

AIR SEPARATION UNIT

[TECHNICAL FIELD]

[0001]

The present invention relates to an air separation unit. For example, the invention relates to a cryogenic air separation unit provided with an oxygen turbine and a heat exchanger.

[BACKGROUND ART]

[0002]

Multi-column rectification systems comprising: a plurality of rectification columns, such as an intermediate-pressure column, a low-pressure column, and a crude-argon column; and an oxygen turbine for expanding oxygen are employed when separating air components into nitrogen, argon, and oxygen, etc., using a cryogenic air separation technique.

In recent years, there has been a demand for large amounts of nitrogen and argon in the semiconductor industry. Meanwhile, the demand for oxygen is limited, and thus, there is a demand for air separation units that are optimized for supplying nitrogen and argon. Demand for nitrogen and argon is high, but in the semiconductor industry where demand for oxygen is limited, the pressure balance in air separation units is increased to optimize the supply of nitrogen and argon, and the required cold air is generated by expanding surplus oxygen obtained from a low-pressure column operated at approximately 3 BarA, for example. In the oxygen turbines used in such an instance, it is necessary to reduce the oxygen concentration by a certain degree, for example 80 to 95%, for equipment safety reasons. Since nitrogen and argon need to be recovered, the oxygen concentration from the low-pressure column is almost 100%, and therefore, it is necessary to dilute the oxygen gas, and for example, a nitrogen-containing gas from the low-pressure column (e.g., Patent Documents 1 and 2) or a vaporized gas from a crude-argon column condenser (e.g., Patent Document 3) is mixed with oxygen gas for dilution.

[PRIOR ART DOCUMENTS]

[PATENT DOCUMENTS]

[0003]

[Patent Document 1] US Patent No. 5129932

[Patent Document 2] US Patent Application Publication No. 2019/293347

[Patent Document 3] US Patent Application Publication No. 2023/358468

[SUMMARY OF INVENTION]

[PROBLEM TO BE SOLVED BY THE INVENTION]

[0004]

Diluting oxygen gas flowing into an oxygen turbine with an inert gas results in process loss, so it is desirable in terms of energy efficiency to use a machine that supports high concentrations of oxygen (for example, 90% or more of oxygen). From the viewpoints of safety and reliability in the air separation unit, the risk of oxygen combustion is high in a high oxygen concentration stream, and there is a possibility that the risk of oxygen combustion will increase in transient operation modes, such as when the air separation unit is started or when the operation mode is changed. The oxygen combustion risk includes, for example, a situation in which there is an oxygen stream in a heat exchanger made of a combustible material such as aluminium, and an ignitable substance enters the heat exchanger for some reason. In large-scale air separation units, from an industrial standpoint, it is extremely difficult to completely eliminate such risks.

[0005]

The present disclosure provides an air separation unit capable of reducing the risk of combustion of a heat exchanger connected to an oxygen turbine.

[SOLUTION TO PROBLEM]

[0006]

An air separation unit (A1, A2) of the present disclosure comprises: a main heat exchanger (1), an intermediate-pressure rectification column (2), a nitrogen condenser (3), a low-pressure rectification column (4), a crude-argon column (5), a crude-argon condenser (6), and an oxygen

turbine (9).

The air separation unit (A1, A2) may be provided with:

an oxygen turbine inlet pipe (L32) for feeding oxygen gas drawn out from a bottom section of the low-pressure rectification column (4) or a gas phase in a refrigerant storage section (32) of the nitrogen condenser (3), to the oxygen turbine (9) via the main heat exchanger (1), and feeding the oxygen gas to the main heat exchanger again (1);

an oxygen bypass pipe (L321) which branches from the oxygen turbine inlet pipe (L32); and

a dilution stream pipe (L42, L621) for drawing out a nitrogen-containing gas, in which the oxygen concentration is lower than the oxygen concentration in the oxygen gas, as a dilution stream, and introducing the dilution stream into the oxygen turbine inlet pipe (L32).

The "dilution stream" is a fluid that is used to dilute the oxygen concentration in an oxygen gas (oxygen-rich gas, high-purity oxygen gas, etc.). The dilution stream may be a low-oxygen-concentration gas, for example, feed air, which can be drawn out from the intermediate-pressure rectification column (2), the nitrogen condenser (3), the low-pressure rectification column (4), and the crude-argon condenser (6), etc.

[0007]

The dilution pipe (L42, L621) may be provided such that it is possible to draw out a nitrogen-containing gas from the intermediate-pressure rectification column (2) or the low-pressure rectification column (4) as a dilution stream, or provided such that it is possible to draw out a nitrogen-containing gas from the crude-argon condenser (6) or a portion of the feed air.

[0008]

The air separation unit (A1, A2) may be provided with:

a gas flowmeter (FIC) and a first flow rate regulation valve (V1), which are provided in the oxygen turbine inlet pipe (L32) on the upstream side of the main heat exchanger (1) and the oxygen bypass pipe (L321);

a second flow rate regulation valve (V2), which is provided in the oxygen bypass pipe (L321) on the upstream side of the main heat exchanger (1);

a third flow rate regulation/check valve (V3), which is provided in the dilution stream pipe (L42, L621);

an oxygen concentration analyser (AIC) for measuring oxygen concentration and a fourth flow rate regulation valve (V4), which are provided in the oxygen turbine inlet pipe (L32) downstream of the main heat exchanger (1); and

a liquid level sensor (LIC), which senses the liquid level of a refrigerant phase in the nitrogen condenser (3).

[0009]

The air separation unit (A1, A2) may be provided with:

an oxygen concentration adjustment unit (10), which sets a target oxygen concentration corresponding to operation of a nozzle of the oxygen turbine (9), sets a dilution flow rate (the flow rate of gas flowing through the dilution stream pipe, or the total flow rate of that flow rate and the flow rate of oxygen gas flowing through the oxygen turbine inlet pipe (L32)) and an oxygen bypass flow rate (the flow rate of oxygen gas flowing through the oxygen bypass pipe) so as to attain the target oxygen concentration, and adjusts the oxygen concentration of the oxygen gas flowing through the oxygen turbine inlet pipe.

[0010]

The air separation unit (A1, A2) may be provided with:

an interlock (11) which stops the oxygen turbine (9) in a case where the oxygen concentration measured by the oxygen concentration analyser (AIC) exceeds a threshold at which it is determined that there is a severe risk of combustion in the oxygen turbine (9).

[0011]

The air separation unit (A1, A2) may be provided with:

an oxygen gas stream shut-off control unit (12), which, in a case where the oxygen concentration measured by the oxygen concentration analyser (AIC) exceeds a threshold at which it is determined that there is a severe risk of combustion in the oxygen turbine (9), performs control so as to

interrupt an oxygen gas stream by closing the first flow rate regulation valve (V1) provided in the oxygen turbine inlet pipe (L32), open the third flow rate regulation/check valve (V3), and introduce a dilution stream into the oxygen turbine inlet pipe (L32) as an inert gas (introduce the dilution stream into the oxygen turbine inlet pipe (L32) upstream of the main heat exchanger (1)).

[0012]

The air separation unit (A1, A2) may be provided with:

a dilution flow rate control unit (13), which controls the dilution flow rate through mass balance adjustment of a dilution stream supply source (for example, the low-pressure rectification column (4), the crude-argon condenser (6), the intermediate-pressure rectification column (2), or the feed air). Mass balance adjustment may be implemented by utilizing the fact that the adjustment target (dilution flow rate) is uniquely determined by the difference between the feed air inflow rate of the supply source and the feed air outflow rate (including product and waste gases). As a result, it is possible to reduce the number of valves for applying a pressure drop to the pipes with flow rates to be adjusted.

[0013]

The oxygen concentration adjustment unit (10) may perform control such that the dilution stream is introduced into the oxygen turbine inlet pipe (L32) downstream of the oxygen turbine (9).

A branched dilution stream pipe which branches from the dilution stream pipe (L42, L621) may be connected to the oxygen turbine inlet pipe (L32) downstream of the oxygen turbine (9).

[0014]

The air separation unit (A1, A2) may be provided with a sub-cooler (7), which cools a liquid (for example, an oxygen-rich liquid) drawn out from the intermediate-pressure rectification column (2), with a gas drawn out from the low-pressure rectification column (4) or the crude-argon condenser (6).

The main heat exchanger (1) may have a divided structure in order to optimize the structure according to design temperature, pressure, and flow rate, and to improve ease of transportation.

[0015]

The air separation unit (A1, A2) of the present disclosure may be provided with:

a main heat exchanger (1) in which feed air is introduced from a warm end and drawn out from a cold end;

an intermediate-pressure rectification column (2) in which feed air drawn out from the cold end of the main heat exchanger (1) is introduced into a bottom section (21);

a nitrogen condenser (3) in which a vapour stream is introduced from an upper section (23) of the intermediate-pressure rectification column (2), and is condensed and drawn out as a reflux liquid;

a low-pressure rectification column (4) in which an oxygen-rich liquid drawn out from the bottom section (21) of the intermediate-pressure rectification column (2) is introduced into a rectification section (42), and/or a vapour stream drawn out from the upper section (23) of the intermediate-pressure rectification column (2) is introduced into a top section (43);

an oxygen turbine (9), which expands and cools oxygen gas drawn out from a bottom section of the low-pressure rectification column (4) or a gas phase in a refrigerant storage section (32) of the nitrogen condenser (3), after the oxygen gas has undergone heat exchange in the main heat exchanger (1);

a crude-argon column (5), in which an oxygen-containing fluid drawn out from the rectification section (42) of the low-pressure rectification column (4) is introduced into a bottom section (51);

a crude-argon condenser (6) in which a vapour stream is introduced from an upper section of the crude-argon column (5), and is condensed and drawn out as a reflux liquid; and

a sub-cooler (7), in which an oxygen-rich liquid drawn out from the bottom section (21) of the intermediate-pressure rectification column (2) is introduced from a warm end and drawn out from a cold end, and/or liquid nitrogen drawn out from the upper section (23) of the intermediate-pressure rectification column (2) is introduced from a warm end and drawn out from a cold end,

and/or nitrogen gas drawn out from the top section (43) of the low-pressure rectification column (4) is introduced from a cold end and drawn out from a warm end.

[0016]

The air separation unit (A1, A2) may be provided with:

- a feed air pipeline (L1) for introducing feed air into the intermediate-pressure rectification column (2) via the main heat exchanger (1);

- an oxygen-rich liquid pipeline (L21) for introducing an oxygen-rich liquid drawn out from the bottom section (21) of the intermediate-pressure rectification column (2) into the rectification section (42) of the low-pressure rectification column (4) via the sub-cooler (7);

- an oxygen-rich liquid branched pipeline (L211) which branches from the oxygen-rich liquid pipeline (L21) downstream from the sub-cooler (7) and serves to introduce the oxygen-rich liquid into a refrigerant storage section (61) of the crude-argon condenser (6);

- a liquid nitrogen pipeline (L23) for introducing liquid nitrogen drawn out from the upper section (23) of the intermediate-pressure rectification column (2) into the top section (43) of the low-pressure rectification column (4) via the sub-cooler (7);

- a liquid nitrogen branched pipeline (L231) which branches from the liquid nitrogen pipeline (L23) downstream from the sub-cooler (7) and draws out a portion of the liquid nitrogen;

- a liquid oxygen extraction line (L31) for extracting, as liquid oxygen (LOX), a refrigerant (oxygen-rich liquid) in the refrigerant storage section (32) of the nitrogen condenser (3);

- an oxygen turbine inlet pipe (L32) for extracting oxygen gas that is drawn out from an upper gas phase of the refrigerant storage section (32) of the nitrogen condenser (3), oxygen gas that is introduced into the middle of the main heat exchanger (1), warmed, and then drawn out, oxygen gas that is expanded by the oxygen turbine (9), and oxygen gas that is re-introduced from the cold end of the main heat exchanger (1) and drawn out from the warm end;

- an oxygen-containing fluid pipeline (L421) for drawing an oxygen-containing fluid from the rectification section (42) of the low-pressure rectification column (4) and introducing the oxygen-containing fluid into the bottom (51) of the crude-argon column (5);

- a nitrogen gas pipeline (L43) which draws nitrogen gas from the top section (43) of the low-pressure rectification column (4) and extracts nitrogen gas (GAN) via the sub-cooler (7) and the main heat exchanger (1);

- a crude-argon column-bottom fluid pipeline (L51) for drawing a bottom fluid from the bottom (51) of the crude-argon column (5), and introducing the bottom fluid below a draw-out position of the oxygen-containing fluid pipeline (L421) in the rectification section (42) of the low-pressure rectification column (4);

- an argon extraction line (L53) for drawing a vapour stream or a reflux liquid from the upper section of the crude-argon column (5); and

- a crude-argon condenser pipeline (L62) for drawing out from an upper gas phase in the refrigerant storage section (62) of the crude-argon condenser (6), and introducing into the rectification section (42) of the low-pressure rectification column (4) above the oxygen-rich liquid pipeline (L21).

[0017]

A fluid introduced into the crude-argon column (5) from the rectification section (42) of the low-pressure rectification column (4) will be referred to as an "oxygen-containing fluid", and a liquid drawn out from a location below the feed air introduction stage (e.g., the bottom of the nitrogen rectification column) will be referred to as an "oxygen-rich liquid". The oxygen-containing fluid may be a liquid or a gas-liquid mixture.

[0018]

The sub-cooler (7) uses a gas drawn out from the low-pressure rectification column (4) or the crude-argon condenser (6) to cool the liquid drawn out from the intermediate-pressure rectification column (2). In this way, the amount of liquid vaporized by decompression when the liquid is introduced into the low-pressure rectification column (4) is reduced, and the amount of liquid contributing to rectification as a reflux liquid is increased, and therefore rectification efficiency can be improved.

[0019]

The air separation unit (A1, A2) may be provided with:
various measuring instruments such as flow rate measuring instruments, pressure measuring instruments, temperature measuring instruments, and liquid level measuring instruments;
various valves such as control valves and gate valves; and
pipes that connect each element.

[0020]

(Effects)

(1) It is possible to reduce the risk of combustion in a heat exchanger connected to an oxygen turbine.

(2) It is possible to generate a low temperature as a result of surplus oxygen being expanded by the oxygen turbine under an optimized pressure balance.

(3) In a case where oxygen dilution is performed when the operation mode of the oxygen turbine is changed, it is possible to lower the concentration of an oxygen stream prior to operation of a nozzle of the oxygen turbine when concentration oxygen dilution is performed.

(4) It is possible to improve safety by reducing risk of combustion in an air separation unit provided with an oxygen turbine.

[BRIEF DESCRIPTION OF DRAWINGS]

[0021]

[Fig. 1] is a diagram illustrating an air separation unit according to embodiment 1.

[Fig. 2] is a diagram illustrating an air separation unit according to embodiment 2.

[DESCRIPTION OF EMBODIMENTS]

[0022]

Several embodiments of the present invention will be described below. The embodiments described below are given as examples of the present disclosure. The present disclosure is in no way limited by the following embodiments, and also includes a number of variants that can be implemented within a scope that does not alter the gist of the present disclosure. It should be noted that not all the configurations described below are necessarily essential to the present disclosure. Upstream and downstream are based on a flow direction of a fluid (liquid or gas).

[0023]

(Embodiment 1)

A first air separation unit A1 according to embodiment 1 will be described with the aid of fig. 1.

The first air separation unit A1 is provided with: a main heat exchanger 1, an intermediate-pressure rectification column 2, a nitrogen condenser 3, a low-pressure rectification column 4, a crude-argon column 5, a crude-argon condenser 6, a sub-cooler 7, an oxygen turbine 9, an oxygen concentration adjustment unit 10, and an interlock 11.

[0024]

The main heat exchanger 1 cools feed air introduced from a hot end and discharges the same from a cold end. The cooled feed air is introduced into the intermediate-pressure rectification column 2 via a feed air pipeline L1.

[0025]

The intermediate-pressure rectification column 2 comprises a bottom section 21, a rectification section 22, and a top section 23. The feed air pipeline L1 is connected to the bottom section 21. Oxygen-rich liquid that collects in the bottom section 21 is delivered via a nitrogen-rich liquid pipeline L21 to a rectification section 42 of the low-pressure rectification column 4 after undergoing heat exchange in a sub-cooler 7. A portion of the oxygen-rich liquid following heat exchange in the sub-cooler 7 is introduced into a refrigerant storage section 61 of the crude-argon condenser 6 via an oxygen-rich liquid branched pipeline L211. A portion of the liquid nitrogen in the top section 23 is fed, via a liquid nitrogen pipeline L23, to a top section 43 of the low-pressure rectification column 4 after undergoing heat exchange in the sub-cooler 7. A liquid nitrogen branched pipeline L231 is a line which branches from the liquid nitrogen

pipeline L23 downstream of the sub-cooler 7, and extracts liquid nitrogen.

[0026]

The nitrogen condenser 3 is provided above the top section 23 of the intermediate-pressure rectification column 2. A portion of the nitrogen gas (vapour stream) drawn out from the top section 23 of the intermediate-pressure rectification column 2 is introduced into the nitrogen condenser 3 via a reflux pipeline and is cooled (condensed) and liquefied by means of heat exchange with oxygen-rich liquid constituting a refrigerant. The liquid nitrogen which has been liquefied is returned to the top section 23 of the intermediate-pressure rectification column 2 as a reflux liquid. The liquid level sensor LIC senses the liquid level of a refrigerant phase of the nitrogen condenser 3.

[0027]

The liquid oxygen extraction line L31 is a line for extracting the refrigerant (oxygen-rich liquid) from the refrigerant storage section 32 of the nitrogen condenser 3, as liquid oxygen (LOX).

[0028]

The low-pressure rectification column 4 comprises a rectification section 42 and a top section 43. The bottom section may also serve as the refrigerant storage section 32 of the nitrogen condenser 3.

An oxygen-containing fluid drawn out from the rectification section 42 of the low-pressure rectification column 4 is introduced into the bottom section 51 of the crude-argon column 5 via the oxygen-containing fluid pipeline L421. Nitrogen gas drawn out from the top section 43 of the low-pressure rectification column 4 is extracted as low-pressure nitrogen gas (GAN) via the nitrogen gas pipeline L43 and via the sub-cooler 7 and the main heat exchanger 1.

[0029]

The crude-argon column 5 comprises a bottom section 51, a rectification section 52, and a top section 53. A crude-argon column-bottom fluid pipeline L51 is a line for drawing a bottom fluid from the bottom section 51 of the crude-argon column 5, and introducing the bottom fluid below a draw-out position of the oxygen-containing fluid pipeline L421 in the rectification section 42 of the low-pressure rectification column 4. The argon extraction line L53 is a line for drawing a vapour stream or reflux liquid (crude argon-containing fluid) from the upper section of the crude-argon column 5.

[0030]

The vapour stream from the upper section of the crude-argon column 5 is introduced into the crude-argon condenser 6 where it is condensed and drawn out as a reflux liquid. The crude-argon condenser pipeline L62 is a line for drawing out from the upper gas phase in the refrigerant storage section 62 of the crude-argon condenser 6, and introducing into the rectification section 42 of the low-pressure rectification column 4 above the oxygen-rich liquid pipeline L21.

[0031]

The oxygen-rich liquid drawn out from the bottom section 21 of the intermediate-pressure rectification column 2 is introduced from the warm end of the sub-cooler 7 and drawn out from the cold end thereof. In addition, in the sub-cooler 7, liquid nitrogen drawn out from the upper section 23 of the intermediate-pressure rectification column 2 is introduced from the warm end and drawn out from the cold end. Furthermore, nitrogen gas drawn out from the top section 43 of the low-pressure rectification column 4 is introduced from the cold end of the sub-cooler 7 and drawn out from the warm end thereof.

[0032]

The oxygen turbine 9 expands and cools oxygen gas drawn out from the gas phase in the refrigerant storage section 32 of the nitrogen condenser 3, after the oxygen gas has undergone heat exchange in the main heat exchanger 1.

[0033]

The oxygen turbine inlet pipe L32 is a line for extracting oxygen gas that is drawn out from an upper gas phase of the refrigerant storage section 32 of the nitrogen condenser 3, oxygen gas that is introduced into the middle (for example, an intermediate position from the cold end) of

the main heat exchanger 1, warmed, and then drawn out, oxygen gas that is expanded by the oxygen turbine 9, and oxygen gas that is re-introduced from the cold end of the main heat exchanger 1 and drawn out from the warm end. The first flow rate regulation valve V1 is provided in the oxygen turbine inlet pipe L32 on the upstream side of the main heat exchanger 1 and the oxygen bypass pipe L321. The oxygen concentration analyser AIC and the fourth flow rate regulation valve V4 are provided in the oxygen turbine inlet pipe L32 at a position projecting from the middle of the main heat exchanger 1 and upstream of the oxygen turbine 9.

[0034]

The oxygen bypass pipe L321 branches from the oxygen turbine inlet pipe L32 and is introduced into the main heat exchanger 1, or is reconnected to the oxygen turbine inlet pipe L32 downstream of the oxygen turbine 9. The second flow rate regulation valve V2 is provided in the oxygen bypass pipe L321 in a position at which it is introduced into the main heat exchanger 1, or on the upstream side of the main heat exchanger 1.

[0035]

The dilution stream pipe L42 draws out a gas (for example, a nitrogen-containing gas) from an upper section of the rectification section 42 of the low-pressure rectification column 4, and connects to the oxygen turbine inlet pipe L32 downstream of the oxygen bypass pipe L321 and on the upstream side of the main heat exchanger 1. The third flow rate regulation/check valve V3 is provided in the dilution stream pipe L42.

[0036]

The oxygen concentration adjustment unit 10 sets a target oxygen concentration corresponding to operation of a nozzle of the oxygen turbine 9, sets a dilution flow rate (the flow rate of gas flowing through the dilution stream pipe, or the total flow rate of that flow rate and the flow rate of oxygen gas flowing through the oxygen turbine inlet pipe L32) and an oxygen bypass flow rate (the flow rate of oxygen gas flowing through the oxygen bypass pipe) so as to attain the target oxygen concentration, and adjusts the oxygen concentration of the oxygen gas flowing through the oxygen turbine inlet pipe L32.

[0037]

The first flow rate regulation valve V1, the second flow rate regulation valve V2, and the oxygen gas flow rate flowing through the oxygen bypass pipe are all controlled in accordance with a gas flow rate measured by the gas flowmeter FIC. Additionally, the third flow rate regulation/check valve V3 is controlled, the oxygen gas stream and the dilution stream are mixed, and control is performed such that the oxygen concentration after mixing reaches the target oxygen concentration.

[0038]

When the cold energy is excessive, the liquid level of the refrigerant in the nitrogen condenser 3 increases. In such a case, the second flow rate regulation valve V2 is closed if the liquid level of the refrigerant as measured by the liquid level sensor LIC exceeds a threshold. By increasing the oxygen gas flow rate flowing to the bypass, it is possible to reduce the load on the oxygen turbine 9, and restore a cold balance.

[0039]

The second flow rate regulation valve V2 is opened if the oxygen concentration as measured by the oxygen concentration analyser AIC exceeds a threshold. As a result of the flow rate of oxygen gas flowing to the bypass increasing, the amount of the oxygen gas stream supplied to the oxygen turbine 9 is reduced while maintaining the gas of the dilution flow, and accordingly, the oxygen concentration of the oxygen turbine 9 is also reduced. Therefore, the degree of opening of the second flow rate regulation valve V2 is determined by a high selector between the liquid level sensor LIC and the oxygen concentration analyser AIC.

In this embodiment, the set value for the oxygen concentration in the oxygen concentration analyser AIC on the inlet side of the oxygen turbine 9 is fixed to an appropriate value when a plant is started or the mode is switched. From the standpoint of safe operation, it is recommended to set a relatively low value when a plant is started or the mode is switched. During plant balance adjustment, when the oxygen concentration on the inlet side of the oxygen turbine 9

approaches a target value, the oxygen concentration analyser AIC takes over control of the second flow rate regulation valve V2 to ensure that the oxygen concentration is less than or equal to the set value. As a result, it is possible to maintain safe operation.

Furthermore, due to the interlock 11, the oxygen turbine 9 is stopped when an abnormal state occurs in which the oxygen concentration measured by the oxygen concentration analyser AIC reaches a high set value.

[0040]

In a case where the oxygen concentration measured by the oxygen concentration analyser AIC exceeds a threshold at which it is determined that there is a severe risk of combustion in the oxygen turbine 9, the oxygen gas stream shut-off control unit 12 performs control so as to interrupt an oxygen gas stream by closing the first flow rate regulation valve V1 provided in the oxygen turbine inlet pipe L32, open the third flow rate regulation/check valve V3, and introduce a dilution stream into the oxygen turbine inlet pipe L32 of the oxygen turbine 9 as an inert gas (introduce the dilution stream into the oxygen turbine inlet pipe L32 upstream of the main heat exchanger 1).

[0041]

The dilution flow rate control unit 13 is capable of controlling the dilution flow rate through mass balance adjustment of a dilution stream supply source (for example, the low-pressure rectification column 4, the crude-argon condenser 6, the intermediate-pressure rectification column 2, or the feed air).

[0042]

(Embodiment 2)

An air separation unit A2 of embodiment 2 will be described with the aid of fig. 2. The same reference numerals as those in embodiment 1 have the same functions, and therefore descriptions thereof may be omitted.

The dilution stream pipe L621 is a line that branches from the crude-argon condenser pipeline L62, which is drawn out from the crude-argon condenser 6, and introduces a low-concentration oxygen gas into the oxygen turbine inlet pipe L32 downstream of the oxygen bypass pipe L321 and on the upstream side of the main heat exchanger 1. The third flow rate regulation/check valve V3 is provided in the dilution stream pipe L621.

[0043]

(Embodiment 3)

In embodiment 3, a branched dilution stream pipe that branches from the dilution stream pipe (L42, L621) is connected to the oxygen turbine inlet pipe L32 downstream of the oxygen turbine 9. A fifth flow rate regulation valve 122 is provided in the branched dilution stream pipe.

The oxygen concentration adjustment unit 10 performs control to open the fifth flow rate regulation valve so as to introduce the dilution stream into the oxygen turbine inlet pipe L32 downstream of the oxygen turbine 9.

In embodiment 3, the fifth flow rate regulation valve on the branched dilution stream pipe bears the role of the second flow rate regulation valve V2 in embodiments 1 and 2. In a case where the actual oxygen concentration becomes higher than the set value of the oxygen concentration analyser AIC, oxygen is reduced as a result of the second flow rate regulation valve V2 moving in an opening direction and bypassing oxygen. On the other hand, in embodiment 3, the fifth flow rate regulation valve moves in a closing direction to increase the dilution stream. In addition, in the first and second embodiments, the second flow rate regulation valve V2 is controlled via the high selector. On the other hand, in embodiment 3, the degree of opening of the fifth flow rate regulation valve can be controlled individually on the basis of measurement values from the oxygen concentration analyser AIC.

[0044]

(Other embodiments)

- (1) Although not explicitly stated, pressure regulating devices and flow rate regulation devices, etc., may be installed in each pipeline in order to regulate pressure and regulate flow rate.
- (2) Although not explicitly stated, control valves and gate valves, etc., may be installed in

each line.

(3) Although not explicitly stated, pressure regulating devices and temperature measuring devices, etc., may be installed in each column in order to regulate pressure and regulate temperature.

(4) In a case where feed air is used as the dilution stream, for example, this may be achieved by branching from the feed air pipeline (L1) and connecting to the dilution stream pipe (L42, L621), or by providing another line.

(5) In a case of drawing out from the intermediate-pressure rectification column (2) as the dilution stream, for example, this may be achieved by branching from the oxygen-rich liquid pipeline (L21) or the liquid nitrogen pipeline (L23) and connecting to the dilution stream pipe (L42, L621), or by providing another line.

[Reference Symbols]

[0045]

- | | |
|---|--|
| 1 | Heat exchanger |
| 2 | Intermediate-pressure rectification column |
| 3 | Nitrogen condenser |
| 4 | Low-pressure rectification column |
| 5 | Crude-argon column |
| 6 | Crude-argon condenser |
| 8 | Nitrogen turbine |
| 9 | Oxygen turbine |

[Claim 1]

An air separation unit comprising:
a main heat exchanger in which feed air is introduced from a warm end and drawn out from a cold end;

an intermediate-pressure rectification column into which feed air drawn out from the main heat exchanger is introduced;

a nitrogen condenser in which a vapour stream is introduced from the intermediate-pressure rectification column, and is condensed and drawn out as a reflux liquid;

a low-pressure rectification column into which an oxygen-rich liquid drawn out from the intermediate-pressure rectification column is introduced;

an oxygen turbine, which expands and cools oxygen gas drawn out from a bottom section of the low-pressure rectification column or a gas phase in a refrigerant storage section of the nitrogen condenser, after the oxygen gas has undergone heat exchange in the main heat exchanger;

an oxygen turbine inlet pipe for feeding the oxygen gas to the oxygen turbine via the main heat exchanger, and feeding the oxygen gas to the main heat exchanger again;

an oxygen bypass pipe which branches from the oxygen turbine inlet pipe; and

a dilution stream pipe for drawing out a nitrogen-containing gas, in which the oxygen concentration is lower than the oxygen concentration in the oxygen gas drawn out from the bottom section of the low-pressure rectification column or the gas phase in the refrigerant storage section, as a dilution stream, and introducing the dilution stream into the oxygen turbine inlet pipe.

[Claim 2]

The air separation unit according to Claim 1, comprising:
a gas flowmeter and a first flow rate regulation valve, which are provided in the oxygen turbine inlet pipe on the upstream side of the main heat exchanger and the oxygen bypass pipe;

a second flow rate regulation valve, which is provided in the oxygen bypass pipe on the upstream side of the main heat exchanger;

a third flow rate regulation/check valve, which is provided in the dilution stream pipe;

an oxygen concentration analyser for measuring oxygen concentration and a fourth flow rate regulation valve, which are provided in the oxygen turbine inlet pipe downstream of the main heat exchanger; and

a liquid level sensor, which senses the liquid level of a refrigerant phase in the nitrogen condenser.

[Claim 3]

The air separation unit according to Claim 1, comprising:
an oxygen concentration adjustment unit, which sets a target oxygen concentration corresponding to operation of a nozzle of the oxygen turbine, sets a dilution flow rate and an oxygen bypass flow rate so as to attain the target oxygen concentration, and adjusts the oxygen concentration of the oxygen gas flowing through the oxygen turbine inlet pipe.

[Claim 4]

The air separation unit according to Claim 2, comprising:
an oxygen gas stream shut-off control unit, which, in a case where the oxygen concentration measured by the oxygen concentration analyser exceeds a threshold at which it is determined that there is a severe risk of combustion in the oxygen turbine, performs control so as to interrupt an oxygen gas stream by closing the first flow rate regulation valve, open the third flow rate regulation/check valve, and introduce a dilution stream into the oxygen turbine inlet pipe as an inert gas.

[Claim 5]

The air separation unit according to Claim 2, comprising:
an interlock which stops the oxygen turbine in a case where the oxygen concentration measured by the oxygen concentration analyser exceeds a threshold at which it is determined that there is a severe risk of combustion in the oxygen turbine.