

DESCRIPTION

LOW-TEMPERATURE GAS SUPPLY DEVICE, HEAT TRANSFER MEDIUM-COOLING DEVICE, AND LOW-TEMPERATURE REACTION CONTROL DEVICE

[Technical Field]

[0001]

The present invention relates to a low-temperature gas supply device, heat transfer medium-cooling device, and low-temperature reaction control device. The present application claims priority on the basis of Japanese Patent Application No. 2011-223716, filed in Japan on October 11, 2011, the contents of which are incorporated herein by reference.

[Background Art]

[0002]

In a chemical process such as an organic synthesis and crystallization, a highly accurate control of temperature is required in the low-temperature range. Therefore, as shown in the Patent documents described below, a low-temperature reaction device may be used. In the low-temperature reaction device, a double structure container disposed with an independent vessel (jacket), in which a heat transfer medium is able to flow outside a reaction vessel, is used, and by supplying a heat transfer medium controlled to a low temperature to the jacket part, the reaction liquid in the reaction vessel is cooled and adjusted to be a constant temperature.

[0003]

The heat transfer medium supplied to the reaction vessel is temperature-controlled in the heat exchanger so as to be cooled below the predefined temperature by heat-exchange with a low-temperature-liquefied gas (for example, liquefied nitrogen) of lower temperature than the solidification point of the heat transfer medium, and then is supplied to the jacket of the reaction vessel.

[0004]

These cooling devices need to be prevented from freezing a heat transfer medium in a heat exchanger. This is because the heat transfer medium freezes and blocks a flow channel, and there is a case where the heat transfer medium cannot be circulated. Also, when the heat transfer medium freezes and blocks a flow channel,

the loss of pressure increases; therefore a pump having greater quality than design quality is needed, heat intrusion from the pump increases, and thus the usage of the low-temperature-liquefied gas for cooling increases.

[0005]

Conventionally, in order to prevent the freezing of the heat transfer medium from advancing, the cooling temperature of the heat transfer medium must be set at a sufficiently higher temperature than the solidification point of the heat transfer medium.

Therefore, the low-temperature quality, which the heat transfer medium potentially has, could not be sufficiently used.

[0006]

Methods for avoiding the freezing of the heat transfer medium described above have already been disclosed in the art. For example, in Patent document 1, it is realized by providing a device for blocking the supply of the low-temperature-liquefied gas using the difference of the pressure of the heat transfer medium between the introducing part and the discharging part in the heat exchanger or using a temperature of an evaporation gas at the discharging part of the low-temperature-liquefied gas in the heat exchanger. Also, in Patent document 2, it is realized by detecting the temperature of the heat-transfer surface in the heat exchanger and controlling a supply quantity of the low-temperature-liquefied gas.

[0007]

In the arts disclosed in the Patent documents above, the development of solidification of the heat transfer medium inside the heat exchanger due to the excess supply of the low-temperature-liquefied gas can be prevented. However, the solidification of the heat transfer medium occurs to some degree.

[0008]

As a method of more reliably lowering the solidification of the heat transfer medium inside the heat exchanger, a method of adjusting the temperature of the low-temperature-liquefied gas supplied to the heat exchanger and in particular, a method of supplying the low-temperature-liquefied gas to the heat exchanger in the state of increasing temperature, has been considered.

[0009]

As one of the methods of increasing the temperature of the

low-temperature-liquefied gas, there is a method of mixing the low-temperature-liquefied gas with a gas of higher temperature than the low-temperature-liquefied gas, for example, mixing the low-temperature-liquefied gas with the same kinds of gas of room temperature. However, in simple mixing equipment, there is a problem in that the temperature of the low-temperature-liquefied gas becomes uneven and pulsative after mixing. For example, a temperature of a liquefied nitrogen is greatly different from that of nitrogen gas of room temperature and because the liquefied nitrogen has large cold energy in a small flow, a control of a very little flow is difficult and after mixing, there is a problem in that a flow of the low-temperature-liquefied nitrogen gas becomes pulsative or a temperature becomes uneven due to poor mixing. In order to solve the problems, for example, as disclosed in Patent document 3, efficient or large mixing equipment is needed, which incurs cost increases.

[Citation List]

[Patent Literature]

[0010]

Patent Document 1: Japanese Unexamined Patent Application, First Publication No. H11-037623

Patent Document 2: Japanese Unexamined Patent Application, First Publication No. 2009-287822

Patent Document 3: Japanese Unexamined Patent Application, First Publication No. H09-287883

[Summary of Invention]

[Problem to be Solved by the Invention]

[0011]

In view of the foregoing problems, the invention provides the following:

a low-temperature gas supply device capable of supplying a low-temperature gas refrigerant which is accurately and stably controlled; a heat transfer medium-cooling device in which the low-temperature gas refrigerant is introduced and a heat transfer medium which does not solidify, which is accurately and stably controlled, can be discharged by heat-exchange with the low-temperature gas refrigerant; and a low-temperature reaction control device, in which stable control can be realized over a broad range using the heat transfer medium.

[Means for Solving the Problem]

[0012]

The present invention employs the following devices in order to solve the above problems.

(1) A low-temperature gas supply device, comprising

a first heat exchanger, in which a mixed gas mixing a vaporization gas of a low-temperature-liquefied gas with a gas of a temperature higher than the low-temperature-liquefied gas and the low-temperature-liquefied gas are introduced and heat-exchanged with each other, and the mixed gas is discharged as a low-temperature gas refrigerant and the low-temperature-liquefied gas is discharged as the vaporization gas;

a mixing unit, in which the gas and the vaporization gas discharged from the first heat exchanger are mixed and discharged as the mixed gas; and

a first control unit, in which, based on the difference between a detected temperature of the low-temperature gas refrigerant and an intended temperature, respective amounts of the gas and the vaporization gas introduced to the mixing unit are adjusted to control the temperature of the low-temperature gas refrigerant to the intended temperature.

(2) A low-temperature gas supply device, comprising

a first heat exchanger, in which a low-temperature-liquefied gas and a gas of a temperature higher than the low-temperature-liquefied gas are introduced and heat-exchanged with each other, and a vaporization gas of the low-temperature-liquefied gas is discharged and the gas after heat-exchanging is discharged as a heat-exchanged gas;

a mixing unit, in which the heat-exchanged gas and the vaporization gas discharged from the first heat exchanger are mixed and discharged as a low-temperature gas refrigerant; and

a first control unit, in which, based on the difference between a detected temperature of the low-temperature gas refrigerant and an intended temperature, respective amounts of the gas of a temperature higher than the low-temperature-liquefied gas, the gas being introduced to the first heat exchanger, and the vaporization gas introduced to the mixing unit are adjusted to control the temperature of the low-temperature gas refrigerant to the intended

temperature.

(3) The low-temperature gas supply device of (1) or (2), wherein the mixing unit is an ejector.

(4) A heat transfer medium-cooling device, comprising

the low-temperature gas supply device of (1) or the low-temperature gas supply device of (2),

a second heat exchanger, in which the low-temperature gas refrigerant discharged from the low-temperature gas supply device, the temperature of the low-temperature gas refrigerant being controlled, and a heat transfer medium circulated in a circulation route are heat-exchanged with each other; and

a second control unit in which, based on the difference between a detected temperature of the heat transfer medium and an intended temperature of the heat transfer medium, an amount of the low-temperature gas refrigerant introduced to the second heat exchanger is adjusted to control a temperature of the heat transfer medium at the intended temperature of the heat transfer medium.

(5) The low-temperature reaction control device, comprising

the heat transfer medium-cooling device of (4); and

a low-temperature reaction vessel, in which, by introducing the heat transfer medium circulated in the circulation route, the temperature of the heat transfer medium being controlled, a reaction liquid in the low-temperature reaction vessel is cooled and adjusted to the intended temperature.

(6) A heat transfer medium-cooling device, comprising

a first heat exchanger, in which a mixed gas mixing a vaporization gas of a low-temperature-liquefied gas with a gas of a temperature higher than the low-temperature-liquefied gas and the low-temperature-liquefied gas are subjected to heat -exchanging with each other, and the mixed gas is discharged as a low-temperature gas refrigerant and the low-temperature-liquefied gas is discharged as the vaporization gas;

a mixing unit, in which the gas and the vaporization gas discharged from the first heat exchanger are mixed and discharged as the mixed gas;

a first control unit, in which, based on the difference between a detected temperature of the low-temperature gas refrigerant and an intended temperature, an amount of the gas introduced to the mixing unit is adjusted to control a temperature

of the low-temperature gas refrigerant to the intended temperature.

a second heat exchanger, in which the low-temperature gas refrigerant discharged from the first heat exchanger, the temperature of the low-temperature gas refrigerant being controlled, and a heat transfer medium circulated in a circulation route are heat-exchanged with each other; and

a second control unit in which, based on the difference between a detected temperature of the heat transfer medium and an intended temperature of the heat transfer medium, an amount of the gas is adjusted to control a temperature of the heat transfer medium to the intended temperature of the heat transfer medium.

(7) A heat transfer medium-cooling device, comprising

a first heat exchanger, in which a low-temperature-liquefied gas and a gas of a temperature higher than the low-temperature-liquefied gas are subjected to heat-exchanging with each other, and a vaporization gas of the low-temperature-liquefied gas is discharged and the gas after heat-exchanging is discharged as a heat-exchanged gas;

a mixing unit, in which the heat-exchanged gas and the vaporization gas discharged from the first heat exchanger are mixed and discharged as a low-temperature gas refrigerant;

a first control unit, in which, based on the difference between a detected temperature of the low-temperature gas refrigerant and an intended temperature, an amount of the vaporization gas introduced to the mixing unit is adjusted to control the temperature of the low-temperature gas refrigerant to the intended temperature;

a second heat exchanger, in which the low-temperature gas refrigerant discharged from the first heat exchanger, the temperature of the low-temperature gas refrigerant being controlled, and a heat transfer medium circulated in a circulation route are heat-exchanged with each other; and

a second control unit in which, based on the difference between a detected temperature of the heat transfer medium and an intended temperature of the heat transfer medium, an amount of the gas is adjusted to control a temperature of the heat transfer medium to the intended temperature of the heat transfer medium.

(8) A low-temperature reaction control device, comprising

the heat transfer medium-cooling device of (6) or the heat transfer medium-cooling device of (7); and

a low-temperature reaction vessel, in which by introducing the heat transfer medium circulated in the circulation route, the temperature of the heat transfer medium being controlled, a reaction liquid in the low-temperature reaction vessel is cooled and adjusted to the intended temperature.

[Effects of the Invention]

[0013]

In the low-temperature gas supply device of the present invention, because, after reducing the difference of temperature between a low-temperature-liquefied gas and a gas of a temperature higher than the low-temperature-liquefied gas, they are mixed, uniform mixing is realized as well as avoiding the particularity of a mixing unit, thereby enlarging the range of choice.

Also, because two gases having similar temperatures are mixed, the temperature control of the low-temperature gas refrigerant is stable by adjusting the respective flows of the respective gases before mixing. In particular, because the control for a pulsatile change of flow is avoided, the pulsatile change of flow resulting from a pulsatile change of temperature due to poor mixing, the control is stable.

Also, if an intended temperature of the low-temperature gas refrigerant is changed, the changed value can be suitably followed. In addition, a cold energy of a low-temperature-liquefied gas can be efficiently used in order to produce low-temperature gas refrigerant.

[0014]

Also, when selecting an ejector as a mixing unit, mixing becomes easier, even if two gases of similar temperatures have different pressures. Moreover, the device can be downsized compared with using a general mixing apparatus.

[0015]

In the heat transfer medium-cooling device of the present invention, since a low-temperature gas refrigerant having a stable temperature is included in a second heat exchange, the temperature of a heat transfer medium circulated in a circulation route can be stably controlled with accuracy, and the intended temperature of the heat transfer medium can be set more suitably with the solidification point of the heat transfer medium in mind. That is, in the second heat exchanger, the intended temperature of the heat transfer medium can be set near to the solidification point without freezing the heat transfer medium. The setting can prevent the circulation

route from being blocked due to freezing and lower the loss of pressure in the route due to blocking, and thus excess heat is prevented from entering, thus saving power of the entire device.

[0016]

Because a low-temperature reaction device of the present invention can control a low temperature of a reaction vessel using the heat transfer medium which is stably and accurately controlled to a low temperature near the solidification point, stable control is possible within a broad temperature range.

[Brief Description of Drawings]

[0017]

Fig. 1 is a schematic diagram showing a low-temperature gas supply device, heat transfer medium-cooling device, and low-temperature reaction control device according to the first embodiment of the present invention.

Fig. 2 is a schematic diagram showing a low-temperature gas supply device, heat transfer medium-cooling device, and low-temperature reaction control device according to the second embodiment of the present invention.

Fig. 3 is a schematic diagram showing a low-temperature gas supply device, heat transfer medium-cooling device, and low-temperature reaction control device according to the third embodiment of the present invention.

Fig. 4 is a schematic diagram showing a low-temperature gas supply device, heat transfer medium-cooling device, and low-temperature reaction control device according to the fourth embodiment of the present invention.

[Description of Embodiments]

[0018]

The following provides an explanation of a low-temperature gas supply device, heat transfer medium-cooling device, and low-temperature reaction control device according to embodiments of the present invention using the drawings. In the following drawings used for the explanation, because there are cases in which characterized parts are enlarged for convenience so as to understand the characterization easily, a dimensional ratio of composition elements are not always correspond with the actual ratio.

[0019]

<First Embodiment>

A low-temperature gas supply device 100A, heat transfer medium-cooling device 200A, and low-temperature reaction control device 300A according to the first embodiment of the present invention will be explained. Fig. 1 is a schematic diagram according to the first embodiment, in which a low-temperature gas supply device, a heat transfer medium-cooling device, and low-temperature reaction control of the present invention are used.

[0020]

As shown in Fig. 1, a low-temperature gas supply device 100A according to the first embodiment of the present invention includes a room temperature route 1A, from an one end of which a room temperature nitrogen gas (GN_2)NNG is introduced as a gas of higher temperature than a low-temperature-liquefied gas described below, a low-temperature route 2A, from an one end of which a liquefied nitrogen (LN_2)LN (for example, -196°C) is introduced as the low-temperature-liquefied gas, a mixing route 3A, in which a mixed gas and a low-temperature nitrogen gas refrigerant described below flows, an ejector (mixed device) 4A, in which the room temperature nitrogen gas NNG introduced from the another end of the room temperature route 1A and a gas (referred to as “liquefied nitrogen vaporization gas” hereinafter) LNG resulting from a vaporization of the liquefied nitrogen LN are mixed to produce a mixed gas CG, a first heat exchanger 5A, through which the low-temperature route 2A penetrates to introduce the liquefied nitrogen LN and to discharge LN as the liquefied nitrogen vaporization gas LNG, and through which the mixing route 3A penetrates to introduce the mixed gas CG and to discharge CG as a low-temperature nitrogen gas refrigerant CNG, a first temperature detector 6A which detects a temperature of the low-temperature nitrogen gas refrigerant CNG flowing at the downstream of the mixing route 3A below the first heat exchanger 5A, a first temperature adjusting device (first control unit) 7A which outputs a first control signal CS1 based on the temperature detected by the first temperature detector 6A, a flow adjusting valve 8A which adjusts a flow of the room temperature nitrogen gas NNG flowing in the room temperature route 1A based on the first control signal CS1, and a first flow adjusting valve 9A which adjusts a flow of the liquefied nitrogen vaporization gas LNG flowing at the downstream of the low-temperature route 2A below the first heat exchanger 5A, based on the first control signal CS1.

[0021]

In the first heat exchanger 5A, the low-temperature route 2A and the mixing route 3A run parallel to each other and are constructed so that the liquefied nitrogen LN and the mixed gas CG flowing through the respective routes are heat-exchanged with each other. In particular, the low-temperature route 2A and the mixing route 3A are disposed so that the liquefied nitrogen LN and the mixed gas CG flow in the opposite direction to each other, i.e., so as to be an opposite flow.

[0022]

Also, a heat transfer medium-cooling device 200A according to the first embodiment includes, in addition to the low-temperature gas supply device 100A described above, a heat transfer medium circulation route 21, in which a heat transfer medium HM is circulated, a second heat exchanger 22, through which the mixing route 3A and the heat transfer medium circulation route 21 running parallel to each other penetrate and which is disposed so that the low-temperature nitrogen gas refrigerant CNG and a heat transfer medium HM flowing through the respective routes are heat-exchanged with each other, a heat transfer medium circulation pump 23 in order to circulate the heat transfer medium HM flowing through the heat transfer medium circulation route 21, a second temperature detector 24 which detects a temperature of the heat transfer medium HM circulated in the heat transfer medium circulation route 21, a second temperature adjusting device 25 which output a second control signal CS2 based on the temperature detected by the second temperature detector 24, a second flow adjusting valve 26 which adjusts a flow of the low-temperature nitrogen gas refrigerant CNG flowing through the mixing route 3A based on the second control signal CS2, and a reserve tank 27 in order to absorb an expansion or shrinkage associated with the temperature change of the heat transfer medium.

[0023]

Also, a low-temperature reaction control device 300A according to the first embodiment of the present invention includes, in addition to the heat transfer medium-cooling device 200A described above, a low-temperature reaction vessel 31. The low-temperature reaction vessel 31 is provided with a jacket 31a which can circulate the heat transfer medium HM, and a stir motor 31b in order to stir a reaction liquid.

[0024]

Next, actions of the low-temperature gas supply device 100A, the heat transfer medium-cooling device 200A, and the low-temperature reaction control device 300A, and functions thereof according to the first embodiment will be explained.

[0025]

The liquefied nitrogen (LN_2) LN is introduced from one end of the low-temperature route 2A to the first heat exchanger 5A. The liquefied nitrogen LN becomes the liquefied nitrogen vaporization gas LNG by heat-exchange with the mixed gas CG flowing through the mixing route 3A in the first heat exchanger 5A. The liquefied nitrogen vaporization gas LNG discharged from the first heat exchanger 5A and the room temperature nitrogen gas NNG introduced from one end of the room temperature route 1A are introduced to the ejector 4A and mixed due to their pressure differences. The mixed gas CG discharged from the ejector 4A is introduced to the first heat exchanger 5A, is heat-exchanged with the liquefied nitrogen LN flowing through the low-temperature route 2A, the temperature of the mixed gas CG being averaged due to an effect of a disturbed flow at the same time, and is discharged as the low-temperature nitrogen gas refrigerant CNG.

[0026]

The first temperature detector 6A detects a temperature of the low-temperature nitrogen gas refrigerant CNG flowing at the downstream of the mixing route 3A below the first heat exchanger 5A. The first temperature adjusting device 7A outputs the first control signal CS1 according to the difference between the temperature detected by the first temperature detector 6A and the designed temperature (intended temperature) of the low-temperature nitrogen gas refrigerant CNG. The flow adjusting valve 8A adjusts the flow of the room temperature nitrogen gas NNG flowing through the room temperature route 1A based on the first control signal CS1. The flow adjusting valve 9A adjusts the flow of the liquefied nitrogen vaporization gas LNG flowing at the downstream of the low-temperature route 2A below the first heat exchanger 5A, based on the first control signal CS1. By a feedback control composed of the first temperature detector 6A, the first temperature adjusting device 7A, the flow adjusting valve 8A, and the first flow adjusting valve 9A, the low-temperature nitrogen gas refrigerant CNG is adjusted to be a designed

temperature.

[0027]

Although the flow of the liquefied nitrogen vaporization gas LNG introduced to the ejector 4A may be adjusted at the first side of the first heat exchanger 5A, when there is a construction so as to adjust the flow at the second side of the first heat exchanger 5A in the above manner, i.e., the flow of the liquefied nitrogen vaporization gas LNG, i.e., the flow of the vaporization gas of a single phase, it is possible to adjust the flow more precisely, compared with the manner in which the flow is adjusted at the first side of the first heat exchanger 5A, i.e., the flow of the heat exchanger LN with a phase-change is adjusted.

[0028]

As above, the low-temperature nitrogen gas refrigerant CNG adjusted to be the designed temperature is supplied to the second heat exchanger 22 and cools the heat transfer medium HM flowing through the heat transfer medium circulation route 21 by heat-exchange. The second temperature detector 24 detects the temperature of the heat transfer medium HM circulated in the heat transfer medium circulation route 21. The second temperature adjusting device 25 outputs the second control signal CS2 according to the difference between the temperature detected by the second temperature detector 24 and the designed temperature (the intended temperature) of the heat transfer medium HM. The second flow adjusting valve 26 adjusts the flow of the low-temperature nitrogen gas refrigerant CNG flowing through the mixing route 3A based on the second control signal CS2. By a feed back control constructed of the second temperature detector 24, the second temperature adjusting device 25, and the second flow adjusting valve 26, the heat transfer medium HM is adjusted to be the desired temperature.

[0029]

The heat transfer medium HM which is adjusted to be the desired temperature as described above is supplied to a jacket 31a of the low-temperature reaction vessel 31 by action of the heat transfer medium circulation pump 23. The reaction liquid inside the reaction vessel is cooled and adjusted to be the constant temperature.

[0030]

As above, according the first embodiment, because the liquefied nitrogen LN is translated to the liquefied nitrogen vaporization gas LNG of the similar temperature

with the room temperature nitrogen gas NNG by using the first heat exchanger 5A and they are mixed, the uniform mixture can be realized. Because the ejector 4A is adopted for mixing, even if their pressures are different from each other, mixing can be realized easily and the device can be downsized compared with when the general mixer is used.

[0031]

Also, because the liquefied nitrogen LN is translated to the liquefied nitrogen vaporization gas LNG of the similar temperature with the room temperature nitrogen gas NNG by using the first heat exchanger 5A and they are mixed, a temperature control of the low-temperature nitrogen gas refrigerant CNG due to the flow control of the room temperature nitrogen gas NNG and the liquefied nitrogen vaporization gas LNG is stable. In particular, because the control of a pulsatile change of the flow is avoided, the pulsatile change of the flow resulting from a pulsatile change of temperature due to poor mixing, the control is stable. Also, if the intended temperature of the low-temperature nitrogen gas refrigerant CNG is changed, the changed value can be suitably followed. On the other side, the cold energy of the liquefied nitrogen LN is efficiently used in order to produce the low-temperature nitrogen gas refrigerant CNG.

[0032]

Moreover, because, by controlling a flow of the low-temperature nitrogen gas refrigerant CNG of a stable temperature, the temperature of the heat transfer medium HM circulated in the heat transfer medium circulation route 21 is stably controlled with accuracy, the intended temperature of the heat transfer medium HM can be set more suitably with the solidification point of the heat transfer medium in mind. That is, in the second heat exchanger 22, the intended temperature of the heat transfer medium HM can be set near to the solidification point without freezing the heat transfer medium HM. The setting can prevent the heat transfer medium circulation route 21 from being blocked due to freezing and lower the loss of pressure in the route due to blocking, and thus excess heat is prevented from entering, thus saving power of the entire device.

[0033]

Also, when the heat transfer medium HM, which is stably and accurately controlled to a low temperature near the solidification point, is used in the

low-temperature reaction vessel 31, the reaction vessel can be more stably controlled at a low temperature and stable control is possible within a broad temperature range.

[0034]

<Second Embodiment>

Next, the second embodiment according to the present invention will be explained. Fig. 2 shows a schematic diagram according to the second embodiment including the low-temperature gas supply device, the heat transfer medium-cooling device, the low-temperature reaction control device of the present invention.

[0035]

As shown in Fig. 2, a low-temperature gas supply device 100B according to the second embodiment of the present invention includes a room temperature route 1B, from an one end of which a room temperature nitrogen gas (GN_2)NNG is introduced, a low-temperature route 2B, from an one end of which a liquefied nitrogen (LN_2)LN (for example, -196°C) is introduced, a mixing route 3B, in which a low-temperature nitrogen gas refrigerant described below flows, a first heat exchanger 5B, in which the room temperature nitrogen gas NNG introduced from the room temperature route 1B and the liquefied nitrogen LN introduced from the low-temperature route 2B are heat-exchanged with each other to discharge each gas as an heat-exchanged nitrogen gas CNNG and a gas (referred to as “liquefied nitrogen vaporization gas” hereinafter) LNG resulting from a vaporization of the liquefied nitrogen LN, an ejector 4B, in which the heat-exchanged nitrogen gas CNNG and the liquefied nitrogen vaporization gas LNG discharged from the first heat exchanger 5B are mixed to produce a low-temperature nitrogen gas refrigerant CNG, a first temperature detector 6B which detects a temperature of the low-temperature nitrogen gas refrigerant CNG flowing in the mixing route 3B, an first temperature adjusting device 7B which outputs an first control signal CS1 based on the temperature detected by the first temperature detector 6B, a flow adjusting valve 8B which adjusts a flow of the room temperature nitrogen gas NNG flowing through the room temperature route 1B based on the first control signal CS1, and a first flow adjusting valve 9B which adjusts a flow of the liquefied nitrogen vaporization gas LNG flowing at a downstream of the low-temperature route 2B below the first heat exchanger 5B, based on the first control signal CS1.

[0036]

In the first heat exchanger 5B, the room temperature route 1B and the

low-temperature route 2B run parallel to each other and are constructed so that the room temperature nitrogen gas NNG and the liquefied nitrogen LN are heat-exchanged with each other. In particular, the room temperature route 1B and the low-temperature route 2B are disposed so that the room temperature nitrogen gas NNG and the liquefied nitrogen LN flow in the same direction.

[0037]

Also, a heat transfer medium-cooling device 200B according to the second embodiment is the same as the heat transfer medium-cooling device 200A according to the first embodiment except that the low-temperature gas supply device 100B having a construction as above is included.

[0038]

Moreover, the low-temperature reaction control device 300B according to the second embodiment is the same as the low-temperature reaction control device 300A according to the first embodiment except that the heat transfer medium-cooling device 200B having a construction as above is included.

[0039]

Next, actions and functions thereof in the low-temperature gas supply device 100B, the heat transfer medium-cooling device 200B, and the low-temperature reaction control device 300B constructed as above will be explained.

[0040]

The room temperature nitrogen gas NNG is introduced into one end of the room temperature route 1B and is introduced into the first heat exchanger 5B. The liquefied nitrogen (LN_2) LN is introduced to one end of the low-temperature route 2B and is introduced to the first heat exchanger 5B. By heat-exchanging the room temperature nitrogen gas NNG introduced from the room temperature route 1B and the liquefied nitrogen LN introduced from the low-temperature route 2B with each other, the first heat exchanger 5B discharges the gases as a heat-exchanged nitrogen gas CNNG and a gas (referred to as “liquefied nitrogen vaporization gas” hereinafter) LNG resulting from a vaporization of the liquefied nitrogen LN. The ejector 4B mixes the heat-exchanged nitrogen gas CNNG and the liquefied nitrogen vaporization gas LNG discharged from the first heat exchanger 5B using the difference of the pressures thereof and produces the low-temperature nitrogen gas refrigerant CNG.

[0041]

The first temperature detector 6B detects a temperature of the low-temperature nitrogen gas refrigerant CNG flowing through the mixing route 3B. The first temperature adjusting device 7B outputs the first control signal CS1 according to the difference between the temperature detected by the first temperature detector 6B and the designed temperature (intended temperature) of the low-temperature nitrogen gas refrigerant CNG. The flow adjusting valve 8B adjusts a flow of the room temperature nitrogen gas NNG flowing at an upper stream of the room temperature route 1B above the first heat exchanger 5B, based on the first control signal CS1. The first flow adjusting valve 9B adjusts a flow of the liquefied nitrogen vaporization gas LNG flowing at a downstream of the low-temperature route 2B below the first heat exchanger 5B, based on the first control signal CS1. By a feed back control constructed of the first temperature detector 6B, the first temperature adjusting device 7B, the flow adjusting valve 8B, and the first flow adjusting valve 9B, the low-temperature nitrogen gas refrigerant CNG is adjusted to be the desired temperature.

[0042]

Although the flow of the vaporization gas introduced to the ejector 4B may be adjusted at the first side of the first heat exchanger 5B, in the above manner, when there is a construction so as to adjust the flow at the second side of the first heat exchanger 5B, i.e., the flow of the liquefied nitrogen vaporization gas LNG, i.e., the flow of the vaporization gas of a single phase, it is possible to adjust the flow more precisely, compared with the manner in which the flow is adjusted at the first side of the first heat exchanger 5B, i.e., the flow of the heat exchanger LN with a phase-change is adjusted.

[0043]

As above, the low-temperature nitrogen gas refrigerant CNG adjusted to be the designed temperature is supplied to the second heat exchanger 22 and cools the heat transfer medium HM flowing through the heat transfer medium circulation route 21 by heat-exchange. The second temperature detector 24 detects a temperature of the heat transfer medium HM circulated in the heat transfer medium circulation route 21. The second temperature adjusting device 25 outputs the second control signal CS2 according to the difference between the temperature detected by the second temperature detector 24 and the designed temperature of the heat transfer medium HM.

The second flow adjusting valve 26 adjusts a flow of the low-temperature nitrogen gas refrigerant CNG flowing through the mixing route 3B, based on the second control signal CS2. In this manner, by a feed back control constructed of the second temperature detector 24, the second temperature adjusting device 25, and the second flow adjusting valve 26, the heat transfer medium HM is adjusted to be the desired temperature.

[0044]

The heat transfer medium HM which is adjusted to be the desired temperature as described above is supplied to a jacket 31a of the low-temperature reaction vessel 31 by action of the heat transfer medium circulation pump 23. By this supply, the reaction liquid inside the reaction vessel is cooled and adjusted to be the constant temperature.

[0045]

As above, in the second embodiment of the present invention, because they are mixed, the uniform mixture can be realized. Because the ejector 4B is adopted for mixing, even if their pressures are different from each other, mixing can be realized easily and the device can be downsized compared with when the general mixer is used.

[0046]

Also, because the room temperature nitrogen gas NNG and the liquefied nitrogen LN are translated to the heat-exchanged nitrogen gas CNNG and the liquefied nitrogen vaporization gas LNG, in which the difference of the temperatures thereof is reduced by using the first heat exchanger 5B, and they are mixed, a temperature control of the low-temperature nitrogen gas refrigerant CNG due to the flow controls of the room temperature nitrogen gas NNG and the liquefied nitrogen vaporization gas LNG is stable. In particular, because the control of a pulsatile change of the flow is avoided, the pulsatile change of the flow resulting from a pulsatile change of temperature due to poor mixing, the control is stable. In addition, if the intended temperature of the low-temperature nitrogen gas refrigerant CNG is changed, the changed value can be suitably followed. On the other side, the cold energy of the liquefied nitrogen LN is used efficiently in order to produce the low-temperature nitrogen gas refrigerant CNG.

[0047]

Moreover, because, by controlling a flow of the low-temperature nitrogen gas refrigerant CNG of a stable temperature, the temperature of the heat transfer medium HM circulated in the heat transfer medium circulation route 21 is stably controlled with accuracy, the intended temperature of the heat transfer medium HM can be set more suitably with the solidification point in mind. That is, in the second heat exchanger 22, the intended temperature of the heat transfer medium HM can be set near to the solidification point without freezing the heat transfer medium HM. The setting can prevent the heat transfer medium circulation route 21 from being blocked due to freezing and lower the loss of pressure in the route due to blocking, and thus excess heat is prevented from entering, thus saving power of the entire device.

[0048]

Also, when the heat transfer medium HM, which is stably and accurately controlled to a low temperature near the solidification point, is used in the low-temperature reaction vessel 31, the reaction vessel can be more stably controlled at a low temperature and stable control is possible within a broad temperature range.

[0049]

<Third Embodiment>

Next, the third embodiment according to the present invention will be explained. Fig. 3 shows a schematic diagram according to the third embodiment including the low-temperature gas supply device, the heat transfer medium-cooling device, and the low-temperature reaction control device of the present invention.

[0050]

As shown in Fig. 3, a low-temperature gas supply device 100C according to the third embodiment of the present invention includes a room temperature route 1C, from an one end of which a room temperature nitrogen gas (GN₂)NNG is introduced as a gas of higher temperature than a low-temperature-liquefied gas described below, a low-temperature route 2C, from one end of which a liquefied nitrogen (LN₂)LN (for example, -196°C) is introduced as the low-temperature-liquefied gas, a mixing route 3C, in which a mixed gas and a low-temperature nitrogen gas refrigerant described below flows, an ejector (mixed device) 4C, in which the room temperature nitrogen gas NNG introduced from the another end of the room temperature route 1C and a gas (referred to as “liquefied nitrogen vaporization gas” hereinafter) LNG resulting from a vaporization of the liquefied nitrogen LN are mixed to produce the mixed gas CG, a

first heat exchanger 5C, through which the low-temperature route 2C penetrates to introduce the liquefied nitrogen LN and to discharge LN as the liquefied nitrogen vaporization gas LNG, and through which the mixing route 3C penetrates to introduce the mixed gas CG and to discharge CG as a low-temperature nitrogen gas refrigerant CNG, a first temperature detector 6C which detects a temperature of the low-temperature nitrogen gas refrigerant CNG flowing at the downstream of the mixing route 3C below the first heat exchanger 5C, a first temperature adjusting device (first control unit) 7C which outputs a first control signal CS1 based on the temperature detected by the first temperature detector 6C, a flow adjusting valve 8C which adjusts a flow of the room temperature nitrogen gas NNG flowing through the room temperature route 1C based on the second control signal CS2 output from a second temperature adjusting device 25 described below, and the first flow adjusting valve 9C which adjusts a flow of the liquefied nitrogen vaporization gas LNG flowing at the downstream of the low-temperature route 2C below the first heat exchanger 5C, based on the first control signal CS1.

[0051]

In the first heat exchanger 5C, the low-temperature route 2C and the mixing route 3C run parallel to each other and are constructed so that the liquefied nitrogen LN and the mixed gas CG which flow through the respective routes are heat-exchanged with each other. In particular, the low-temperature route 2C and the mixing route 3C are disposed so that the liquefied nitrogen LN and the mixed gas CG flow in the opposite direction to each other, i.e., so as to be an opposite flow..

[0052]

Also, a heat transfer medium-cooling device 200C according to the third embodiment includes, in addition to the low-temperature gas supply device 100C described above, a heat transfer medium circulation route 21, in which a heat transfer medium HM is circulated, a second heat exchanger 22, through which the mixing route 3C and the heat transfer medium circulation route 21 running parallel to each other penetrate and which is disposed so that the low-temperature nitrogen gas refrigerant CNG and a heat transfer medium HM flowing through the respective routes are heat-exchanged with each other, a heat transfer medium circulation pump 23 in order to circulate the heat transfer medium HM in the heat transfer medium circulation route 21, a second temperature detector 24 which detects a temperature

of the heat transfer medium HM circulated in the heat transfer medium circulation route 21, a second temperature adjusting device 25 which output a second control signal CS2 based on the temperature detected by the second temperature detector 24, and a reserve tank 27 in order to absorb an expansion or shrinkage associated with the temperature change of the heat transfer medium.

[0053]

Also, a low-temperature reaction control device 300C according to the third embodiment is the same as the low-temperature reaction control device 300A and 300B according to the first and second embodiments, except that the heat transfer medium-cooling device 200C constructed as above is included.

[0054]

Next, actions and functions thereof in the low-temperature gas supply device 100C, the heat transfer medium-cooling device 200C, and the low-temperature reaction control device 300C according to the third embodiment are explained.

[0055]

The liquefied nitrogen (LN_2) LN is introduced from one end of the low-temperature route 2C and to the first heat exchanger 5C. The liquefied nitrogen LN becomes the liquefied nitrogen vaporization gas LNG by heat-exchange with the mixed gas CG flowing through the mixing route 3C in the first heat exchanger 5C. The liquefied nitrogen vaporization gas LNG discharged from the first heat exchanger 5C and the room temperature nitrogen gas NNG introduced from one end of the room temperature route 1C are introduced to the ejector 4C and mixed using the difference of pressures thereof. The mixed gas CG discharged from the ejector 4C is introduced to the first heat exchanger 5C, is heat-exchanged with the liquefied nitrogen LN flowing through the low-temperature route 2C, the temperature of CG being averaged due to an effect of a disturbed flow at the same time, and is discharged as the low-temperature nitrogen gas refrigerant CNG.

[0056]

The first temperature detector 6C detects a temperature of the low-temperature nitrogen gas refrigerant CNG flowing at the downstream of the mixing route 3C below the first heat exchanger 5C. The first temperature adjusting device 7C outputs a first control signal CS1 according to the difference between the temperature detected by the first temperature detector 6C and the designed

temperature (intended temperature) of the low-temperature nitrogen gas refrigerant CNG. The flow adjusting valve 8C adjusts a flow of the room temperature nitrogen gas NNG flowing through the room temperature route 1C based on the second control signal CS2 output from the second temperature adjusting device 25. The flow adjusting valve 9C adjusts a flow of the liquefied nitrogen vaporization gas LNG flowing at the downstream of the low-temperature route 2C below the first heat exchanger 5C, based on the first control signal CS1.

[0057]

Although the flow of the liquefied nitrogen vaporization gas LNG introduced to the ejector 4C may be adjusted at the first side of the first heat exchanger 5C, when there is a construction so as to adjust the flow at the second side of the first heat exchanger 5C in the above manner, i.e., the flow of the liquefied nitrogen vaporization gas LNG, i.e., the flow of the vaporization gas of a single phase, it is possible to adjust the flow more precisely, compared with the manner in which the flow is adjusted at the first side of the first heat exchanger 5C, i.e., the flow of the heat exchanger LN with a phase-change is adjusted.

[0058]

The low-temperature nitrogen gas refrigerant CNG discharged from the heat exchanger 5C is supplied to the second heat exchanger 22 and cools the heat transfer medium HM flowing through the heat transfer medium circulation route 21 by heat-exchange. The second temperature detector 24 detects the temperature of the heat transfer medium HM circulated in the heat transfer medium circulation route 21. The second temperature adjusting device 25 outputs the second control signal CS2 according to the difference between the temperature detected by the second temperature detector 24 and the designed temperature (the intended temperature) of the heat transfer medium HM.

[0059]

As above, by a feed back control constructed of the first temperature detector 6C, the first temperature adjusting device 7C, the flow adjusting valve 8C, the first flow adjusting valve 9C, the second temperature detector 24, and the second temperature adjusting device 25, the heat transfer medium HM is adjusted to be the desired temperature.

[0060]

The heat transfer medium HM adjusted to be the desired temperature is supplied to a jacket 31a of the low-temperature reaction vessel 31 by action of the heat transfer medium circulation pump 23. By supplying the HM, the reaction liquid inside the reaction vessel is cooled and adjusted to be the constant temperature.

[0061]

As above, in the third embodiment of the present invention, because the liquefied nitrogen LN is translated to the liquefied nitrogen vaporization gas LNG of the similar temperature with the room temperature nitrogen gas NNG by using the first heat exchanger 5C and they are mixed, the uniform mixture can be realized. Because the ejector 4A is adopted for mixing, even if their pressures are different from each other, mixing can be realized easily and the device can be downsized compared with when the general mixer is used.

[0062]

Also, because the liquefied nitrogen LN is translated to the liquefied nitrogen vaporization gas LNG of the similar temperature with the room temperature nitrogen gas NNG by using the first heat exchanger 5C and they are mixed, a temperature control of the low-temperature nitrogen gas refrigerant CNG due to the flow control of the room temperature nitrogen gas NNG and the liquefied nitrogen vaporization gas LNG is stable. In particular, because the control of a pulsatile change of the flow is avoided, the pulsatile change of the flow resulting from a pulsatile change of temperature due to poor mixing, the control is stable. Also, if the intended temperature of the low-temperature nitrogen gas refrigerant CNG is changed, the changed value can be suitably followed. On the other side, the cold energy of the liquefied nitrogen LN is used efficiently in order to produce the low-temperature nitrogen gas refrigerant CNG.

[0063]

Moreover, because, by introducing a flow of the low-temperature nitrogen gas refrigerant CNG of a stable temperature to the second heat exchanger 22, the temperature of the heat transfer medium HM circulated in the heat transfer medium circulation route 21 is stably controlled with accuracy, the intended temperature of the heat transfer medium HM can be set more suitably with the solidification point in mind. That is, in the second heat exchanger 22, the intended temperature of the heat transfer medium HM can be set near to the solidification point without freezing the

heat transfer medium HM. The setting can prevent the heat transfer medium circulation route 21 from being blocked due to freezing and lower the loss of pressure in the route due to blocking, and thus excess heat is prevented from entering, thus saving power of the entire device.

[0064]

Also, when the heat transfer medium HM, which is stably and accurately controlled to a low temperature near the solidification point, is used in the low-temperature reaction vessel 31, the reaction vessel can be more stably controlled at a low temperature and stable control is possible within a broad temperature range.

[0065]

The first low-temperature gas supply device 100A, the heat transfer medium-cooling device 200A, and the low-temperature reaction control device 300A according to the first embodiment as above, have a construction in which flows of the room temperature nitrogen gas NNG introduced to the room temperature route 1A and the liquefied nitrogen vaporization gas LNG introduced to the low-temperature route 2A are adjusted based on the temperature of the low-temperature nitrogen gas refrigerant CNG detected by the temperature detector 6A, i.e., the temperature of the low-temperature nitrogen gas refrigerant CNG flowing at the downstream of the mixing route 3A below the first heat exchanger 5A. The construction has advantages that, after the temperature of the low-temperature nitrogen gas refrigerant CNG detected by the temperature detector 6A reaching within the designed range, the flow of the low-temperature nitrogen gas refrigerant CNG discharged from the heat exchanger 5A is stable, not is variable.

[0066]

On the other hand, in the low-temperature reaction control device 300A, when the necessary cold energy for the heat transfer medium HM increases with increasing a load on the low-temperature reaction vessel 31, there may be case where the flow of the low-temperature nitrogen gas refrigerant CNG needs to be increased in order to heat-exchanging with the heat transfer medium HM. In the low-temperature gas supply device 100A, the heat transfer medium-cooling device 200A, and the low-temperature reaction control device 300A according to the first embodiment, when the open level of the flow adjusting valve 26 is maximum, the flow of the low-temperature nitrogen gas refrigerant CNG becomes maximum.

[0067]

In contrast, the low-temperature gas supply device 100C, the heat transfer medium-cooling device 200C, and the low-temperature reaction control device 300C according to the third embodiment, have a construction which adjusts a flow of the room temperature nitrogen gas NNG as a based flow for increasing or decreasing the flow of the low-temperature nitrogen gas refrigerant CNG based on the temperature of the heat transfer medium HM detected by the temperature detector 24, i.e., the temperature of the heat transfer medium HM flowing at the downstream of heat transfer medium circulation route 21 below the second heat exchanger 22. By the construction, when the necessary cold energy for the heat transfer medium HM increases with increasing a load on the low-temperature reaction vessel 31 and the flow of the low-temperature nitrogen gas refrigerant CNG needs to be increased in order to heat-exchanging with the heat transfer medium HM, the flow of the low-temperature nitrogen gas refrigerant CNG discharged from the first heat exchanger 5C can increase or decrease so as to be the designed value according to the temperature of the heat transfer medium HM. Therefore, in order to obtain a necessary cold energy for cooling the heat transfer medium HM, both of the temperature and flow in the low-temperature nitrogen gas refrigerant CNG are adjusted to realize more stable temperature control of the heat transfer medium HM.

[0068]

In addition, because the flow adjusting valve 26 used in the first embodiment can be omitted, the device can be downsizing and be low in cost.

[0069]

<Fourth embodiment>

Next, the fourth embodiment of the present invention will be explained. Fig. 4 shows a schematic diagram according to the fourth embodiment including the low-temperature gas supply device, the heat transfer medium-cooling device, and the low-temperature reaction control device of the present invention.

[0070]

As shown in Fig. 4, a low-temperature gas supply device 100D according to the fourth embodiment of the present invention includes a room temperature route 1D, from an one end of which a room temperature nitrogen gas (GN_2)NNG is introduced, a low-temperature route 2D, from an one end of which a liquefied

nitrogen (LN_2)LN (for example, -196°C) is introduced, a mixing route 3D, in which a low-temperature nitrogen gas refrigerant described below flows, a first heat exchanger 5D, in which the room temperature nitrogen gas NNG introduced from the room temperature route 1D and the liquefied nitrogen LN introduced from the low-temperature route 2D are heat-exchanged with each other to discharge each gas as an heat-exchanged nitrogen gas CNNG and a gas (referred to as “liquefied nitrogen vaporization gas” hereinafter) LNG resulting from a vaporization of the liquefied nitrogen LN, an ejector 4D, in which the heat-exchanged nitrogen gas CNNG and the liquefied nitrogen vaporization gas LNG discharged from the first heat exchanger 5D are mixed to produce a low-temperature nitrogen gas refrigerant CNG, an first temperature detector 6D which detects a temperature of the low-temperature nitrogen gas refrigerant CNG flowing through the mixing route 3D, an first temperature adjusting device 7D which outputs an first control signal CS1 based on the temperature detected by the first temperature detector 6D, a flow adjusting valve 8D which adjusts a flow of the room temperature nitrogen gas NNG flowing through the room temperature route 1D based on the second control signal CS2 described as below, and a first flow adjusting valve 9D which adjusts a flow of the liquefied nitrogen vaporization gas LNG flowing at a downstream of the low-temperature route 2D below the first heat exchanger 5D, based on the first control signal CS1.

[0071]

In the first heat exchanger 5B, the room temperature route 1D and the low-temperature route 2D run parallel to each other and are constructed so that the room temperature nitrogen gas NNG and the liquefied nitrogen LN are heat-exchanged with each other. In particular, the room temperature route 1D and the low-temperature route 2D are disposed so that the room temperature nitrogen gas NNG and the liquefied nitrogen LN flow in the same direction.

[0072]

Also, a heat transfer medium-cooling device 200D according to the fourth embodiment includes, in addition to the low-temperature gas supply device 100D as above, a heat transfer medium circulation route 21, in which a heat transfer medium HM is circulated, a second heat exchanger 22, through which the mixing route 3D and the heat transfer medium circulation route 21 running parallel to each other

penetrate and which is disposed so that the low-temperature nitrogen gas refrigerant CNG and a heat transfer medium HM flowing through the respective routes are heat-exchanged with each other, a heat transfer medium circulation pump 23 in order to circulate the heat transfer medium HM circulated in the heat transfer medium circulation route 21, a second temperature detector 24 which detects a temperature of the heat transfer medium HM circulated in the heat transfer medium circulation route 21, a second temperature adjusting device 25 which output a second control signal CS2 based on the temperature detected by the second temperature detector 24, and a reserve tank 27 in order to absorb an expansion or shrinkage associated with the temperature change of the heat transfer medium.

[0073]

Also, a low-temperature reaction control device 300D according to the fourth embodiment is the same as the low-temperature reaction control devices 300A, 300B, and 300C according to the first, second, and third embodiments, except that the heat transfer medium-cooling device 200D constructed as above is included.

[0074]

Next, actions and functions thereof in the low-temperature gas supply device 100D, the heat transfer medium-cooling device 200D, and the low-temperature reaction control device 300D according to the fourth embodiment will be explained.

[0075]

The room temperature nitrogen gas NNG is introduced from one end of the room temperature route 1D to the first heat exchanger 5D. The liquefied nitrogen (LN_2) LN is introduced from one end of the low-temperature route 2D to the first heat exchanger 5D. By heat-exchanging the room temperature nitrogen gas NNG introduced from the room temperature route 1D and the liquefied nitrogen LN introduced from the low-temperature route 2D with each other, the first heat exchanger 5D discharges the gases as a heat-exchanged nitrogen gas CNNG and a gas (referred to as “liquefied nitrogen vaporization gas” hereinafter) LNG resulting from a vaporization of the liquefied nitrogen LN, in which the difference of the temperatures thereof is reduced. The ejector 4D mixes the heat-exchanged nitrogen gas CNNG and the liquefied nitrogen vaporization gas LNG discharged from the first heat exchanger 5D using the difference of the pressures thereof and produces the low-temperature nitrogen gas refrigerant CNG.

[0076]

The first temperature detector 6D detects a temperature of the low-temperature nitrogen gas refrigerant CNG flowing through the mixing route 3D. The temperature adjusting device 7D outputs the first control signal CS1 according to the difference between the temperature detected by the first temperature detector 6D and the designed temperature (intended temperature) of the low-temperature nitrogen gas refrigerant CNG. The flow adjusting valve 8D adjusts a flow of the room temperature nitrogen gas NNG flowing at the upper stream of the room temperature route 1D above the first heat exchanger 5D based on the second control signal CS2 output from the second temperature adjusting device 25. The first flow adjusting valve 9D adjusts a flow of the liquefied nitrogen vaporization gas LNG flowing at the downstream of the low-temperature route 2D below the first heat exchanger 5D based on the first control signal CS1.

[0077]

Although the flow of the vaporization gas LNG introduced to the ejector 4D may be adjusted at the first side of the first heat exchanger 5D, when there is a construction so as to adjust the flow at the second side of the first heat exchanger 5D in the above manner, i.e., the flow of the liquefied nitrogen vaporization gas LNG, i.e., the flow of the vaporization gas of a single phase, it is possible to adjust the flow more precisely, compared with the manner in which the flow at the first side of the first heat exchanger 5D, i.e., the flow of the heat exchanger LN with a phase-change, is adjusted.

[0078]

The low-temperature nitrogen gas refrigerant CNG discharged from the ejector 4D is supplied to the second heat exchanger 22 and cools the heat transfer medium HM flowing in the heat transfer medium circulation route 21 by heat-exchange. The second temperature detector 24 detects a temperature of the heat transfer medium HM circulated in the heat transfer medium circulation route 21. The second temperature adjusting device 25 outputs the second control signal CS2 according to the difference between the temperature detected by the second temperature detector 24 and the designed temperature of the heat transfer medium HM.

[0079]

As above, by a feedback control composed of the first temperature detector 6D, the first temperature adjusting device 7D, the flow adjusting valve 8D, the first flow adjusting valve 9D, the second temperature detector 24, and the second temperature adjusting device 25, the low-temperature nitrogen gas refrigerant CNG and the heat transfer medium HM are adjusted to be a designed temperature.

[0080]

The heat transfer medium HM adjusted to be the desired temperature is supplied to a jacket 31a of the low-temperature reaction vessel 31 by action of the heat transfer medium circulation pump 23. By supplying HM, the reaction liquid inside the reaction vessel is cooled and adjusted to be the constant temperature.

[0081]

As above, in the fourth embodiment of the present invention, because they are mixed, the uniform mixture can be realized. Because the ejector 4D is adopted for mixing, even if their pressures are different from each other, mixing can be realized easily and the device can be downsized compared with when the general mixer is used.

[0082]

Also, because the room temperature nitrogen gas NNG and the liquefied nitrogen LN are translated to the heat-exchanged nitrogen gas CNNG and the liquefied nitrogen vaporization gas LNG, in which the difference of the temperatures thereof is reduced by using the first heat exchanger 5D, and they are mixed, a temperature control of the low-temperature nitrogen gas refrigerant CNG due to the flow controls of the room temperature nitrogen gas NNG and the liquefied nitrogen vaporization gas LNG is stable. In particular, because the control of a pulsatile change of the flow is avoided, the pulsatile change of the flow resulting from a pulsatile change of temperature due to poor mixing, the control is stable. In addition, if the intended temperature of the low-temperature nitrogen gas refrigerant CNG is changed, the changed value can be suitably followed. On the other side, the cold energy of the liquefied nitrogen LN is used efficiently in order to produce the low-temperature nitrogen gas refrigerant CNG.

[0083]

Moreover, because, by introducing the low-temperature nitrogen gas

refrigerant CNG to the second heat exchanger 22, the temperature of the heat transfer medium HM circulated in the heat transfer medium circulation route 21 is stably controlled with accuracy, the intended temperature of the heat transfer medium HM can be set more suitably with the solidification point in mind. That is, in the second heat exchanger 22, the intended temperature of the heat transfer medium HM can be set near to the solidification point without freezing the heat transfer medium HM. The setting can prevent the heat transfer medium circulation route 21 from being blocked due to freezing and lower the loss of pressure in the route due to blocking, and thus excess heat is prevented from entering, thus saving power of the entire device.

[0084]

Also, when the heat transfer medium HM, which is stably and accurately controlled to a low-temperature near the solidification point, is used in the low-temperature reaction vessel 31, the reaction vessel can be more stably controlled at a low temperature and stable control is possible within a broad temperature range.

[0085]

The low-temperature gas supply device 100B, the heat transfer medium-cooling device 200B, and the low-temperature reaction control device 300B according to the second embodiment as above, have a construction in which flows of the room temperature nitrogen gas NNG introduced to the room temperature route 1B and the liquefied nitrogen vaporization gas LNG introduced to the low-temperature route 2B are adjusted based on the temperature of the low-temperature nitrogen gas refrigerant CNG detected by the temperature detector 6B, i.e., the temperature of low-temperature nitrogen gas refrigerant CNG flowing at the downstream of the mixing route 3B below the ejector 4B. The construction has advantages that, after the temperature of the low-temperature nitrogen gas refrigerant CNG detected by the temperature detector 6B reaching within the designed range, the flow of the low-temperature nitrogen gas refrigerant CNG discharged from the ejector 4B is stable, not is variable.

[0086]

On the other hand, in the low-temperature reaction control device 300B, when the necessary cold energy for the heat transfer medium HM increases with increasing a load on the low-temperature reaction vessel 31, there may be case where the flow of

the low-temperature nitrogen gas refrigerant CNG needs to be increased in order to heat-exchanging with the heat transfer medium HM. In the low-temperature gas supply device 100B, the heat transfer medium-cooling device 200B, and the low-temperature reaction control device 300B according to the second embodiment, when the open level of the flow adjusting valve 26 is maximum, the flow of the low-temperature nitrogen gas refrigerant CNG becomes maximum.

[0087]

In contrast, the low-temperature gas supply device 100D, the heat transfer medium-cooling device 200D, and the low-temperature reaction control device 300D according to the fourth embodiment, have a construction which adjusts a flow of the room temperature nitrogen gas NNG as a based flow for increasing or decreasing the flow of the low-temperature nitrogen gas refrigerant CNG, based on the temperature of the heat transfer medium HM detected by the temperature detector 24, i.e., the temperature of the heat transfer medium HM flowing at the downstream of the heat transfer medium circulation route 21 below the second heat exchanger 22. By the construction, when the necessary cold energy for the heat transfer medium HM increases with increasing a load on the low-temperature reaction vessel 31 and the flow of the low-temperature nitrogen gas refrigerant CNG needs to be increased in order to heat-exchanging with the heat transfer medium HM, the flow of the low-temperature nitrogen gas refrigerant CNG discharged from the ejector 4D can increase or decrease so as to be the designed value according to the temperature of the heat transfer medium HM. Therefore, in order to obtain a necessary cold energy for cooling the heat transfer medium HM, both of the temperature and flow in the low-temperature nitrogen gas refrigerant CNG are adjusted to realize more stable temperature control of the heat transfer medium HM.

[0088]

In addition, because the flow adjusting valve 26 used in the second embodiment can be omitted, the device can be downsized and be low in cost.

[0089]

<Modified Examples of each embodiment>

The low-temperature gas supply devices 100A-100D as above according to the first to fourth embodiments can adopt the following device in addition to the heat transfer medium-cooling devices 200A to 200D.

[0090]

This is, they can adopt a cooling tank for cooling food or metal heat treatment and the subjected material is uniformly cooled without the need for stir fan by supplying a low-temperature gas preliminary adjusted in temperature. Also, a reaction vessel saving a reaction liquid includes a jacket around the reaction vessel or a heat exchanger disposed in the reaction vessel, they can adopt a low-temperature reaction control device which supplies the low-temperature gas to the jacket or the heat exchanger, and thus the reaction liquid can be cooled without freezing at a heat-transfer surface by supplying a preliminary adjusted low-temperature gas. Moreover, they can adopt a cold trap which cools, condenses, or solidifies vapor using a coiled tube or other heat exchangers, wherein the vapor is condensed or solidified in uniformly temperature with accuracy by passing the preliminary adjusted low-temperature gas through the inside of the heat exchanger.

[0091]

In the explanation of each embodiment of the present invention as above, as means for adjusting a flow of the room temperature nitrogen gas NNG and means for adjusting a flow of the liquefied nitrogen vaporization gas LNG, a flow adjusting valve is shown, but it is not limited to those and can adopt other means for adjusting as appropriate, for example, a massflow controller.

[0092]

Also, as the second heat exchanger 22, for example, a double-pipe heat exchanger, plate heat exchanger, plate fin type heat exchanger, shell & tube heat exchanger, and tank & coil heat exchanger can be adopted. In particular, a plate heat exchanger is desirable. It is because it is high efficient and contributes the device downsizing. In addition, as the first heat exchanger, a high efficient heat exchanger such as plate-type is desirable. It is because the temperature difference at the ends becomes small to make mixing easier and the device can be downsizing.

[0093]

Moreover, in each embodiment as above, although a room temperature nitrogen gas NNG and a liquefied nitrogen LN are adopted, they are not necessarily same kind and the different kinds of gases may be mixed. As the intended gas, in addition to nitrogen, fluorine-based refrigerants such as oxygen, argon, carbon dioxide gas, LNG, hydrofluorocarbons, and chlorofluorocarbons can be used. Also,

as long as a gas has a temperature higher than the low-temperature-liquefied gas, a gas can be mixed with the low-temperature-liquefied gas, the gas applying any temperature, not only room temperature.

[Industrial Applicability]

[0094]

A low-temperature gas supply device, heat transfer medium-cooling device, and low-temperature reaction control device can be used for temperature control in a chemical reaction such as organic synthesis or a crystallization reaction.

[Reference Signs List]

[0095]

100A, 100B, 100C, 100D ... low-temperature gas supply device

1A, 1B, 1C, 1D ... room temperature route

2A, 2B, 2C, 2D ... low-temperature route

3A, 3B, 3C, 3D ... mixing route

4A, 4B, 4C, 4D ... ejector (mixing unit)

5A, 5B, 5C, 5D ... first heat exchanger

6A, 6B, 6C, 6D ... first temperature detector

7A, 7B, 7C, 7D ... first temperature adjusting device (first control unit)

8A, 8B, 8C, 8D ... flow adjusting valve

9A, 9B, 9C, 9D ... first adjusting valve

200A, 200B, 200C, 200D ... heat transfer medium-cooling device

21 ... heat transfer medium circulation route

22 ... second heat exchanger

23 ... heat transfer medium circulation pump

24 ... second temperature detector

25 ... second temperature adjusting device

26 ... second adjusting valve

27 ... reserve tank

300A, 300B, 300C, 300D ... low-temperature reaction control device

31 ... low-temperature reaction vessel

31a ... jacket

31b ... stir motor

[Claims]

[Claim 1]

A low-temperature gas supply device, comprising:

a first heat exchanger, in which a mixed gas mixing a vaporization gas of a low-temperature-liquefied gas with a gas of a temperature higher than the low-temperature-liquefied gas and the low-temperature-liquefied gas are introduced and heat-exchanged with each other, and the mixed gas is discharged as a low-temperature gas refrigerant and the low-temperature-liquefied gas is discharged as the vaporization gas;

a mixing unit, in which the gas and the vaporization gas discharged from the first heat exchanger are mixed and discharged as the mixed gas; and

a first control unit, in which, based on the difference between a detected temperature of the low-temperature gas refrigerant and an intended temperature, respective amounts of the gas introduced to the mixing unit and the vaporization gas are adjusted to control the temperature of the low-temperature gas refrigerant to the intended temperature.

[Claim 2]

A low-temperature gas supply device, comprising:

a first heat exchanger, in which a low-temperature-liquefied gas and a gas of a temperature higher than the low-temperature-liquefied gas are introduced and heat-exchanged with each other and a vaporization gas of the low-temperature-liquefied gas is discharged and the gas after heat-exchanging is discharged as a heat-exchanged gas;

a mixing unit, in which the heat-exchanged gas and the vaporization gas discharged from the first heat exchanger are mixed and discharged as a low-temperature gas refrigerant; and

a first control unit, in which, based on the difference between a detected temperature of the low-temperature gas refrigerant and an intended temperature, respective amounts of the gas of a temperature higher than the low-temperature-liquefied gas, the gas being introduced to the first heat exchanger, and the vaporization gas introduced to the mixing unit are adjusted to control the temperature of the low-temperature gas refrigerant to the intended temperature.

[Claim 3]

The low-temperature gas supply device according to Claim 1 or 2, wherein the mixing unit is an ejector.

[Claim 4]

A heat transfer medium-cooling device, comprising:

the low-temperature gas supply device of Claim 1 or the low-temperature gas supply device of Claim 2;

a second heat exchanger, in which the low-temperature gas refrigerant discharged from the low-temperature gas supply device, the temperature of the low-temperature gas refrigerant being controlled, and a heat transfer medium circulated in a circulation route are heat-exchanged with each other; and

a second control unit, in which, based on the difference between a detected temperature of the heat transfer medium and an intended temperature for the heat transfer medium, an amount of the low-temperature gas refrigerant introduced to the second heat exchanger is adjusted to control a temperature of the heat transfer medium to the intended temperature for the heat transfer medium.

[Claim 5]

The low-temperature reaction control device, comprising:

the heat transfer medium-cooling device of Claim 4; and

a low-temperature reaction vessel, in which the heat transfer medium circulated in the circulation route is introduced, the temperature of the heat transfer medium being controlled, a reaction liquid in the low-temperature reaction vessel is cooled and adjusted to the intended temperature.

[Claim 6]

A heat transfer medium-cooling device, comprising:

a first heat exchanger, in which a mixed gas mixing a vaporization gas of a low-temperature-liquefied gas with a gas of a temperature higher than the low-temperature-liquefied gas and the low-temperature-liquefied gas are introduced and heat-exchanged with each other, and the mixed gas is discharged as a low-temperature gas refrigerant and the low-temperature-liquefied gas is discharged as the vaporization gas;

a mixing unit, in which the gas and the vaporization gas discharged from the first heat exchanger are mixed and discharged as the mixed gas;

a first control unit, in which, based on the difference between a detected

temperature of the low-temperature gas refrigerant and an intended temperature, an amount of the gas introduced to the mixing unit is adjusted to control a temperature of the low-temperature gas refrigerant to the intended temperature;

a second heat exchanger, in which the low-temperature gas refrigerant discharged from the first heat exchanger, the temperature of the low-temperature gas refrigerant being controlled, and a heat transfer medium circulated in a circulation route are heat-exchanged with each other; and

a second control unit, in which, based on the difference between a detected temperature of the heat transfer medium and an intended temperature for the heat transfer medium, an amount of the gas is adjusted to control a temperature of the heat transfer medium to the intended temperature for the heat transfer medium.

[Claim 7]

A heat transfer medium-cooling device, comprising

a first heat exchanger, in which a low-temperature-liquefied gas and a gas of a temperature higher than the low-temperature-liquefied gas are introduced and heat-exchanged with each other and a vaporization gas of the low-temperature-liquefied gas is discharged and the gas after heat-exchanging is discharged as a heat-exchanged gas;

a mixing unit, in which the heat-exchanged gas and the vaporization gas discharged from the first heat exchanger are mixed and discharged as a low-temperature gas refrigerant;

a first control unit, in which, based on the difference between a detected temperature of the low-temperature gas refrigerant and an intended temperature, an amount of the vaporization gas introduced to the mixing unit is adjusted to control the temperature of the low-temperature gas refrigerant to the intended temperature;

a second heat exchanger, in which the low-temperature gas refrigerant discharged from the first heat exchanger, the temperature of the low-temperature gas refrigerant being controlled, and a heat transfer medium circulated in a circulation route are heat-exchanged with each other; and

a second control unit in which, based on the difference between a detected temperature of the heat transfer medium and an intended temperature for the heat transfer medium, an amount of the gas is adjusted to control a temperature of the heat transfer medium to the intended temperature for the heat transfer medium.

[Claim 8]

A low-temperature reaction control device, comprising:

the heat transfer medium-cooling device of Claim 6 or the heat transfer medium-cooling device of Claim 7; and

a low-temperature reaction vessel, in which the heat transfer medium circulated in the circulation route is introduced, the temperature of the heat transfer medium being controlled, and a reaction liquid in the low-temperature reaction vessel is cooled and adjusted to the intended temperature.