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(54) **METHOD AND CRYOGENIC PRODUCTION ARRANGEMENT FOR PRODUCING A LIQUID NITROGEN PRODUCT**

(57) A method for producing a liquid nitrogen product using a cryogenic production arrangement (1000) comprising one or more air separation units (100), the or each of the air separation unit(s) (100) comprising a rectification column system (10), a main heat exchanger (3), and a nitrogen compressor (5) is proposed, wherein nitrogen is, in the order indicated, withdrawn from the rectification column system(s) (10), heated in the main heat exchanger(s) (3) and fed to the nitrogen compressor(s) (5) of the air separation unit(s) (100) in a first compressor feed amount. The arrangement (1000) further comprises one or more and one or more nitrogen liquefaction units (300), and in that the arrangement (1000) is operated in a first mode of operation and a second mode of operation, wherein the first compressor feed amount is made to be larger in the second mode of operation as compared to the first mode of operation by increasing a production capacity of the air separation unit(s) (100), wherein nitrogen withdrawn from the nitrogen compressor(s) (5) of the air separation unit(s) (100) is, in the first mode of operation, partially fed to the nitrogen liquefaction unit(s) (300) in a liquefaction feed amount, wherein, in the first mode of operation, the liquefaction feed amount is partially liquefied in the nitrogen liquefaction unit(s) (300) forming the liquid nitrogen product and leaving an unliquefied remainder, and wherein the unliquefied remainder is at least in part fed to the nitrogen compressor(s) (5) of the air separation unit(s) in a second com-

pressor feed amount. A corresponding arrangement (1000) is also part of the present invention.

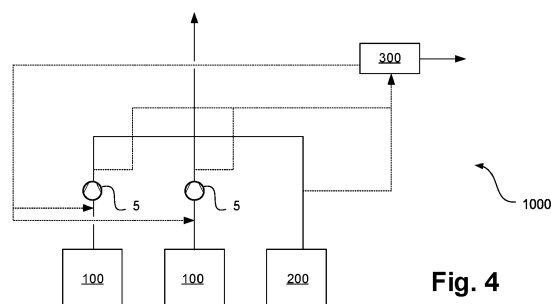


Fig. 4

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Description

[0001] The present invention relates to a method for producing a liquid nitrogen product and to a cryogenic production arrangement according to the pre-characterizing clauses of the independent claims.

Background

[0002] Liquid and gaseous air products may be produced by cryogenic separation of air in an air separation unit (ASU) as e.g. described in H.-W. Haring (ed.), Industrial Gases Processing, Wiley-VCH, 2006, especially section 2.2.5, "Cryogenic Rectification."

[0003] A cryogenic air separation unit comprises a rectification column system which is classically provided as a two-column system, in particular as a double-column system, but air separation units including single-, three- or multi-column systems are known as well. In addition to rectification columns for the recovery of nitrogen and/or oxygen in liquid and/or gaseous form, i.e. for nitrogen-oxygen separation, rectification columns can be provided for the recovery of further air components.

[0004] The rectification columns of the aforementioned column systems are operated at different pressures. Known double-column systems comprise a so-called pressure column (also referred to as a high-pressure column, medium-pressure column or lower column) and a so-called low-pressure column (upper column).

[0005] Air separation units can be designed differently depending on the air products to be supplied and their pressures and physical states. For example, so-called internal compression is used to provide pressurized gaseous air products, particularly oxygen. For internal compression, a cryogenic liquid is withdrawn from the rectification column system, subjected to a pressurization in liquid state, and converted to the gaseous or supercritical state by heating in the main heat exchanger. For details, reference is made to Haring (see above), Section 2.2.5.2, "Internal Compression."

[0006] For converting a pressurized, cryogenic liquid in an air separation unit including internal compression to the gaseous or supercritical state, a high-pressure counter-current stream of nitrogen or air is required for thermodynamic reasons. One possibility to provide a counter-current nitrogen stream is to use a so-called recycle nitrogen compressor (RNC). In a recycle nitrogen compressor, nitrogen which was withdrawn from the rectification column system and heated in the main air compressor is further compressed, passed through the main heat exchanger for the purpose mentioned, and thereafter expanded into the rectification column system in the form of so-called recycle nitrogen. Recycle nitrogen may particularly be withdrawn from the pressure column of a double-column system.

[0007] As an alternative to a dedicated recycle nitrogen compressor, nitrogen to be used as recycle nitrogen may also be withdrawn from a nitrogen product stream com-

pressed in a nitrogen product compressor. The present invention particularly relates to such an embodiment in which, in other words, nitrogen is withdrawn from the rectification column system, heated in the main heat exchanger, compressed in a nitrogen compressor (the term "compressor" also relating to certain compressor stages of a larger machine which may also compress further process streams or, more generally, any arrangement suitable for compressing a gas) and is in one part used as a nitrogen product and in a further part cooled in the main heat exchanger and recycled into the rectification column system.

[0008] The present invention is not limited to cases in which recycle nitrogen is used in the context of internal compression or any other specific configuration of an air separation unit such as defined by the number of columns, of the specific air product(s) produced, their physical state(s) and the production amount(s).

[0009] The present invention targets at improving air separation processes and apparatus in which recycle nitrogen streams are formed in the way just explained, i.e. by branching off a partial stream from a nitrogen product downstream of a nitrogen compressor.

Disclosure of the invention

[0010] Against this background, the present invention proposes method for producing a liquid nitrogen product and a cryogenic production arrangement including the features of the independent claims. Preferred embodiments are the subject of the dependent claims and of the description that follows.

[0011] The present invention particularly provides an advantageous solution for cases in which an air separation unit including a nitrogen compressor used for compressing a gaseous nitrogen product as well as recycle nitrogen is operated in turndown mode in certain phases. Such a turndown mode includes operating the air separation unit in an operation mode in which less air products are provided and less feed air is processed in the air separation unit, i.e. wherein the air separation unit is not operated at full load. This also results in the nitrogen compressor being only partially loaded and therefore not being fully utilized.

[0012] A turndown mode may also be the regular operation mode of an air separation unit which is part of a gas production arrangement including the one or several, e.g. two or three, air separation units. Such an arrangement may e.g. be adapted to provide air separation products to a semiconductor manufacturing plant (i.e. a so-called fab) or a different consumer. During normal operation, each of the air separation units in such an arrangement may operate in said turn-down mode, providing a certain degree of redundancy: If one of the air separation units needs to be shut down, e.g. for maintenance or in case of an equipment failure, the operating mode of the remaining air separation unit(s) may be changed to full load, compensating for the air separation unit being hav-

ing been shut down.

[0013] To tackle the problem of the nitrogen compressor being only partially loaded and therefore not being fully utilized in turndown mode, the present invention proposes to use the free capacity of the nitrogen compressor by providing a nitrogen liquefaction unit (NLU) and to compress unliquefied nitrogen this nitrogen liquefaction unit, at least partly substituting a recycle compressor in the nitrogen liquefaction unit.

[0014] Nitrogen liquefaction units are also well known from the art. Atypical example of a nitrogen liquefaction unit comprising two expansion turbines for gas is shown in Haussinger et al., Nitrogen, Ullmann's Encyclopedia of Industrial Chemistry, Wiley-VCH, 2005, page 10, paragraph "Nitrogen Liquefaction" and Figure 8 therein.

[0015] Nitrogen liquefaction in such a nitrogen liquefaction unit typically comprises compressing a first nitrogen feed stream from atmospheric pressure or slightly above in a first nitrogen compression unit, forming an intermediate pressure nitrogen stream. The intermediate pressure nitrogen stream is used in forming a second nitrogen feed stream which is further compressed in a second nitrogen compression unit, forming a high pressure nitrogen stream.

[0016] A first partial stream of the high pressure nitrogen stream is boosted to a yet higher pressure in serially arranged boosters coupled with expansion turbines. After boosting, the first partial stream is cooled in a heat exchanger system of the nitrogen liquefaction unit and expanded, using one of the expansion turbines and a throttle valve, into a phase separation vessel to form a liquid fraction and a gaseous fraction. The gaseous fraction is heated in the heat exchanger system and is combined with a second partial stream of the high pressure nitrogen stream which is, without being boosted, partially cooled in the heat exchanger system, expanded in the other one of the expansion turbines and heated as well in the heat exchanger system, thereby forming a gas stream which is used in forming the second nitrogen feed stream together with the intermediate pressure nitrogen stream.

[0017] The liquid phase formed in the phase separation vessel is subcooled against itself, forming a gaseous fraction which is used in forming the first nitrogen feed stream. A subcooled liquid fraction is provided as a nitrogen product.

[0018] The present invention proposes a method for producing a liquid nitrogen product using a cryogenic production arrangement comprising one or more (such as 2, 3, 4, 5 and up to 10) air separation units, the or each of the air separation unit(s) comprising a rectification column system, a main heat exchanger and a nitrogen compressor. According to the present invention, nitrogen is withdrawn from the rectification column system(s), heated in the main heat exchanger(s) and fed to the nitrogen compressor(s) of the (or each of the) air separation unit(s) in an amount referred to as "first compressor feed amount." As mentioned below, this first compressor feed

amount may be larger or smaller in different operating modes.

[0019] If reference is made to "nitrogen" herein, this is intended to not only relate to a fluid exclusively contain nitrogen but also to mixtures of components rich in nitrogen, "rich" denoting a content of at least 90, 95 or 99% on a molar, weight, or volume basis.

[0020] According to the present invention, the arrangement comprises one or more nitrogen liquefaction units which is or are used in forming the liquid nitrogen product. The arrangement is operated in a first mode of operation and a second mode of operation, wherein the first compressor feed amount is made to be larger in the second mode of operation as compared to the first mode of operation by increasing a load or production capacity of the air separation unit(s). In other words, the first mode of operation corresponds to a turndown mode of the air separation unit(s) and the second mode of operation corresponds to a mode wherein the air separation unit(s) is/are operated at a higher load as compared to the turndown mode, a "load" particularly corresponding to the amounts of fluids processed in, and provided by, the air separation unit(s).

[0021] Nitrogen withdrawn from the nitrogen compressor(s) of the air separation unit(s) is, in the first mode of operation, partially fed to the nitrogen liquefaction unit(s) in a liquefaction feed amount, wherein, in the first mode of operation, the liquefaction feed amount is partially liquefied in the nitrogen liquefaction unit(s) forming the liquid nitrogen product and leaving an unliquefied remainder, and wherein the unliquefied remainder is, in the first mode of operation, at least in part fed to the nitrogen compressor(s) of the air separation unit(s) in a second compressor feed amount.

[0022] Advantages of operating the arrangement according to the present invention, which includes utilizing the "free" capacity of the nitrogen compressor(s) for compressing further nitrogen have already been explained before.

[0023] According to the present invention, preferably further nitrogen withdrawn from the nitrogen compressor(s) of the air separation unit(s) is, in the order indicated, withdrawn from the nitrogen compressor(s), cooled in the main heat exchanger(s) and recycled to the rectification column system(s) of the air separation unit(s) in a recycle amount. Also the recycle amount may be larger or smaller in different operating modes. The recycle amount is typically smaller than the first compressor feed amount as a further part of the nitrogen compressed in the nitrogen compressor(s) is used as a nitrogen product.

[0024] In the second mode of operation as compared to the first mode of operation, particularly less nitrogen withdrawn from the nitrogen compressor(s) of the first air separation unit(s), or no such nitrogen, is fed to the nitrogen liquefaction unit(s).

[0025] In an embodiment, the arrangement comprises the air separation units as (a) first air separation unit(s) and further comprises one or more second air separation

units not comprising a nitrogen compressor and providing compressed gaseous nitrogen to the nitrogen liquefaction unit(s).

[0026] According to a particularly preferred embodiment of the present invention, three first air separation units, one second air separation unit, and one nitrogen liquefaction unit may be used. This configuration has been shown to be operable in a particularly balanced manner best utilizing the resources available.

[0027] In the second mode of operation as compared to the first mode of operation, particularly less nitrogen withdrawn from the nitrogen compressor(s) of the first air separation unit(s), or no such nitrogen, is fed to the nitrogen liquefaction unit(s).

[0028] Furthermore, in the first and the second mode of operation, further nitrogen withdrawn from the nitrogen compressor(s) of the first air separation unit(s) may be used for forming a pressurized gaseous liquid nitrogen product, as mentioned before.

[0029] In the first mode of operation and in the second mode of operation according to the invention, particularly no nitrogen withdrawn from the nitrogen compressor(s) of the first air separation unit(s) is fed to the second air separation unit(s), the second air separation unit(s) being particularly adapted to be operated without recycle nitrogen.

[0030] In any case, the nitrogen liquefied using the nitrogen liquefaction unit(s) may be directly used or may be stored for later retrieval, e.g. in a tank system.

[0031] The method the present invention may particularly include that, in the first mode of operation, the nitrogen fed to the nitrogen liquefaction unit(s) is further compressed in the liquefaction unit(s), as generally mentioned before. Only such (further) compression is required as the main compression tasks are realized by the nitrogen compressor(s) of the first air separation unit(s).

[0032] According to the present invention, in the first mode of operation, the first compressor feed amount may be fed to the nitrogen compressor(s) of the air separation unit(s) at an absolute pressure of 2 to 4 bar, the liquefaction feed amount may be fed to the nitrogen liquefaction unit(s) at an absolute pressure of 9 to 14 bar, and the liquefaction feed amount may be further compressed in the liquefaction unit(s) to a pressure of 13 to 25 bar. For specific advantages, reference is made to the explanations above.

[0033] A cryogenic production arrangement for producing a liquid nitrogen product comprising one or a plurality of air separation units is also part of the present invention. The or each of the air separation unit(s) comprise(s) a rectification column system, a main heat exchanger and a nitrogen compressor, and the production arrangement is adapted for nitrogen, in the order indicated, to be withdrawn from the rectification column system(s), heated in the main heat exchanger(s) and fed to the nitrogen compressor(s) of the first air separation unit(s) in a first compressor feed amount.

[0034] According to the present invention, the arrangement comprises one or more nitrogen liquefaction units adapted to form the liquid nitrogen product, and the arrangement is adapted to be operated in a first mode of operation and a second mode of operation, wherein the first compressor feed amount is made to be larger in the second mode of operation as compared to the first mode of operation by increasing a load of the first air separation unit(s). Nitrogen withdrawn from the nitrogen compressor(s) of the air separation unit(s) is, in the first mode of operation, partially fed to the nitrogen liquefaction unit(s) in a liquefaction feed amount, wherein, in the first mode of operation, the liquefaction feed amount is partially liquefied in the nitrogen liquefaction unit(s) forming the liquid nitrogen product and leaving an unliquefied remainder, and wherein the unliquefied remainder is at least in part fed to the nitrogen compressor(s) of the air separation unit(s) in a second compressor feed amount.

[0035] As to further features and advantages of the arrangement according to the present invention and preferred embodiments thereof, specific reference is made to the explanations above relating to the inventive method and its embodiments. This particularly holds for an arrangement which is adapted to perform a method as explained above in different embodiments, such an arrangement also being provided according to an embodiment of the present invention.

[0036] Further advantageous embodiments of the invention will now be described with reference to the appended drawings.

Short description of the Figures

[0037]

Figure 1 schematically illustrates an air separation unit which may be part of an arrangement according to an embodiment of the present invention.

Figure 2 schematically illustrates a nitrogen liquefaction unit which may be part of an arrangement according to an embodiment of the present invention.

Figure 3 schematically illustrates a further air separation unit which may be part of an arrangement according to an embodiment of the present invention.

Figure 4 schematically illustrates an arrangement according to an embodiment of the present invention in a simplified block diagram.

Embodiments of the invention

[0038] Hereinbelow, explanations relating to specific method steps likewise apply to hardware components, plant units and the like used for performing such method steps, and vice versa. Repeated explanations of method

steps or hardware components with an identical or comparable function and/or of identical or similar technical realisation are not repeated for reasons of conciseness.

[0039] In Figure 1, an air separation unit which may be (particularly as a "first" air separation unit) part of an arrangement according to an embodiment of the invention, is designated 100.

[0040] As essential components, the air separation unit 100 comprises a compression section 1, an air pre-purification unit 2, a main heat exchanger 3, and a rectification column system 10. The rectification column system 10 comprises, in the embodiment shown, a high pressure column or pressure column 11, a low pressure column subdivided into a first column section 12a and a second column section 12b, a crude argon column subdivided into a first column section 13a and a second column section 13b, a pure argon column 14, and a column 15 for providing ultrapure oxygen.

[0041] In the air separation unit 100, a stream of atmospheric air is aspirated by the compression section 1, as generally known in the art, and prepurified in the pre-purification section 2. A stream of prepurified and compressed air thus formed is introduced into the main heat exchanger 3 and withdrawn therefrom at its cold end. The cooled and particularly essentially liquefied stream of air thus formed is introduced as a stream a into the high-pressure column 11 of the rectification column system 10.

[0042] Operation of the rectification column system 10, which may also be configured differently, may essentially correspond to the operation of a conventional air separation unit. The division of the low pressure column into the first column section 12a and the second column section 12b is preferably such that the position of division corresponds to a position of the argon maximum or a position in proximity thereto, such that the crude argon column may be supplied with gas withdrawn from the top of column section 12a of the low pressure column. With the exception of the crude argon column being subdivided into the first column section 13a and the second column section 13, its operation may correspond to the operation of a regular, undivided argon column.

[0043] An essential aspect of the operation of the rectification column system 10 as shown in figure 1 is that, from the top of the second section 12b of the low-pressure column (like it would be the case for the top of an undivided low pressure column), a stream c of nitrogen is withdrawn and, after having been passed through a counter-stream subcooler 4, heated in the main heat exchanger 3. The heated stream c, now referred to with d, is partially or fully compressed in a nitrogen compressor 5, forming a compressed nitrogen stream e.

[0044] A partial stream f of the compressed nitrogen stream e is withdrawn from the air separation unit 100 as a compressed nitrogen product, while a further partial stream g of the compressed nitrogen stream e is used as a nitrogen recycle and, to this purpose, cooled in the main heat exchanger 3, thereafter passed through a main

condenser thermally connecting the pressure column 11 and the first section 12a of the low pressure column together with gas withdrawn from the top of the pressure column 11 and, after having been liquefied in the main condenser, fed into the pressure column 11 and/or to the upper part of the second section 12b of the low pressure column.

[0045] The air separation unit 100 may particularly be adapted to provide a stream h of pure argon which may be passed through a subcooler 6 and which may thereafter be stored in a liquid argon tank 7. Liquid argon from tank 7 may be gasified using the main heat exchanger 3 to form a gaseous argon product.

[0046] As a further product of the air separation unit 100, a stream i of (ultra)pure oxygen may be provided and e.g. pressurized in a run tank system 9 or using a pump (not shown). The air separation unit 100 is operated using a rest gas turbine to which a stream k of impure nitrogen may be provided as generally known in the art.

[0047] As mentioned before, operation of the air separation unit 100 as shown in figure 1 in a turn-down mode particularly results in a partial load of the nitrogen compressor 5 such that its capacity is not fully utilized. Turn-down mode operation of the air separation unit 100 may, as also explained before, also be the regular mode of operation of the air separation unit 100 in an arrangement comprising several such units 100, e.g. for supplying nitrogen to a semiconductor manufacturing unit.

[0048] Figure 2 illustrates a nitrogen liquefaction unit which may be used in an arrangement according to an embodiment of the present invention. The nitrogen liquefaction unit shown in figure 2 is designated 300. It comprises a feed compressor 310, booster/expander arrangements 320 and 330, a heat exchanger 340, a phase separation vessel 350, a subcooler 360 and a liquid nitrogen storage tank 370.

[0049] A feed stream of nitrogen A is fed into the nitrogen liquefaction unit 300 at an absolute pressure of e.g. about 12 bar. After further compression in the feed compressor 310, e.g. to an absolute pressure of about 17.9 bar, the nitrogen is subdivided into a first partial stream B and a second partial stream C.

[0050] The nitrogen of stream B is serially boosted in boosters of the booster/expander combinations 320 and 330 and is afterwards, at an absolute pressure of e.g. about 46 bar, partially liquefied in the heat exchanger 340, forming a stream C, which is passed into the phase separation vessel 350. A partial stream of stream B is, after having been partially cooled in the heat exchanger 340, withdrawn therefrom and, as a stream E, expanded in the expander of the booster/expander combination 330, e.g. to an absolute pressure of about 3.5 bar. Stream E is thereafter also fed into the phase separation vessel 350 at the bottom of which a liquid phase forms, which is withdrawn as stream F, cooled against itself in the subcooler 360, and, in a subcooled state, stored in the liquid nitrogen storage tank 370.

[0051] Partial stream C mentioned already before is

partially cooled in the heat exchanger 340 and thereafter expanded in the expander of the booster/expander combination 320, before it is combined, in the heat exchanger 340, with a gas phase withdrawn from the top of phase separation vessel 350. Said combined gas phase, i.e. a stream G of so-called recycle nitrogen, is withdrawn from the nitrogen liquefaction unit 300 as shown in figure 2 at an absolute pressure of e.g. about 3 bar. A gas phase (not specifically indicated) forming in the subcooler 360 is vented to the atmosphere (as shown) or separately compressed to e.g. about 3 bar abs. and mixed to the stream G.

[0052] Figure 3 illustrates an air separation unit which may be used (as a "second" air separation unit) in an arrangement according to an embodiment of the present invention. The air separation unit shown in figure 3 is designated 200. Air separation units of the type shown in figure 3 and variants thereof have been extensively described elsewhere, such as e.g. in EP 2 789 958 A1, and detailed explanations are therefore omitted. Particularly, and in contrast to the air separation unit 100 as illustrated in figure 1, the air separation unit 200 as illustrated in figure 3 features a single rectification column 210 in the rectification column system 10.

[0053] In figure 4, an arrangement according to a particularly preferred embodiment of the present invention is shown and designated 1000. The arrangement 1000 is shown in a strictly simplified manner and includes, in the example shown, two "first" air separation units, such as the air separation unit 100 shown in figure 1, which are therefore designated accordingly in figure 4, and one "second" air separation unit, e.g. as shown in figure 3, which is therefore designated 200.

[0054] The nitrogen compressors of the first air separation units 100 are shown separately and are indicated 5, essentially as in figure 1. A nitrogen liquefaction unit is also part of the arrangement shown in an embodiment in figure 4. The nitrogen liquefaction unit may be provided as shown in figure 2 and is therefore designated 300.

[0055] As shown with dashed lines in figure 4, the nitrogen compressors 5 of the first air separation units 100, which operate in a turn-down mode in the illustration of figure 4, are supplied with additional nitrogen from nitrogen liquefaction unit 300, particularly with nitrogen in the form of recycle nitrogen at an absolute pressure of, e.g. about 3 bar. A part of the nitrogen compressed in the nitrogen compressors 5 of the first air separation units 100 is provided as a nitrogen product, as indicated with a solid arrow, and further nitrogen is, as again shown with dashed lines, withdrawn from the nitrogen product at a pressure of, in the example shown, e.g. about 12 bar and passed through to the nitrogen liquefaction unit 300, together with further nitrogen from the second air separation unit 300.

Claims

1. A method for producing a liquid nitrogen product using a cryogenic production arrangement (1000) comprising one or more air separation units (100), the or each of the air separation unit(s) (100) comprising a rectification column system (10), a main heat exchanger (3), and a nitrogen compressor (9), wherein nitrogen is, in the order indicated, withdrawn from the rectification column system(s) (10), heated in the main heat exchanger(s) (3) and fed to the nitrogen compressor(s) (9) of the air separation unit(s) (100) in a first compressor feed amount, **characterized in that** the arrangement (1000) further comprises one or more nitrogen liquefaction units (300), and **in that** the arrangement (1000) is operated in a first mode of operation and a second mode of operation, wherein the first compressor feed amount is made to be larger in the second mode of operation as compared to the first mode of operation by increasing a nitrogen production capacity of the air separation unit(s) (100), wherein nitrogen withdrawn from the nitrogen compressor(s) (5) of the air separation unit(s) (100) is, in the first mode of operation, partially fed to the nitrogen liquefaction unit(s) (300) in a liquefaction feed amount, wherein, in the first mode of operation, the liquefaction feed amount is partially liquefied in the nitrogen liquefaction unit(s) (300) forming the liquid nitrogen product and leaving an unliquefied remainder, and wherein the unliquefied remainder is at least in part fed to the nitrogen compressor(s) (5) of the air separation unit(s) in a second compressor feed amount.
2. The method according to claim 1, wherein further nitrogen withdrawn from the nitrogen compressor(s) (5) of the air separation unit(s) (100) is, in the order indicated, withdrawn from the nitrogen compressor(s) (5), cooled in the main heat exchanger(s) (3) and recycled to the rectification column system(s) (10) of the air separation unit(s) in a recycle amount.
3. The method according to claim 1 or according to claim 2, wherein further nitrogen withdrawn from the nitrogen compressor(s) (5) of the air separation unit(s) (100) is used as a gaseous nitrogen product.
4. The method according to any one of the preceding claims, wherein, in the second mode of operation as compared to the first mode of operation, less or no nitrogen withdrawn from the nitrogen compressor(s) (5) of the air separation unit(s) (100) is fed to the nitrogen liquefaction unit(s) (300).
5. The method according to any one of the preceding claims, wherein the arrangement (1000) comprises the air separation units (100) as first air separation unit(s) (100) and further comprises one or more sec-

ond air separation units (200) not comprising a nitrogen compressor (5) and providing compressed gaseous nitrogen to the nitrogen liquefaction unit(s) (300).

6. The method according to claim 5, wherein, neither in the first nor in the second mode of operation, nitrogen withdrawn from the nitrogen compressor(s) (5) of the first air separation unit(s) (100) is fed to the second air separation unit(s) (200). 5
7. The method according to any one of the preceding claims, wherein the nitrogen liquefied using the nitrogen liquefaction unit(s) (300) is stored for later retrieval. 10 15
8. The method according to any one of the preceding claims, wherein, in the first mode of operation, the nitrogen fed to the nitrogen liquefaction unit(s) (300) in the liquefaction amount is further compressed in the liquefaction unit(s) (300). 20
9. The method according to claim 8, wherein, in the first mode of operation, the first compressor feed amount is fed to the nitrogen compressor(s) (5) of the air separation unit(s) (100) at an absolute pressure of 2 to 4 bar, the liquefaction feed amount is fed to the nitrogen liquefaction unit(s) (300) at an absolute pressure of 9 to 14 bar, and/or the liquefaction feed amount is further compressed in the liquefaction unit(s) (300) to a pressure of 13 to 25 bar. 25 30
10. A cryogenic production arrangement (1000) for producing a liquid nitrogen product comprising one or more air separation units (100), the or each of the air separation unit(s) (100) comprising a rectification column system (10), a main heat exchanger (3) and a nitrogen compressor (5), wherein the arrangement (1000) is adapted, in the order indicated, for nitrogen to be withdrawn from the rectification column system(s) (10), heated in the main heat exchanger(s) (3) and fed to the nitrogen compressor(s) (5) of the air separation unit(s) (100) in a first compressor feed amount, **characterized in that** the arrangement (1000) further comprises one or more and one or more nitrogen liquefaction units (300), and **in that** the arrangement (1000) is adapted to be operated in a first mode of operation and a second mode of operation, wherein the first compressor feed amount is made to be larger in the second mode of operation as compared to the first mode of operation by increasing a nitrogen production capacity of the air separation unit(s) (100), wherein nitrogen withdrawn from the nitrogen compressor(s) (5) of the air separation unit(s) (100) is, in the first mode of operation, partially fed to the to the nitrogen liquefaction unit(s) (300) in a liquefaction feed amount, wherein, in the first mode of operation, the liquefaction feed amount 35 40 45 50 55

is partially liquefied in the nitrogen liquefaction unit(s) (300) forming the liquid nitrogen product and leaving an unliquefied remainder, and wherein the unliquefied remainder is at least in part fed to the nitrogen compressor(s) (5) of the air separation unit(s) in a second compressor feed amount.

11. The arrangement (1000) according to claim 10, comprising means adapted to perform a method according to any one of claims 1 to 9.

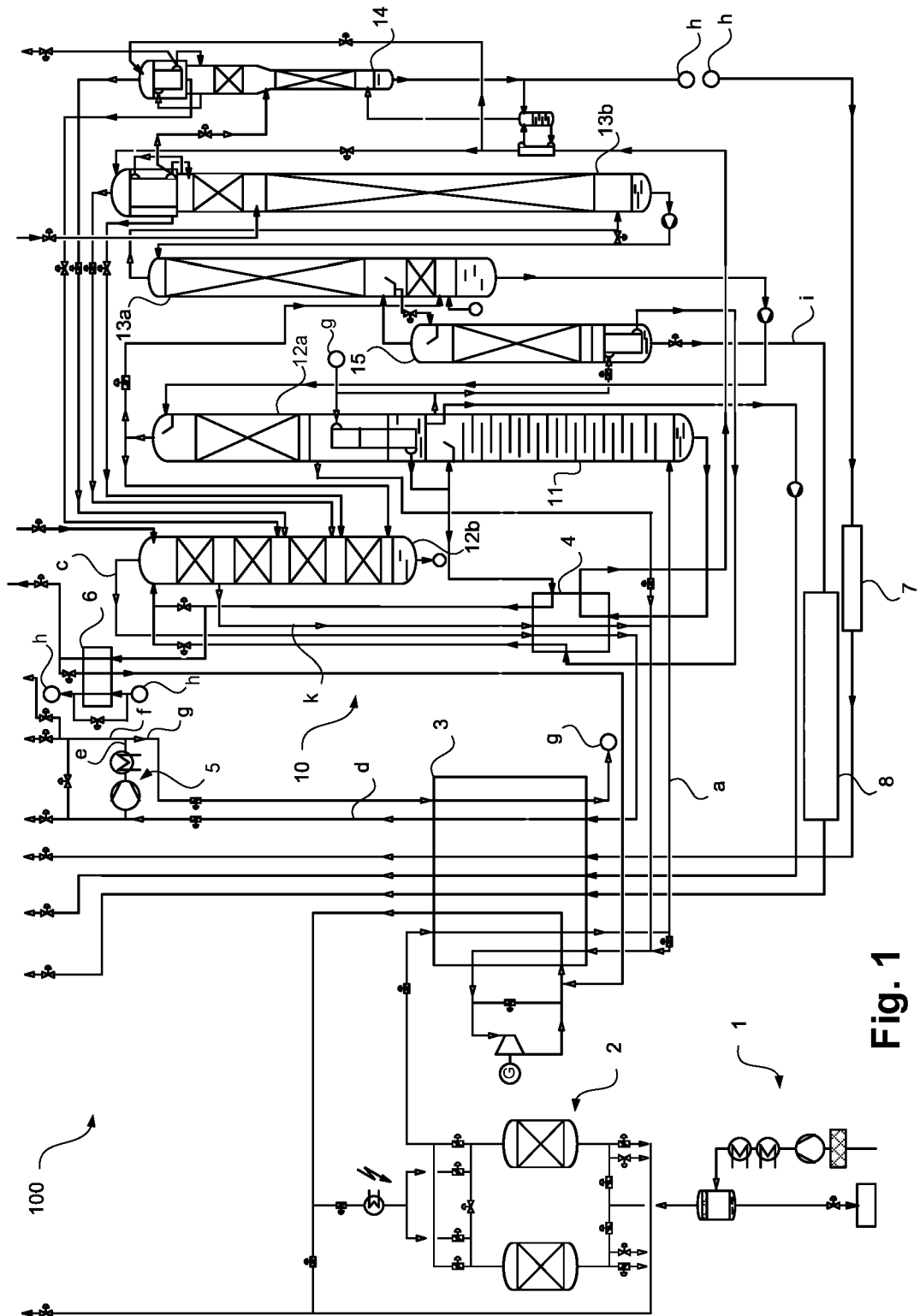


Fig. 1

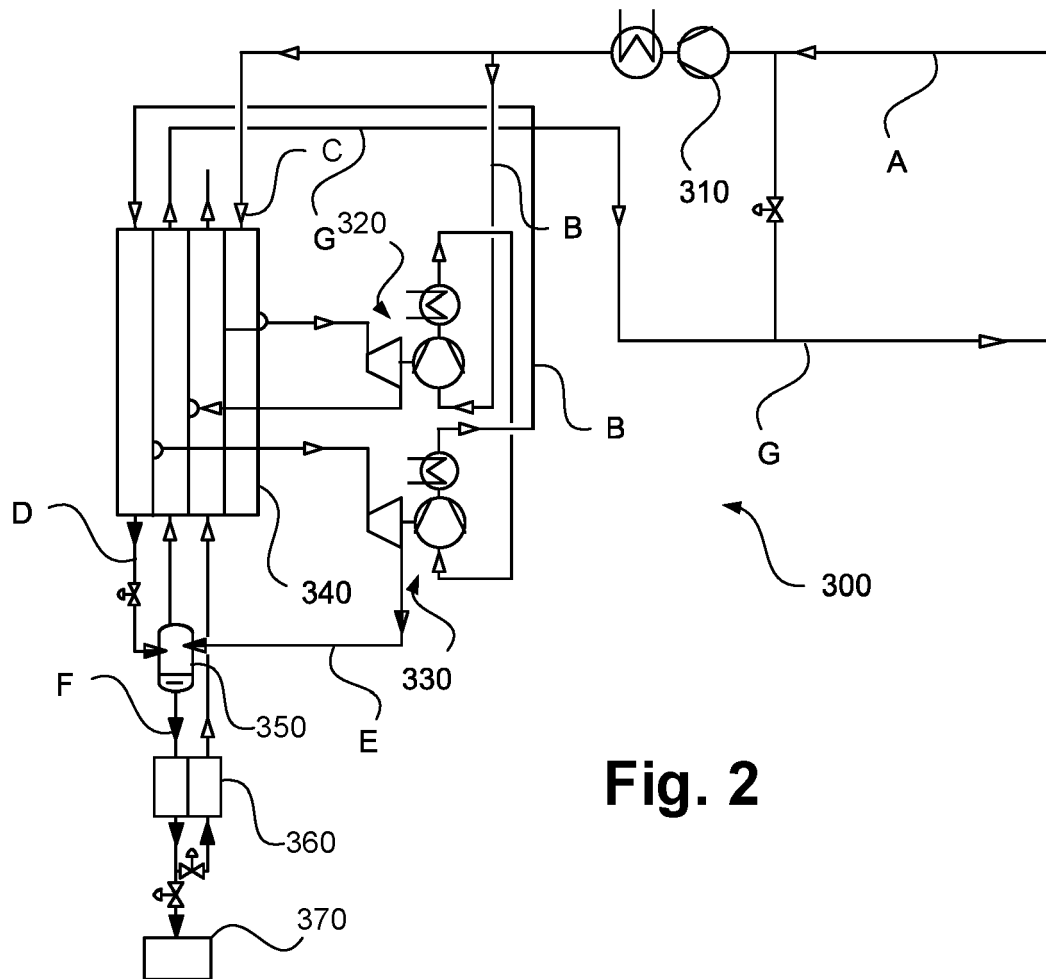


Fig. 2

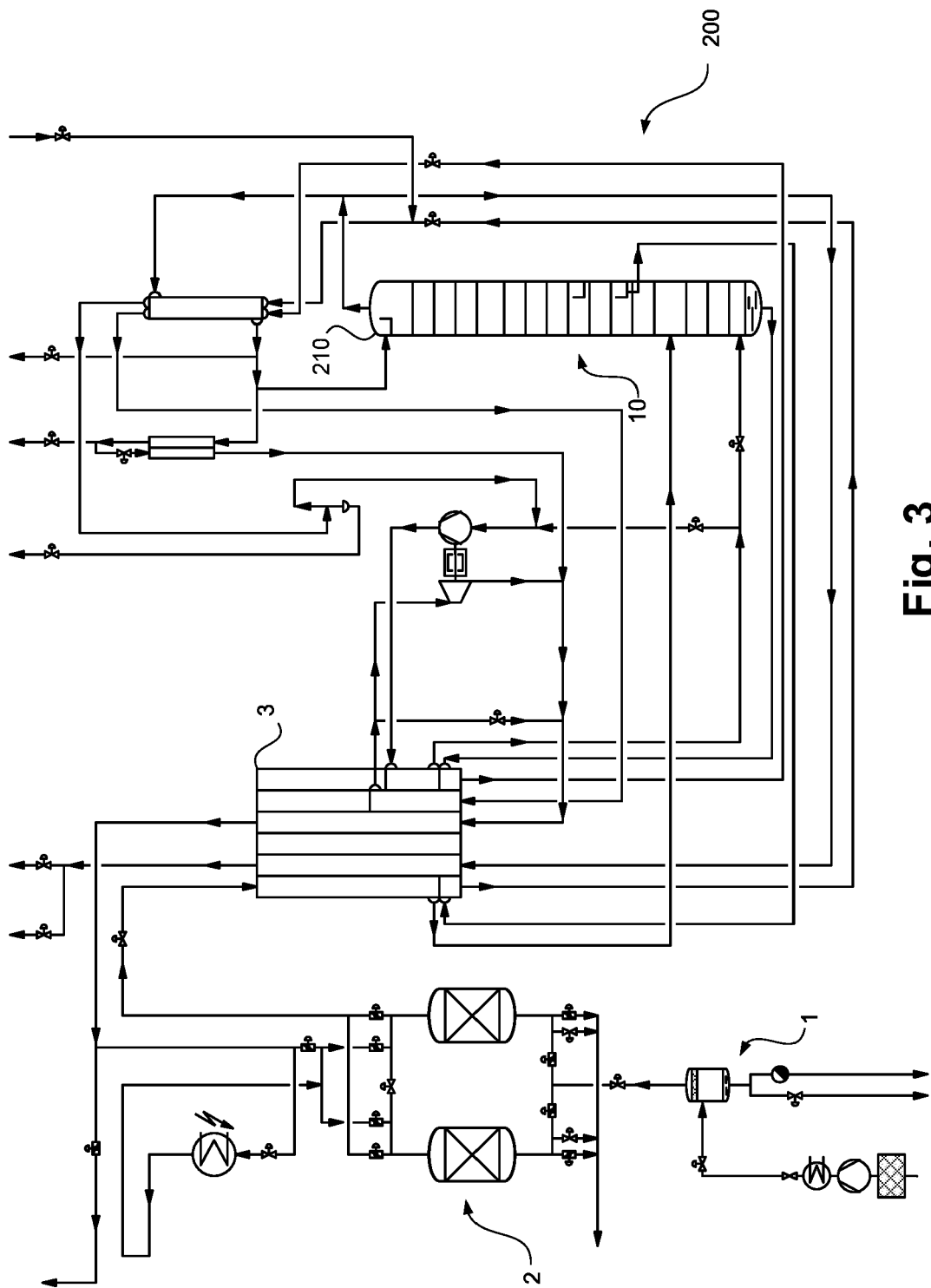


Fig. 3

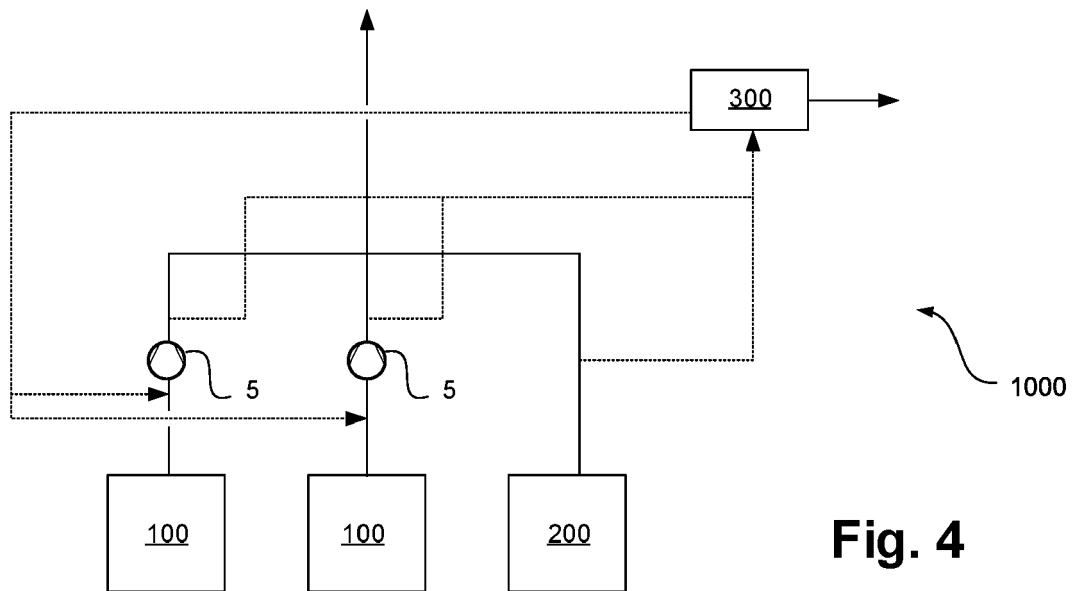


Fig. 4



EUROPEAN SEARCH REPORT

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	CN 210 119 067 U (LAN WENXU) 28 February 2020 (2020-02-28)	1, 7-11	INV. F25J3/04
Y	* figures 1-3 *	2, 3, 5, 6	F25J1/00
A		4	F25J1/02
X	----- "System and Method to Supply Gaseous Nitrogen from a LNG-based Liquefier Associated with Air Separation ED - Darl Kuhn", IP.COM, IP.COM INC., WEST HENRIETTA, NY, US, 28 December 2010 (2010-12-28), XP013143217, ISSN: 1533-0001	1, 3, 7-11	
Y	* page 1, paragraph 1; figures 2-6 *	5, 6	
A		2, 4	
Y	----- ADRIAN CASPARI ET AL: "A flexible air separation process: 1. Design and steady-state optimizations", AICHE JOURNAL, JOHN WILEY & SONS, INC, US, vol. 65, no. 11, 17 July 2019 (2019-07-17), XP071010698, ISSN: 0001-1541, DOI: 10.1002/AIC.16705 * page 2, paragraph 2.1 - page 4, paragraph 2.2; figure 1 * * page 10 - paragraph 5.5; figure 6 *	1-11	TECHNICAL FIELDS SEARCHED (IPC) F25J
Y	----- EP 3 339 784 A1 (LINDE AG [DE]) 27 June 2018 (2018-06-27) * paragraphs [0018] - [0020]; figures 1, 4 *	1-11	
Y	----- WO 2021/204424 A2 (LINDE GMBH [DE]) 14 October 2021 (2021-10-14) * page 17, line 31 - page 18, line 6; figure 4 *	5, 6	

The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 4 May 2022	Examiner Göritz, Dirk
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-11 (partially)

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).



LACK OF UNITY OF INVENTION SHEET B

Application Number

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The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-11 (partially)

A method for producing a liquid nitrogen product using a cryogenic production arrangement comprising one (and not more than one) air separation unit, the air separation unit comprising a rectification column system, a main heat exchanger, and a nitrogen compressor, wherein nitrogen is, in the order indicated, withdrawn from the rectification column system, heated in the main heat exchanger and fed to the nitrogen compressor of the air separation unit in a first compressor feed amount, characterized in that the arrangement further comprises one or more nitrogen liquefaction units, and in that the arrangement is operated in a first mode of operation and a second mode of operation, wherein the first compressor feed amount is made to be larger in the second mode of operation as compared to the first mode of operation by increasing a nitrogen production capacity of the air separation unit, wherein nitrogen withdrawn from the nitrogen compressor of the air separation unit is, in the first mode of operation, partially fed to the nitrogen liquefaction unit(s) in a liquefaction feed amount, wherein, in the first mode of operation, the liquefaction feed amount is partially liquefied in the nitrogen liquefaction unit(s) forming the liquid nitrogen product and leaving an unliquefied remainder, and wherein the unliquefied remainder is at least in part fed to the nitrogen compressor of the air separation unit in a second compressor feed amount.

2. claims: 1-11 (partially)

A method for producing a liquid nitrogen product using a cryogenic production arrangement comprising more than one air separation units, each of the air separation units comprising a rectification column system, a main heat exchanger, and a nitrogen compressor, wherein nitrogen is, in the order indicated, withdrawn from the rectification column systems, heated in the main heat exchangers and fed to the nitrogen compressors of the air separation units in a first compressor feed amount, characterized in that the arrangement further comprises one or more nitrogen liquefaction units, and in that the arrangement is operated in a first mode of operation and a second mode of operation, wherein the first compressor feed amount is made to be larger in the second mode of operation as compared to the first mode of operation by increasing a nitrogen production capacity of the air separation units, wherein nitrogen withdrawn from the nitrogen compressors of the air separation units is, in the first mode of operation, partially fed to the nitrogen liquefaction unit(s) in a



LACK OF UNITY OF INVENTION
SHEET B

Application Number

EP 21 02 0577

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

liquefaction feed amount, wherein, in the first mode of operation, the liquefaction feed amount is partially liquefied in the nitrogen liquefaction unit(s) forming the liquid nitrogen product and leaving an unliquefied remainder, and wherein the unliquefied remainder is at least in part fed to the nitrogen compressors of the air separation units in a second compressor feed amount.

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 21 02 0577

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

04-05-2022

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 210119067 U	28-02-2020	NONE	
EP 3339784 A1	27-06-2018	NONE	
WO 2021204424 A2	14-10-2021	TW 202140974 A WO 2021204424 A2	01-11-2021 14-10-2021

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP 2789958 A1 [0052]

Non-patent literature cited in the description

- Cryogenic Rectification. Industrial Gases Processing. Wiley-VCH, 2006 [0002]
- Nitrogen Liquefaction. **HAUSSINGER et al.** Nitrogen, Ullmann's Encyclopedia of Industrial Chemistry. Wiley-VCH, 2005, 10 [0014]