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(72) Inventors:
• **KANEDA, Takuya**
Hyogo, 651-0087 (JP)
• **MORI, Hiromu**
Aichi, 441-3436 (JP)

(74) Representative: **Air Liquide**
L'Air Liquide S.A.
Direction de la Propriété Intellectuelle
75, Quai d'Orsay
75321 Paris Cedex 07 (FR)

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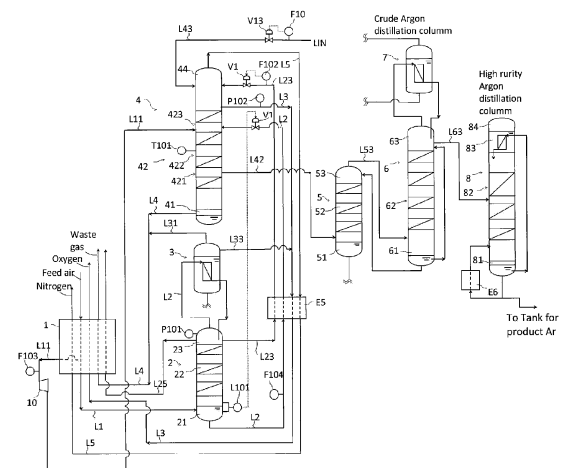
(71) Applicant: **L'AIR LIQUIDE, SOCIETE ANONYME POUR L'ETUDE ET L'EXPLOITATION DES PROCEDES GEORGES CLAUDE**
75007 Paris (FR)

(54) **AIR SEPARATION SYSTEM**

(57) To provide an air separation system with which the extraction rate of high-purity product argon that can be withdrawn from an argon distillation column can be improved, even if production quantities such as the quantity of withdrawn product oxygen or the quantity of withdrawn product nitrogen change.

The air separation system is provided with a main heat exchanger 1, a high pressure column 2, a first condensing unit 3, a low pressure column 4, and a crude argon column 5. The air separation system is provided with: a process control unit 201 for controlling components constituting the air separation system; an oxygen concentration estimating unit 202 for estimating, by calculation, the oxygen concentration (EC_{O_2}) of oxygen-enriched liquid that accumulates in a column bottom portion 21 of the high pressure column 2; a flow rate estimating unit 203 for estimating, by calculation, the flow rate (EF_{O_2}) of oxygen-enriched liquid that has been discharged from the column bottom portion 21 of the high pressure column 2 and that is to be introduced into a distillation portion of the low pressure column 4; and a target temperature calculating unit 204 for calculating a target temperature (T_t) of an argon extraction portion 421 on the basis of the flow rate (F_{FA}) of feed air that has passed through at least a portion of the main heat exchanger 1 and that is to be sent to an expansion turbine 10, the oxygen concentration (EC_{O_2}) of the oxygen-enriched liquid, and the flow rate (EF_{O_2}) of the oxygen-enriched liquid.

Figure 1



Description

[0001] The present invention relates to an air separation system for improving the extraction rate of product argon.

Background art

[0002] Conventionally, an oxygen-enriched gas-liquid substance containing argon, extracted from an air separating device, is sent to an argon distillation column from which high-purity product argon is withdrawn.

[0003] For example, patent literature article 1 discloses an air separating device for the production of products such as oxygen, nitrogen and argon. The air separation device comprises a plurality of distillation columns for efficiently producing these products, such as a high pressure distillation column, a low pressure distillation column, and a crude argon distillation column.

Prior art literature

Patent Documents

[0004] French Patent Publication No. 2964451

Summary of invention

Problems to be resolved by the invention

[0005] Conventionally, the extraction rate of product argon is controlled by controlling the concentration of oxygen in oxygen-enriched liquid that accumulates in an intermediate stage of the low pressure column of the air separating device, to a predetermined concentration.

[0006] However, since the state of the low pressure column of the air separating device varies in accordance with changes in production quantities, such as the quantity of withdrawn product oxygen or the quantity of withdrawn product nitrogen from the air separating device, the extraction rate of high-purity product argon that can be withdrawn from the final stage argon distillation column varies greatly.

[0007] In view of the circumstances described hereinabove, the objective of the present invention is to provide an air separation system with which the extraction rate of high-purity product argon that can be withdrawn from the argon distillation column can be improved, even if production quantities such as the quantity of withdrawn product oxygen or the quantity of withdrawn product nitrogen change.

Means of overcoming the problem

[0008] The inventors of the present invention found that nitrogen (gaseous, liquid, or a mixture thereof) contaminates an argon extraction portion (intermediate stage of distillation portion of low pressure column of air

separating device) for extracting an oxygen-enriched gas-liquid mixture containing argon, as a result of changes in the state of the low pressure column of the air separating device concomitant with changes in production quantities such as the quantity of withdrawn product oxygen or the quantity of withdrawn product nitrogen from the air separating device. Nitrogen contamination causes the extraction rate of high-purity product argon that can be withdrawn from the final stage argon distillation column to fluctuate greatly and to decrease. Accordingly, the inventors of the present invention created a novel configuration in order to resolve the abovementioned problem.

[0009] The air separation system of the present invention is provided with:

- a main heat exchanger (1);
- a high pressure column (2) into which feed air that has passed through the main heat exchanger (1) is introduced;
- a first condensing unit (3) for condensing gas discharged from a column top portion (23) of the high pressure column (2);
- a low pressure column (4) into which oxygen-enriched liquid discharged from a column bottom portion (21) of the high pressure column (2) is introduced;
- crude argon columns (5, 6) into which an argon-containing oxygen-enriched gas-liquid substance discharged from an argon extraction portion, which is an intermediate stage of a distillation portion of the low pressure column (4), is introduced; and
- a pure argon distillation column (8) into which an argon-enriched gas-liquid substance discharged from a distillation portion (intermediate stage or upper portion) or a column top portion of the pure argon distillation columns (5, 6) is introduced.

[0010] The crude argon columns may be separate or may be configured from a single column.

[0011] The air separation system is provided with:

- a process control unit (201) for controlling components (such as the temperatures of heat exchangers, opening and closing of valves, flow regulating valves, pressure regulating valves, compressors, expansion turbine) constituting the air separation system; an oxygen concentration estimating unit (202) for estimating, by calculation, the oxygen concentration (EC_{O₂}) of the oxygen-enriched liquid that accumulates in the column bottom portion (21) of the high pressure column (2);
- a flow rate estimating unit (203) for estimating, by calculation, the flow rate (EF_{O₂}) of the oxygen-enriched liquid that has been discharged from the column bottom portion (21) of the high pressure column (2) and that is to be introduced into the distillation portion of the low pressure column (3);

- a target temperature calculating unit (204) for calculating a target temperature (T) of the argon extraction portion on the basis of the flow rate (F_FA) of the feed air that has passed through at least a portion of the main heat exchanger (1) and that is to be sent to an expansion turbine (10), the oxygen concentration (EC-O₂) of the oxygen-enriched liquid, and the flow rate (EF_O₂) of the oxygen-enriched liquid; and
- a memory (208) for storing various types of data.

[0012] The target temperature calculating unit (204) may calculate the target temperature (T) using a statistical method such as multivariate analysis or regression analysis.

[0013] The process control unit may control the replenishment amount flow rate (flowmeter F101 and valve 13) of liquid nitrogen, and/or the flow rate (flowmeter F102 and valve V12) of reflux liquid discharged from the column top portion (23) of the high pressure column (2), such that the measured temperature (T-Ar) of the argon extraction portion reaches a target temperature (Tt).

[0014] The oxygen concentration estimating unit (202) can estimate the oxygen concentration (EC_O₂) of the oxygen-enriched liquid by calculating the material balance in the high pressure column (2).

[0015] The flow rate estimating unit (203) can estimate the flow rate (EF_O₂) of the oxygen-enriched liquid by calculating the degree of opening of a valve which supplies the oxygen-enriched liquid to the low pressure column (3), and the pressure difference before and after the valve.

Effect of the invention

[0016] Nitrogen contamination of the argon extraction portion can be prevented, and the argon extraction rate improved, by detecting a decrease in the temperature of the argon extraction portion resulting from a fluctuation in the operating pressure in the low pressure column, or a decrease in the temperature of the argon extraction portion due to other causes.

Brief description of the drawings

[0017]

Figure 1 is a drawing illustrating embodiment 1 of an air separation system.

Figure 2 is a drawing illustrating an example of the control elements of the air separation system in embodiment 1.

Modes of embodying the invention

[0018] Several modes of embodiment of the present invention will be described below. The modes of embodiment described below are exemplary descriptions of the present invention. The present invention is in no way lim-

ited by the following modes of embodiment, and also includes a number of variant modes which are implemented within a scope that does not alter the essential point of the present invention. It should be noted that the constituent elements described below are not all limited to being essential constituent elements of the present invention.

Mode of Embodiment 1

[0019] The air separation system in embodiment 1 will be described with reference to Figure 1.

The air separation system is provided with: the main heat exchanger 1; the high pressure column 2 into which feed air that has passed through the main heat exchanger 1 is introduced via a pipeline L1; the first condensing unit (nitrogen condenser) 3 for condensing high pressure column distillate discharged through a pipeline L231 from the column top portion 23 of the high pressure column 2; and the low pressure column 4 into which oxygen-enriched liquid discharged from the column bottom portion 21 of the high pressure column 2 is introduced.

[0020] Feed air introduced into the main heat exchanger 1 branches off midway through the main heat exchanger 1 and is sent to the expansion turbine 10 via a branched pipeline L11, and is discharged from the expansion turbine 10 and sent to an intermediate stage 423 of a distillation portion 42 of the low pressure column 4.

[0021] The flow rate (F_FA) of the feed air sent to the expansion turbine 10 is measured using a flowmeter (F103). Measured data are sent to a control device 200 and are stored as time-series data in the memory 208.

[0022] A liquid surface level gauge (L101) for measuring the liquid surface height of oxygen-enriched liquid is provided in the column bottom portion 21 of the high pressure column 2. Measured data are sent to a control device 200 and are stored as time-series data in the memory 208.

[0023] The oxygen-enriched liquid discharged from the column bottom portion 21 is subjected to heat exchange in a heat exchanger E5, and is then introduced via a pipeline L2 into a distillation stage that is the same as, or vertically close to, the intermediate stage 423 of the distillation portion 42 of the low pressure column 4 into which the feed air discharged from the expansion turbine 10 is introduced. A control valve V11 is provided in the pipeline L2, and the control valve V11 is controlled by the control device 1 in accordance with the measured data from the liquid surface level gauge (L101), thereby regulating the amount of oxygen-enriched liquid that is introduced.

[0024] A flowmeter (F104) for measuring the flow rate (F_O₂) of the oxygen-enriched liquid that has been discharged from the column bottom portion 21 of the high pressure column 2 and that is to be introduced into the distillation portion 42 of the low pressure column 4 is provided in the pipeline L2. Measured data are sent to a control device 200 and are stored as time-series data in

the memory 208.

[0025] A pressure gauge (P101) is provided in the column top portion 23 of the high pressure column 2 to measure the pressure in the column top portion 23. Measured data are sent to a control device 200 and are stored as time-series data in the memory 208.

[0026] High pressure column distillate (reflux liquid) discharged through a pipeline L25 from the column top portion 23 of the high pressure column 2 is sent to the main heat exchanger 1.

[0027] A thermometer (T101) for measuring the distillation atmosphere temperature is provided in the position of the intermediate stage 422 of the distillation portion 42 of the low pressure column 4 (below the intermediate stage 423 and above the argon extraction portion 421). An argon-containing oxygen-enriched gas-liquid substance is introduced via a pipeline L42 from the argon extraction portion 421, which is the distillation stage below the intermediate stage 422, into a column bottom portion 51 of a first crude argon column 5, or below an intermediate stage of a distillation portion 52 thereof.

[0028] A low pressure column distilled gas-liquid substance discharged through a pipeline L3 from an upper portion of the distillation portion 42 of the low pressure column 4 or from a column top portion 44 thereof is subjected to heat exchange in the heat exchanger E5, and is then sent to the main heat exchanger 1. A pressure gauge (P102) is provided in the pipeline L3 to measure the pressure of the low pressure column distilled gas-liquid substance. Measured data are sent to a control device 200 and are stored as time-series data in the memory 208.

[0029] The pipeline L3 merges with the pipeline L33 ahead of the heat exchanger E5, and vaporised gas-liquid substance discharged from an upper portion of the first condenser 3 merges and is sent together to the heat exchanger E5.

[0030] A low pressure column top portion distillate discharged through a pipeline L5 from the column top portion 44 of the low pressure column 4 is subjected to heat exchange in the heat exchanger E5, and is then sent to the main heat exchanger 1.

[0031] A high pressure column distillate (reflux liquid) discharged through a pipeline L23 from the column top portion 23 of the high pressure column 2 is subjected to heat exchange in the heat exchanger E5, and is then sent to the column top portion 44 of the low pressure column 4. A flowmeter (F102) for measuring the flow rate of the high pressure column distillate, and a control valve V12, are provided in the pipeline L23. Measured data are sent to a control device 200 and are stored as time-series data in the memory 208. The control valve V12 is controlled by the control device 200 in accordance with the measured data from the flowmeter (F102), thereby regulating the amount of high pressure column distillate (reflux liquid) that is introduced.

[0032] Supplementary liquid nitrogen (LIN) is sent to the column top portion 44 of the low pressure column 4

via a pipeline L43. A flowmeter (F101) for measuring the flow rate of the liquid nitrogen, and a control valve V13, are provided in the pipeline L43. Measured data are sent to a control device 200 and are stored as time-series data in the memory 208. The control valve V13 is controlled by the control device 200 in accordance with the measured data from the flowmeter (F103), thereby regulating the amount of liquid nitrogen that is introduced.

[0033] A gas-liquid substance discharged through a pipeline L4 from a column bottom portion 41 of the low pressure column 4 and a gas-liquid substance discharged through a pipeline L31 from a top portion of the first condenser 3 merge and are sent to the main heat exchanger 1.

[0034] Further, the air separation system is provided with: the first crude argon column 5 in which the argon-containing oxygen-enriched gas-liquid substance discharged from the argon extraction portion 421 of the low pressure column 4 is introduced via the pipeline L42 into the column bottom portion 51, or below the intermediate stage of the distillation portion 52; and a second crude argon column 6 in which an argon-enriched gas-liquid substance discharged via a pipeline L53 from a column bottom portion 53 of the first crude argon column 5 is introduced into a column bottom portion 61, or below an intermediate stage of a distillation portion 62.

[0035] Further, the air separation system is provided with: a third condenser 7 for condensing second crude argon distillate discharged from a column top portion 63 of the second crude argon column 6; and a pure argon distillation column 8 in which a high-argon-enriched gas-liquid substance discharged through a pipeline L63 from the column top portion 63 of the second crude argon column 6 is introduced into an intermediate stage of a distillation portion 82.

[0036] The argon content concentrations have the following relationship.

[0037] Argon-containing oxygen-enriched gas-liquid substance < argon-enriched gas-liquid substance < second crude argon distillate < high-argon-enriched gas-liquid substance

[0038] A fourth condenser 83 is provided above the distillation portion 82 of the pure argon column 8 to condense high-purity argon liquid discharged from a column bottom portion 81. The high-purity argon liquid discharged from the column bottom portion 81 of the pure argon column 8 is subjected to heat exchange in a heat exchanger E6 (or reboiler) and is returned to the column bottom portion 81. The high-purity argon liquid discharged from the column bottom portion 81 of the pure argon column 8 is withdrawn as product argon and is sent to a product tank.

[0039] Valves (such as gate valves, flow regulating valves, and pressure regulating valves) may be provided in the pipelines and in the lines shown in Figure 1.

[0040] Further, compressors, pressure regulating devices, flow rate control devices or the like may be provided as necessary in each pipeline to perform pressure

regulation or flow rate regulation.

[0041] The control device 200 in Figure 2 will next be described.

[0042] The control device 200 includes a process control unit 201, an oxygen concentration estimating unit 202, a flow rate estimating unit 203, a target temperature calculating unit 204, and a memory 208 for storing various types of data (such as setting data, process data, and the measured data discussed hereinabove).

[0043] The process control unit 201 controls components constituting the air separation system (such as the temperatures of the heat exchangers, opening and closing of the valves, the flow regulating valves, the pressure regulating valves, the compressors, and the expansion turbine).

[0044] The oxygen concentration estimating unit 202 estimates the oxygen concentration (EC_{O₂}) of the oxygen-enriched liquid that accumulates in the column bottom portion 21 of the high pressure column 2.

[0045] The flow rate estimating unit 203 estimates, by calculation, the flow rate (EF_{O₂}) of the oxygen-enriched liquid that has been discharged from the column bottom portion 21 of the high pressure column 2 and that is to be introduced into the distillation portion 42 of the low pressure column 4.

[0046] The target temperature calculating unit 204 calculates the target temperature (T_t) of the argon extraction portion 421 on the basis of flow rate (F_{FA}) of the feed air that has passed through at least a portion of the main heat exchanger 1 and that is to be sent to the expansion turbine 10, the oxygen concentration (EC_{O₂}) of the oxygen-enriched liquid, and the flow rate (EF_{O₂}) of the oxygen-enriched liquid. The target temperature calculating unit 204 calculates the target temperature (T_t) using a statistical method such as multivariate analysis or regression analysis.

[0047] The process control unit 201 controls the replenishment amount flow rate (flowmeter F101 and valve V13) of liquid nitrogen, and/or the flow rate (flowmeter F102 and valve V12) of the high pressure column distillate (reflux liquid) discharged from the column 23 of the high pressure column 2, such that the measured temperature (T101) of the argon extraction portion 421 reaches the target temperature (T_t).

Exemplary embodiment

[0048] The effect on the argon extraction rate was verified using the configuration in Figure 1.

[0049] Comparative example: Process control to keep the concentration of the oxygen-enriched liquid constant was performed as in a conventional case.

[0050] Exemplary embodiment: Control was performed such that the temperature of the argon extraction portion reached the target temperature.

[0051] An improvement in the argon extraction rate of 9% on average was seen using the exemplary embodiment exhibited compared with the comparative example.

Explanation of the reference codes

[0052]

5	1	Main heat exchanger
	2	High pressure column
	21	Column bottom portion
	22	Distillation portion
	23	Column top portion
10	3	First condenser
	4	Low pressure column
	41	Column bottom portion
	42	Distillation portion
	44	Column top portion
15	5	First crude argon column
	6	Second crude argon column
	7	Third condenser
	8	Pure argon column
	83	Fourth condenser
20	10	Expansion turbine
	E5	Heat exchanger
	E6	Heat exchanger

25 **Claims**

1.
 - a main heat exchanger (1);
 - a high pressure column (2) into which feed air that has passed through the main heat exchanger (1) is introduced,
 - a first condensing unit (3) for condensing gas discharged from a column top portion (23) of the high pressure column (2),
 - a low pressure column (4) into which oxygen-enriched liquid discharged from a column bottom portion (21) of the high pressure column (2) is introduced, and
 - a crude argon column (5) into which an argon-containing oxygen-enriched gas-liquid substance discharged from an argon extraction portion, which is an intermediate stage of a distillation portion of the low pressure column (4), is introduced, and also provided with:
 - a process control unit (201) for controlling components constituting the air separation system;
 - an oxygen concentration estimating unit (202) for estimating, by calculation, the oxygen concentration (EC_{O₂}) of the oxygen-enriched liquid that accumulates in the column bottom portion (21) of the high pressure column (2);
 - a flow rate estimating unit (203) for estimating, by calculation, the flow rate (EF_{O₂}) of the oxygen-enriched liquid that has been discharged from the column bottom portion (21) of the high pressure column (2) and that is to be introduced into the distillation portion of the low pressure column (3); and
 - a target temperature calculating unit (204) for

calculating a target temperature (T_t) of the argon extraction portion on the basis of the flow rate (F_{FA}) of the feed air that has passed through at least a portion of the main heat exchanger (1) and that is to be sent to the expansion turbine (10), the oxygen concentration ($EC-O_2$) of the oxygen-enriched liquid, and the flow rate (EF_{O_2}) of the oxygen-enriched liquid.

2. Air separation system according to Claim 1, wherein the process control unit controls a replenishment amount flow rate of liquid nitrogen, and/or the flow rate of reflux liquid, such that the measured temperature of the argon extraction portion reaches the target temperature (T_t).

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Figure 1

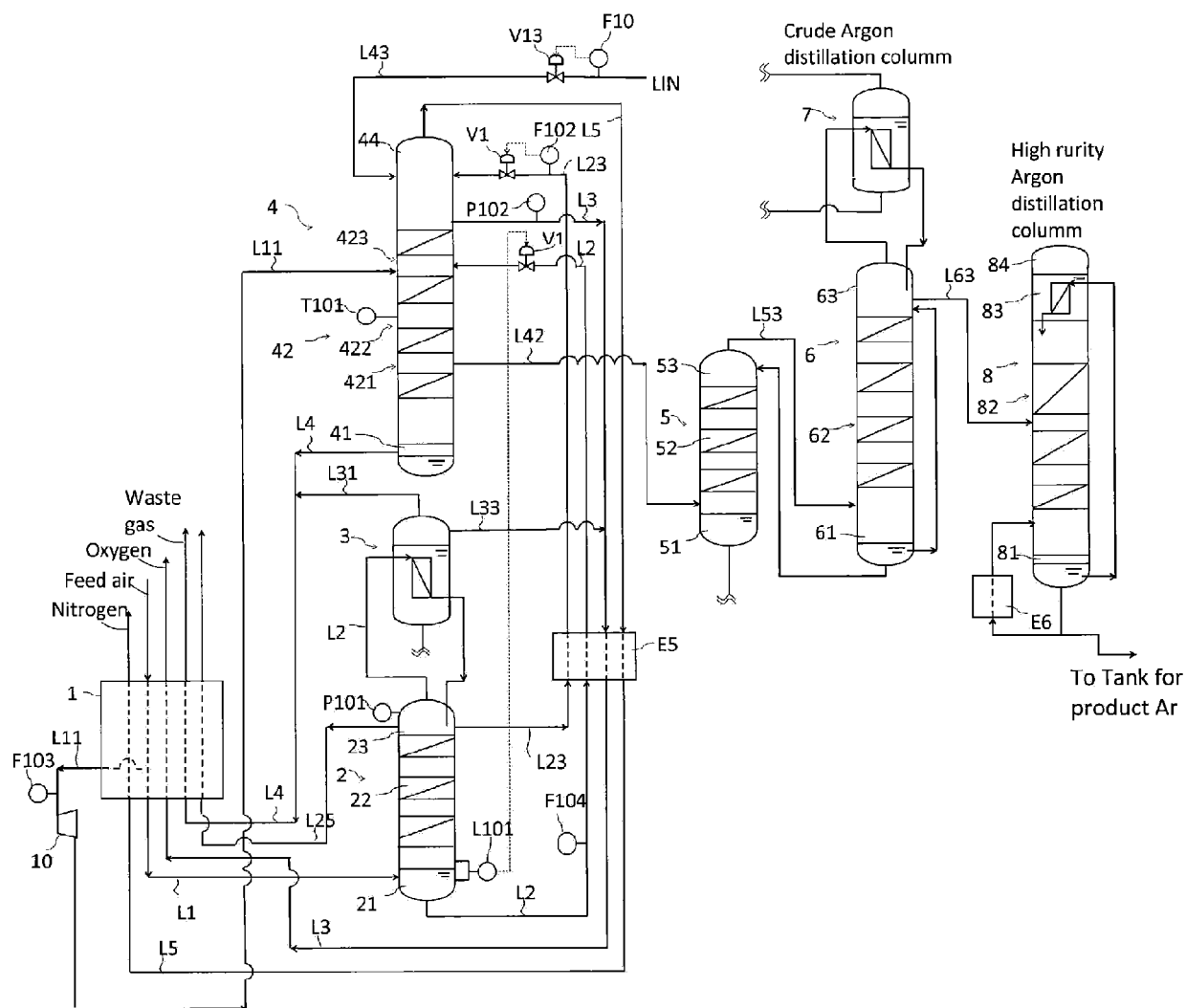
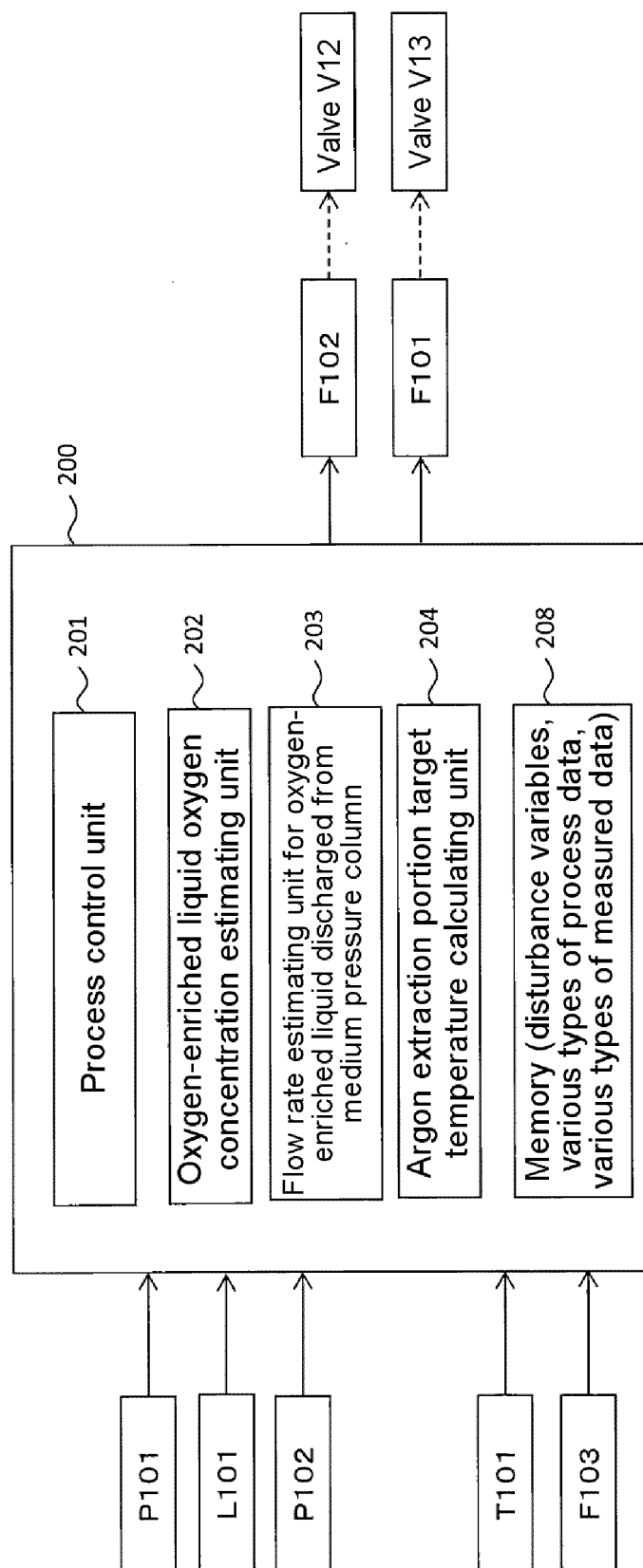


Figure 2





EUROPEAN SEARCH REPORT

Application Number
EP 20 21 6694

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DOCUMENTS CONSIDERED TO BE RELEVANT				
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A	* figure 1 * * column 1, line 42 - line 54 * * column 2, line 19 - column 3, line 4 * * column 4, line 23 - column 5, line 34 * * column 5, line 64 - line 75 *	2		
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A	* figure 3 * * column 7, line 23 - line 42 *	2		
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The present search report has been drawn up for all claims				
Place of search Munich		Date of completion of the search 21 May 2021	Examiner Karspeck, Sabine	
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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