverging portion (41g) that increases the passage cross-sectional area from the throat portion to the fluid injection port, and
in the reference cross-section, a nozzle inner periphery line (L3) passes through a smallest diameter point (Pmn3) at which a diameter is smallest in the diverging portion and a largest diameter point (Pmx3) at which the diameter is largest in the diverging portion, and
the nozzle inner periphery line (L3) intersects with the mixing portion of the body in the reference cross-section.

5. An ejector comprising:

a nozzle (41) configured to decompress a fluid and eject the fluid from a fluid injection port (41e); and
a body (42) that has

a fluid suction port (42a) through which the fluid is drawn in the body by an entrainment effect of a jet fluid ejected from the fluid injection port,
a mixing portion (42b) in which the jet fluid and a suction fluid drawn through the fluid suction port are mixed, and
a pressure increase portion (42d) configured to convert a velocity energy of the mixed fluid flowing out of the mixing portion into a pressure energy, wherein

at least a part of the nozzle is housed in the body,
a suction passage (42c) through which the suction fluid flows is defined between an outer surface of the nozzle and an inner surface of the body,
the mixing portion has a shape of a solid of revolution about a central axis (CL) of the nozzle,
the nozzle defines therein a nozzle passage that includes

a converging portion (41b) decreasing a passage cross-sectional area toward a

downstream side of a fluid flow,
 a throat portion (41c) located at most down-
 stream part of the converging portion, the
 passage cross-sectional area at the throat
 portion being smallest in the nozzle pas- 5
 sage, and
 a diverging portion (41g) increasing the pas-
 sage cross-sectional area from the throat
 portion to the fluid injection port,

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a length of the diverging portion in a direction
 along the central axis (CL) is equal to or less
 than twice a diameter of an opening (ϕD) of the
 fluid injection port,
 a reference cross-section is a cross-section in- 15
 cluding the central axis (CL),
 in the reference cross-section, a nozzle inner
 periphery line (L3) passes through a smallest
 diameter point (Pmn3) of the diverging portion
 at which a diameter of the diverging portion is 20
 smallest and a largest diameter point (Pmx3) of
 the diverging portion at which the diameter of
 the diverging portion is largest, and
 the nozzle inner periphery line (L3) intersects
 with the mixing portion of the body in the refer- 25
 ence cross-section.

6. The ejector according to claim 4 or 5, wherein
 in the reference cross-section, the part of the outer
 surface of the nozzle defining the suction passage 30
 approaches the central axis (CL) toward the down-
 stream side of the fluid flow,
 in the reference cross-section, a nozzle shape inter-
 section point (P3) is an intersection point of the noz-
 zle inner periphery line (L3) and a nozzle outer pe- 35
 riphery line (L1) passing through a largest diameter
 point (Pmx1) and a smallest diameter point (Pmn1)
 of the part of the outer surface of the nozzle defining
 the suction passage, a diameter of the part of the
 outer surface of the nozzle being largest at the larg- 40
 est diameter point (Pmx1) and being smallest at the
 smallest diameter point (Pmn1), and
 the nozzle shape intersection point (P3) is located
 inside the mixing portion.

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FIG. 1

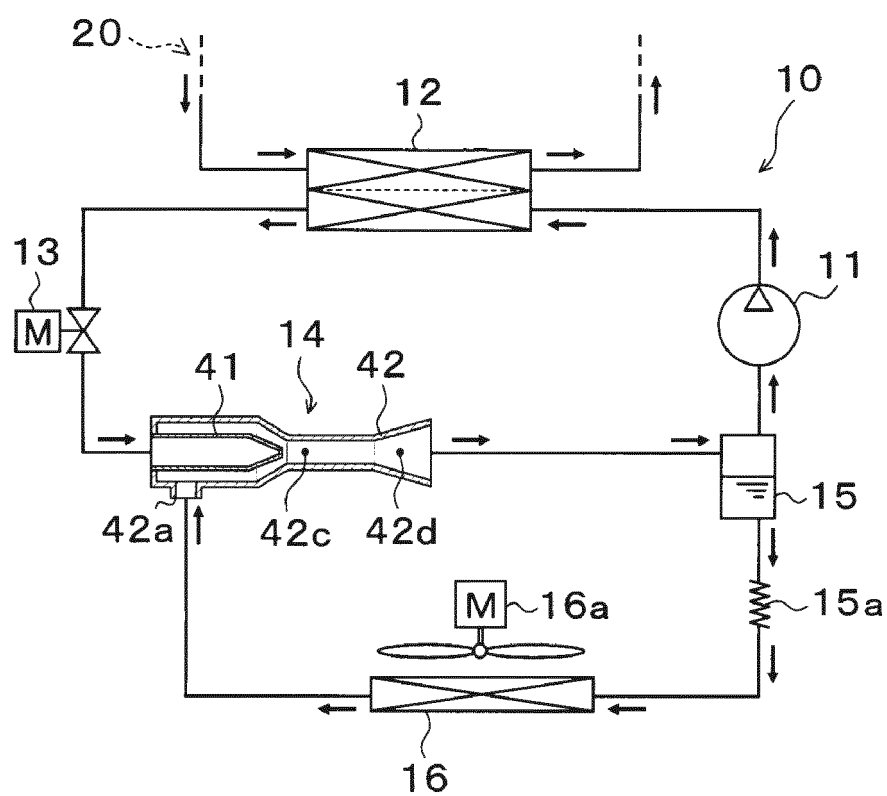


FIG. 2

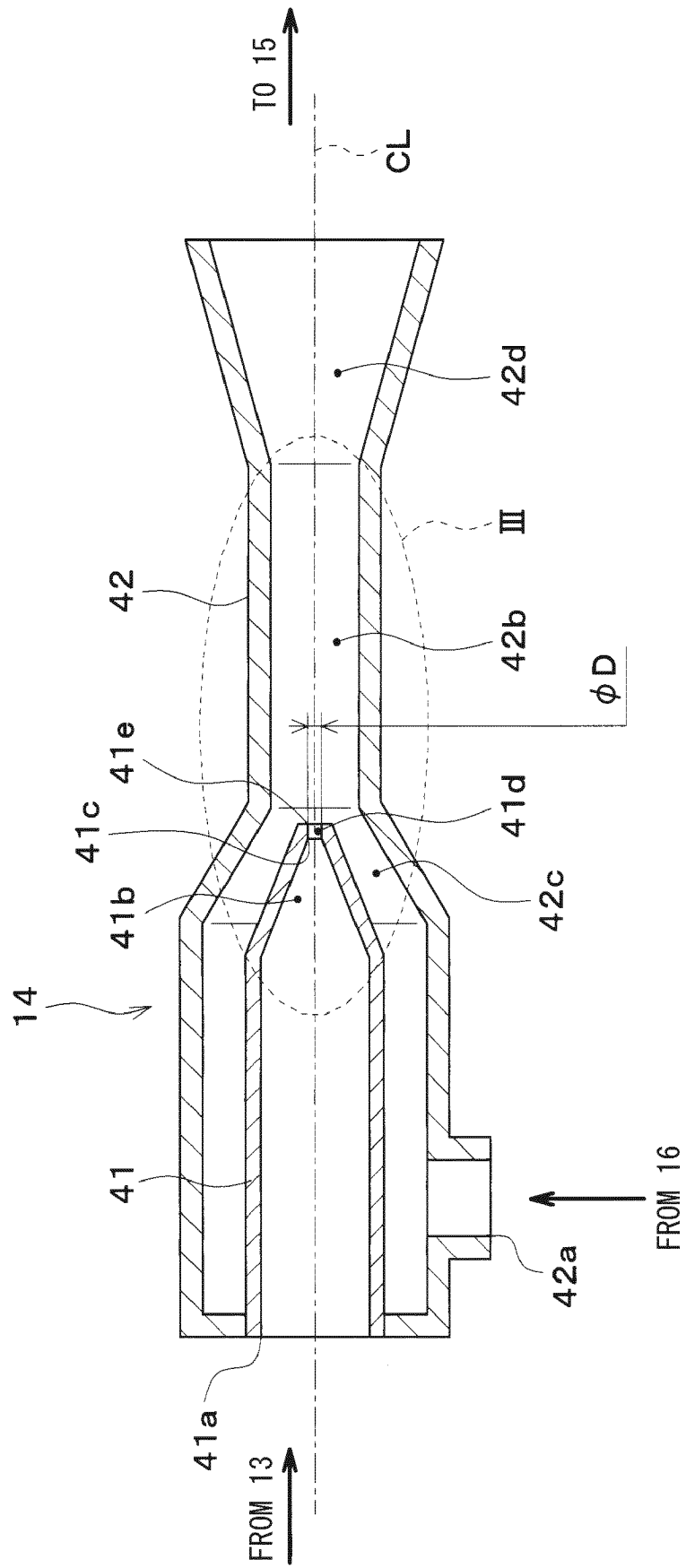


FIG. 3

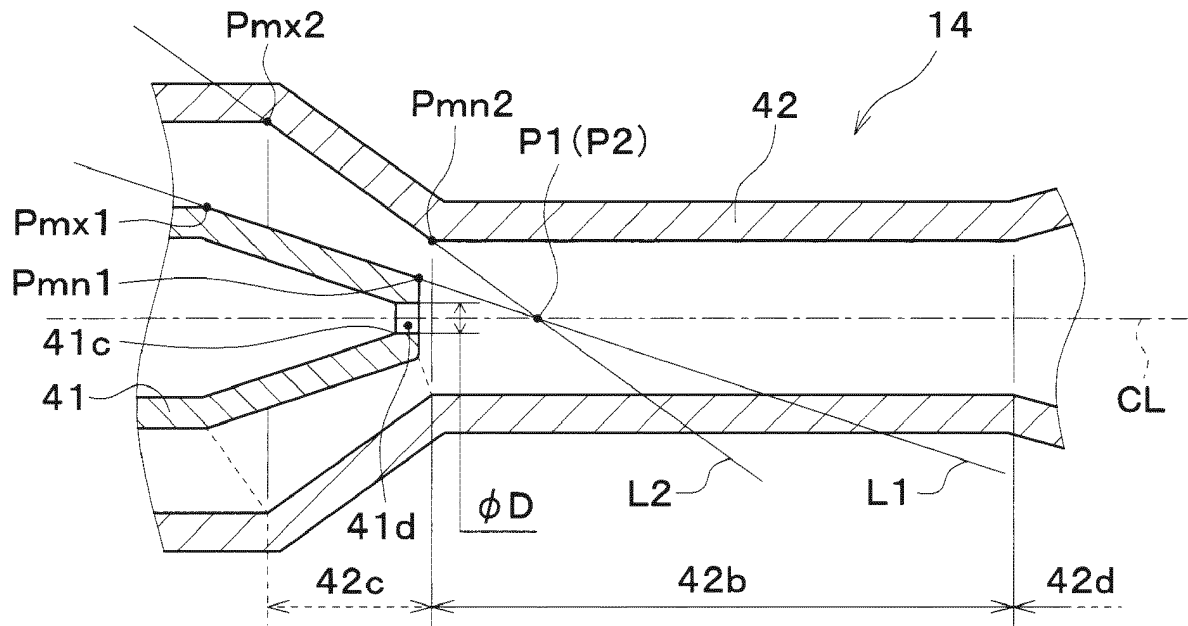


FIG. 4

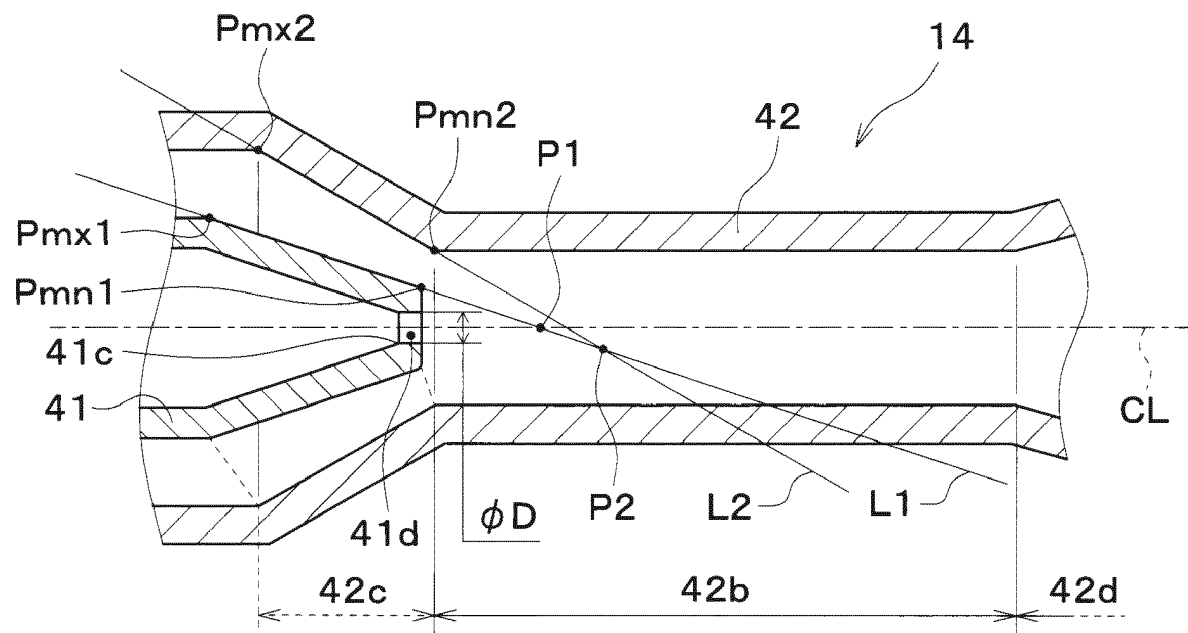


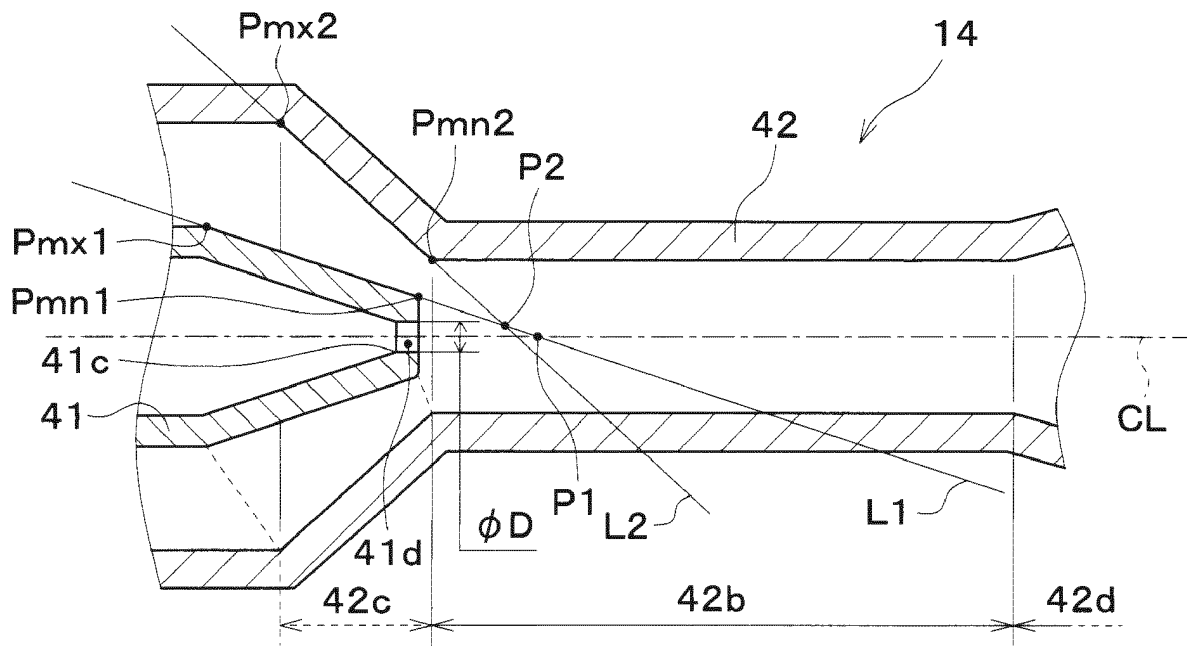
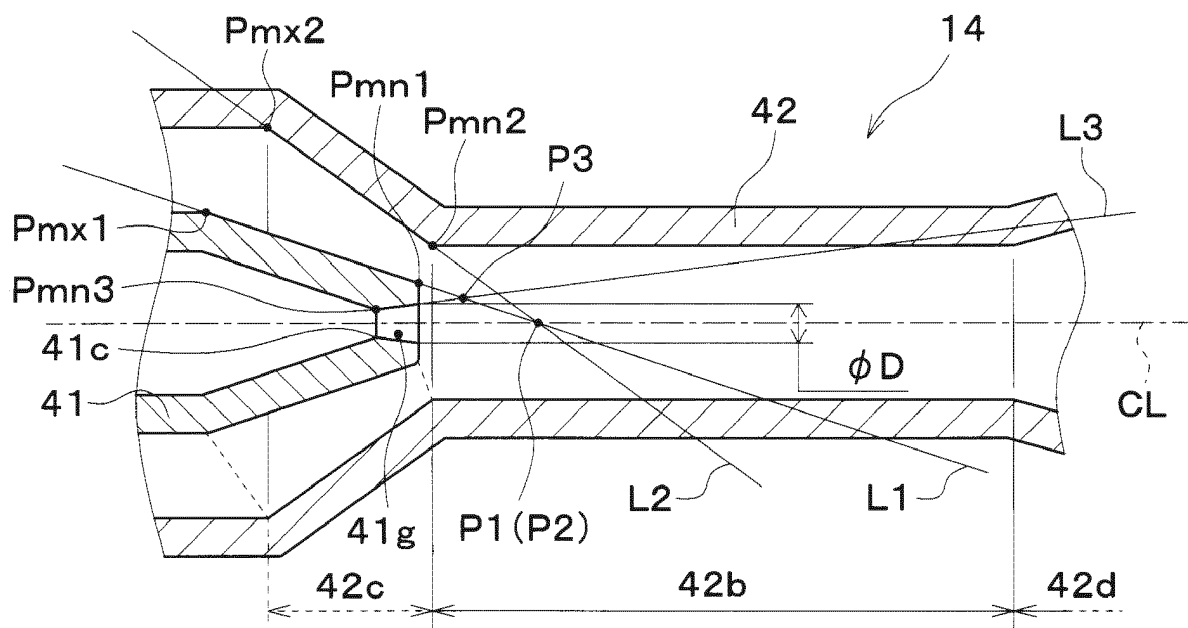
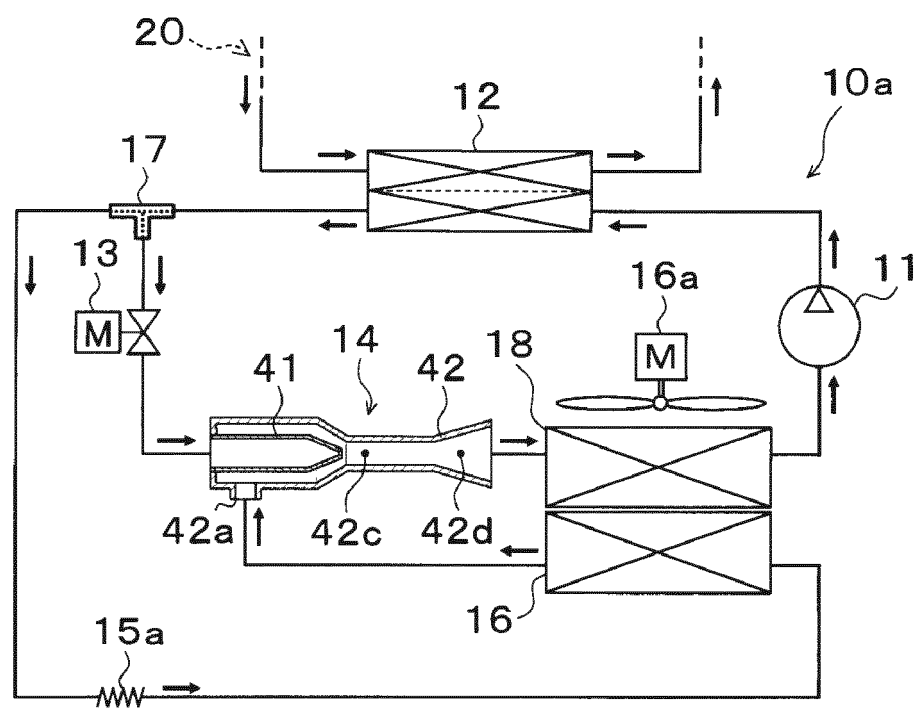
FIG. 5**FIG. 6**

FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/046853

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. F04F5/46 (2006.01) i, F04F5/16 (2006.01) i, F25B1/00 (2006.01) n

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl. F04F5/46, F04F5/16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2019

Registered utility model specifications of Japan 1996-2019

Published registered utility model applications of Japan 1994-2019

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 6-2964 A (NIPPONDENSO CO., LTD.) 11 January 1994, fig. 1 (Family: none)	1-5
X	CN 105065341 A (XI'AN JIAOTONG UNIVERSITY) 18 November 2015, fig. 1 (Family: none)	1-5
X	CN 106640777 A (JIANGSU ZHENHUA PUMP IND CO., LTD.) 10 May 2017, fig. 1 (Family: none)	1-3
X	CN 206636848 U (TAIXING THERMAL METERS FACTORY) 14 November 2017, fig. 1, 2 (Family: none)	1-2
X	CN 103644149 A (SICHUAN JINYU CHEMICAL MACHINERY CO., LTD.) 19 March 2014, fig. 1, 2 (Family: none)	1-2



Further documents are listed in the continuation of Box C.



See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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Date of the actual completion of the international search

05.03.2019

Date of mailing of the international search report

12.03.2019

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Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/046853

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 107620743 A (ZHANG, Yan) 23 January 2018, fig. 1 (Family: none)	1, 3
X	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 120951/1981 (Laid-open No. 27600/1983) (MITSUBISHI HEAVY INDUSTRIES, LTD.) 22 February 1983, fig. 3 (Family: none)	1, 3
X	CN 205446214 U (THE 404 COMPANY LIMITED OF CHINA NATIONAL NUCLEAR CORPORATION) 10 August 2016, fig. 1, 2 (Family: none)	5-6

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- JP 2018009477 A [0001]
- JP 2004270460 A [0008]
- US 20160187037 [0008]