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(54) **PROCESS AND APPARATUS FOR AIR SEPARATION BY CRYOGENIC DISTILLATION**

(57) In an air separation process by distillation, a portion of air is compressed, condensed, expanded, vaporised and sent back to the compression step and a gaseous nitrogen stream (13) is removed from a distillation column (K01), warmed in a heat exchanger, expanded

in a turbine (T03), warmed in the heat exchanger and sent to the atmosphere, wherein the expanded gaseous nitrogen corresponds to between 5 and 10% mol of the feed air compressed in the first air compressor.

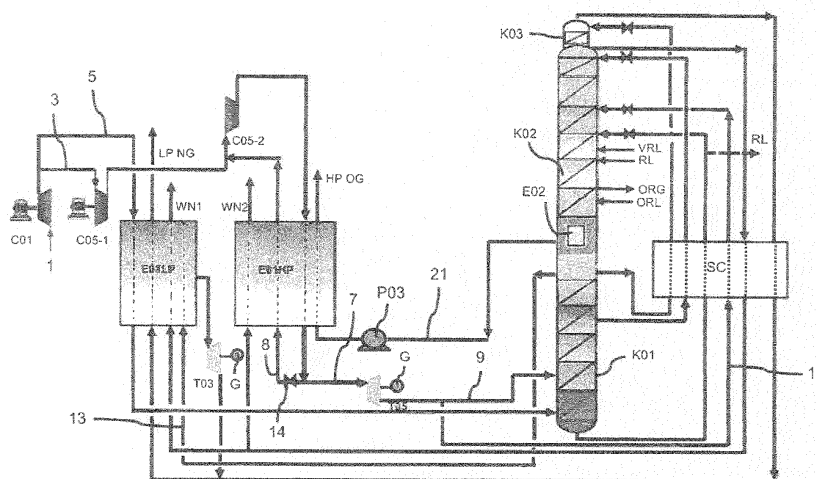


Figure 1

Description

[0001] The present invention relates to a process and apparatus for air separation by cryogenic distillation. In particular, it relates to processes and apparatus for producing oxygen under high pressure.

[0002] Oxygen gas produced by air separation units often has a high pressure of about 20 to 50 bar. The production process is usually a dual column process involving a first column operating at a first column pressure and a second column operating at a second column pressure, lower than the pressure of the first column. The top of the first column is thermally linked to the bottom of the second column. Oxygen is produced at the bottom of the second column, operating under a pressure of 1 to 4 bar. Oxygen is compressed to a higher pressure, using an oxygen compressor or by pumping liquid oxygen. Due to safety problems associated with the oxygen compressors, oxygen production units generally use the process involving pumping and then vaporizing liquid. To vaporize the liquid oxygen at high pressure, an additional booster compressor is used to raise a portion of feed air or nitrogen to higher pressure, in the range of 40 to 80 bar. In essence, the booster replaces the oxygen compressor. One of the goals of the development of new cycles according to the invention is to reduce the power consumption of a production unit of oxygen.

[0003] In an effort to reduce the power consumption, it is desirable to introduce all supply air flows into the columns at a temperature close to the temperature of the column, at the point where the irreversibilities are introduced, to reduce the thermodynamics of the system. Unfortunately, this cannot be done with a classical pumping cycle.

[0004] The present invention therefore aims to address the shortcomings of these process, in particular by introducing all feed air flows into the columns at a temperature close to the temperature of the column at the point where the flow is introduced, in order to reduce thermodynamic irreversibilities of the system without using additional stage of compression. The overall cost of the products of a production unit of oxygen can therefore be reduced. The main improvement results from the use of a booster air compressor air to recirculate the air once it has been used to recover the heat produced by the vaporization of a high pressure liquid in the primary heat exchanger.

[0005] All the percentages mentioned are molar percentages by moles.

[0006] According to the present invention there is provided an air separation process by distillation in a cryogenic column system comprising a first column operating at a pressure and a second column operating at a lower pressure than the first column, comprising the steps of:

- i) compression of all the feed air in a first air compressor to a first outlet pressure which not more than one bar higher than and preferably substantially equal to the pressure at which the first column op-

erates,

- ii) sending a gas which is a first gaseous portion of the air at the first pressure or a stream of nitrogen to a second compressor, compressing the gas to a second pressure which is the outlet pressure of the second compressor, compressing the gas at the second pressure to a third pressure which is the outlet pressure of a third compressor

- iii) cooling and condensation or pseudo condensation at the third pressure of at least a portion of the gas compressed in the third compressor in the heat exchanger,

- iv) sending at least part of the air, preferably a second gaseous air portion under the first outlet pressure to the system of columns, without further compression, and separation of the at least part of the air, preferably the second gaseous air portion, in the system of columns,

- v) withdrawing liquid oxygen from the second column, pressurizing of the liquid oxygen and vaporizing of the liquid oxygen by heat exchange in the heat exchanger, and

- vi) expanding at least one fraction of the cooled and condensed gas from at least the third pressure to a fourth pressure, at least partially vaporizing the expanded gas, preferably air, in the heat exchanger at the fourth pressure, the fourth pressure being between the first pressure and the third pressure at which the gas condenses or pseudo-condenses in step iii), optionally heating the at least partially vaporized said gas, preferably air in the heat exchanger, sending at least a portion of the vaporised gas, preferably air, to the third compressor to be compressed to the third pressure

characterized in that at least 50%, preferably at least 90%, of the refrigeration for the process is provided by removing a gaseous nitrogen stream from the first column, warming the gaseous nitrogen in the heat exchanger, expanding the warmed gaseous nitrogen in a turbine, warming the expanded gaseous nitrogen in the heat exchanger and sending it to the atmosphere, wherein the expanded gaseous nitrogen corresponds to between 5 and 10% mol of the feed air compressed in the first air compressor.

[0007] According to other optional features of the invention which may be combined together:

- the expansion of the gas, preferably air, from the third pressure to the fourth pressure is performed in at least one valve or in at least one turbine, the fourth pressure preferably being subcritical.
- no part of the feed air is expanded in gaseous form in a turbine
- the temperature of the at least one fraction before expansion is lower than the sum of the vaporization temperature of the liquid oxygen and the minimum temperature approach in the heat exchanger in

which the fraction vaporises.

- the inlet temperature of the at least one fraction immediately before expansion is below room temperature.
- the second gaseous air portion represents at least 90% of the gaseous feed air entering the column system.
- the heat exchanger comprises two sections, one section in which the second gaseous air portion is cooled by warming the nitrogen to be expanded in the turbine and another section in which the liquid oxygen and condensed air vaporize by cooling the air to be condensed.
- part of the refrigeration of the process is provided by Joule-Thomson expansion
- the heat exchanger comprises two sections, one section in which the gaseous nitrogen to be sent to the second compressor is warmed, all the air at the first outlet pressure is cooled and the nitrogen to be expanded in the turbine is warmed and another section in which the liquid oxygen and condensed nitrogen vaporizes by cooling the nitrogen to be condensed after compression in the second and third compressors.
- expanding only one fraction of the cooled and condensed gas from the third pressure to a fourth pressure and completely vaporizing the expanded gas, preferably air, in the heat exchanger at the fourth pressure.
- the production of final product or products in liquid form is not greater than 5% mol of the feed air, preferably no more than 2% mol of the feed air.
- part of the condensed or pseudo condensed gas, preferably air is expanded in a further expansion device and sent to the column system in liquid form.
- the fourth pressure is substantially equal to the second pressure.
- the turbine is coupled to a generator.
- the turbine expands the nitrogen substantially to atmospheric pressure
- the process comprises sending the first gaseous portion of the air at the first pressure to the second compressor, and compressing the first gaseous portion of the air to a second pressure which is the outlet pressure of the second compressor, dividing the first gaseous portion of the air at the second pressure into a first part and a second part, compressing the first part in a first booster compressor to a fourth pressure, compressing the second part in a second booster compressor to the fourth pressure, the third compressor being comprised of the first and second booster compressors,

cooling and condensation or pseudo condensation at the fourth pressure of the first and second parts compressed respectively in the first and second booster compressors, sending the second gaseous air portion under the first outlet pressure to the system of columns, without further

compression, and separation of the at least part of the air, preferably the second gaseous air portion, in the system of columns, wherein the first booster compressor is coupled to the turbine.

- the expanded at least one fraction of air is warmed and sent to the inlet of the first and second booster compressors.

[0008] According to another aspect of the invention, there is provided an air separation apparatus using distillation in a cryogenic column system comprising a first column operating at a pressure and a second column operating at a lower pressure than the first column, a first air compressor, a second compressor, a third compressor and a heat exchanger, means for sending all the feed air to be compressed in the first air compressor to a first outlet pressure which not more than one bar higher than and preferably substantially equal to the pressure at which the first column operates, means for sending a gas which is a first gaseous portion of the air at the first pressure or a stream of nitrogen to the second compressor, means for sending gas compressed in the second compressor to third compressor, means for sending gas compressed in the third compressor be cooled and condensed or pseudo condensed at the third pressure in the heat exchanger, means for sending at least part of the air, preferably a second gaseous air portion under the first outlet pressure to the system of columns, without further compression, and separation of the at least part of the air, preferably the second gaseous air portion, in the system of columns, means for withdrawing liquid oxygen from the second column, pressurizing of the liquid oxygen and vaporizing of the liquid oxygen by heat exchange in the heat exchanger, expansion means for expanding at least one fraction of the cooled and condensed gas from at least the third pressure to a fourth pressure, means for sending the expanded fraction from the expansion means to the heat exchanger and then to the inlet of the third compressor, a turbine and means for removing a gaseous nitrogen stream from the first column, warming the gaseous nitrogen in the heat exchanger, sending the warmed gaseous nitrogen to expand in the turbine, means for sending the expanded gaseous nitrogen to the heat exchanger to be warmed and means for sending the warmed nitrogen to the atmosphere.

[0009] In a preferred option, the third compressor comprises first and second booster compressors connected in parallel, one of the booster compressors being coupled to the turbine.

[0010] Preferably the turbine is coupled to a booster compressor which compresses part of the expanded fraction.

[0011] The compressor may be connected to the heat exchanger to receive part of the expanded fraction after warming in the heat exchanger.

[0012] Alternatively the turbine may be coupled to a booster compressor which compresses part of the feed

air to the third pressure, the outlet of the booster compressor being connected to the heat exchanger. Preferably the inlet of the booster compressor is in this case connected to the second compressor.

[0013] The invention will be described in greater detail, referring to the figures, where Figures 1,3 and 4 show processes according to the invention and Figure 2 shows a detail of a process according to the invention.

[0014] The separation takes place in a double column, comprising a first column K01 and a second column K02, the second column operating at a lower pressure than the first column and the bottom of the second column being heated using nitrogen from the first column.

[0015] The second column feeds argon enriched vapor ORG to an argon column (not shown).

[0016] The total air flow 1 sent to the column system K01,K02 is compressed to a first pressure, slightly higher than the first column pressure, in compressor C01. The air stream is divided in two to form two streams 3, 5. The first stream 3 is compressed in the first stage of a booster compressor C05-1 to a second pressure, higher than the first pressure and then compressed in the second stage of the booster compressor C05-02 to a third pressure, which may be a supercritical pressure. The first stream 3 is then sent at the third pressure to a high pressure section E01HP of the main heat exchanger in which some of the streams are at pressures of above at least 10 bars. The first air stream 3 is cooled to a cryogenic temperature, thereby condensing or pseudo condensing and is then divided in two. A first part 8 is expanded in a valve 14 (or in a turbine) to the fourth pressure, preferably slightly above the second pressure to account for pressure drop. It forms a liquid stream and is vaporised in exchanger E01HP to form a gaseous stream which is mixed with the first stream 3 downstream of booster compressor C05-1 and then compressed once again in compressor stage C05-2.

[0017] The other part 7 of the condensed or pseudo condensed air is expanded in a valve or a turbine T05 to form a liquid stream, part 9 of which is sent to the first column K01 and the rest 11 of which is sent to the second column K02.

[0018] The turbine T05 may be coupled to a generator.

[0019] A liquid oxygen stream 21 is removed from the bottom of the second column K02, pressurized in a pump P03 and vaporised in the exchanger E01HP to form a product of the process which is pressurized gaseous oxygen. The exchanger also warms part of the waste nitrogen WN2 from the second column.

[0020] A second portion 5 of the air is cooled in the heat exchanger E01LP where all the streams are at at most 10 bars. The cooled air is introduced in gaseous form into the first column K01. The exchanger E01LP also warms part of the waste nitrogen WN1 from the second column.

[0021] Gaseous nitrogen 13 is removed from the top of the first column, warmed in heat exchanger E01LP to an intermediate temperature thereof and then expanded

in a turbine T03 to the pressure of the second column K02. It is then mixed with the nitrogen from the minaret K03 of the second column and removed as waste or as a low pressure product.

[0022] The nitrogen turbine T03 may be coupled to a booster in order to generate more refrigeration. In the example, it is coupled to a generator. The nitrogen stream 13 used for the expansion constitutes between 5 and 10% mol of the total air stream 1. None of the nitrogen produced by the process is at the pressure of the first column K01. The quantity of nitrogen expanded is chosen to increase the energy recovered by the nitrogen expansion, whilst avoiding undue loss of oxygen recovery and permitting an argon recovery of around 65-75 %.

[0023] The nitrogen turbine T03 generates at least 90% of the refrigeration of the system, the rest being provided by Joule-Thomson expansion in valves. It will be appreciated that the process does not involve any air turbine sending gaseous air to the first or second columns.

[0024] If small amounts of nitrogen are required at higher pressure, part of the nitrogen 13 may be compressed in a booster to a pressure above that of the first column, the booster being driven by the turbine T03 expanding another part of the nitrogen 13.

[0025] Nitrogen enriched liquid from top of the first column is sent directly to the second column K02.

[0026] Oxygen enriched liquid from the first column is subcooled in subcooler SC and sent in part directly to the second column K02 and in part RL to the top condenser of the argon column. The liquid VRL vaporised in the top condenser is then sent back to the second column. The argon column is fed with argon enriched gas ORG from the second column K02 and the bottom liquid ORL of the argon column is sent back to the second column K02. The argon column produces an argon rich fluid at the top of the column which may or may not be a product of the process.

[0027] The heat exchangers E01HP and LP may be combined in a single heat exchanger. The first column may be thermally linked to the second column via a double stage vaporiser or a film type vaporiser.

[0028] The production of final product or products in liquid form is not greater than 5% mol of the feed air, preferably no more than 2% mol of the feed air.

[0029] Figure 2 shows a variant of Figures 1 and 3 in which the gas to be condensed in heat exchanger E01HP (air or nitrogen) 3 is compressed in a first booster C05-1, cooled in a cooler E1 and then compressed in two booster in parallel C05-2, C05-3 from the second pressure to the third pressure. Thus booster C05-2 of Figure 1 is replaced by two booster in parallel, the booster C05-3 being driven by expander T03.

[0030] The cooler E2 is common to the two booster C05-2 and C05-3 and the expanded gas 8 is recycled to the inlets of both boosters C05-2 and C05-3.

[0031] Line 23 is an anti-surge system for both boosters.

[0032] Figure 3 shows the case where the gas to be condensed and revaporised in the high pressure exchanger E01HP is nitrogen. Here only part of the nitrogen from the top of column K01 is expanded in turbine T03 coupled to generator G. The rest of the nitrogen is compressed first in compressor C05-1 to the second pressure and then in compressor C05-2 to the third pressure.

[0033] The nitrogen 3 is then sent at the third pressure to a high pressure section E01HP of the main heat exchanger in which some of the streams are at pressures of above at least 10 bars. The nitrogen 3 is cooled to a cryogenic temperature, thereby condensing or pseudo condensing and is then divided in two. A first part 8 is expanded in a valve 14 (or in a turbine) to the fourth pressure, preferably slightly above the second pressure to account for pressure drop. It forms a liquid stream and is vaporised in exchanger E01HP to form a gaseous stream which is mixed with the first stream 3 downstream of booster compressor C05-1 and then compressed once again in compressor stage C05-2.

[0034] The other part 7 of the condensed or pseudo condensed nitrogen is expanded in a valve or a turbine T05 to form a liquid stream, part 9 of which is sent to the top of the first column K01 and the rest 11 of which is sent to the top of the second column K02.

[0035] Figure 4 shows the incorporation of the system of Figure 2 in a process such as that of Figure 1. The streams 3 and 5 result from the splitting in two of a stream 1 as in Figures 1 and 3.

[0036] Air stream 8 is warmed in heat exchanger E01HP and is divided in two, one part being sent to the inlet of booster C05-2 and another part, here the rest, being sent to a booster T03C having the same inlet and outlet pressures as booster C05-2.

[0037] The booster T03C is coupled to the nitrogen turbine T03, replacing the generator.

[0038] Alternatively the air at the second pressure coming from second compressor C05-1 may be divided in two, upstream of the point of return of stream 8 and both parts may be then compressed to the third pressure in separate booster C05-2, T03-C. The booster T03C is, as before, coupled to the nitrogen turbine T03, replacing the generator.

[0039] It is to be noted that the process does not require any expansion of gaseous air, thus the normal Claude turbine and/or insufflation turbine are not present. The nitrogen expander coupled with the air cycle generates enough cold for the ASU in normal operation.

[0040] The nitrogen turbine is possibly coupled for instance to a generator: when no or only small quantities of nitrogen under pressure are required by customer, the nitrogen expander T03 will recover the energy contained in the MP nitrogen extracted from the MP column, by expanding it to atmospheric pressure.

[0041] However coupling the turbine to a booster as in Figures 2 and 4 reduces the cost of the machine and allows the size of the boosters to be reduced.

[0042] The quantity of nitrogen extracted will be a

trade-off between the energy recovered with by the nitrogen expansion and the loss of oxygen and argon recovery. Typically an optimum can be found in the range of a 5 to 10% expanded nitrogen / air flow ratio, with no loss of oxygen recovery and an argon recovery in the range of 70% in the case where argon is produced.

Claims

1. Air separation process by distillation in a cryogenic column system comprising a first column (K01) operating at a pressure and a second column (K02) operating at a lower pressure than the first column, comprising the steps of:

- i) compression of all the feed air in a first air compressor to a first outlet pressure which not more than one bar higher than and preferably substantially equal to the pressure at which the first column operates,
- ii) sending a gas (3) which is a first gaseous portion of the air at the first pressure or a stream of nitrogen to a second compressor (C05-1), compressing the gas to a second pressure which is the outlet pressure of the second compressor, compressing the gas at the second pressure to a third pressure which is the outlet pressure of a third compressor (C05-2, C05-3, T03-C)
- iii) cooling and condensation or pseudo condensation at the third pressure of at least a portion of the gas compressed in the third compressor in a heat exchanger (E01LP, E01HP),
- iv) sending at least part of the air, preferably a second gaseous air portion (5) under the first outlet pressure to the system of columns, without further compression, and separation of the at least part of the air, preferably the second gaseous air portion, in the system of columns,
- v) withdrawing liquid oxygen (21) from the second column, pressurizing of the liquid oxygen and vaporizing of the liquid oxygen by heat exchange in the heat exchanger, and
- vi) expanding at least one fraction (8) of the cooled and condensed gas from at least the third pressure to a fourth pressure, at least partially vaporizing the expanded gas, preferably air, in the heat exchanger at the fourth pressure, the fourth pressure being between the first pressure and the third pressure at which the gas condenses or pseudo-condenses in step iii), optionally heating the at least partially vaporized said gas, preferably air in the heat exchanger, sending at least a portion of the vaporised gas, preferably air, to the third compressor to be compressed to the third pressure

characterized in that at least 50% of the refrigera-

- tion for the process is provided by removing a gaseous nitrogen stream (13) from the first column, warming the gaseous nitrogen in the heat exchanger, expanding the warmed gaseous nitrogen in a turbine (T03), warming the expanded gaseous nitrogen in the heat exchanger and sending it to the atmosphere, wherein the expanded gaseous nitrogen corresponds to between 5 and 10% mol of the feed air compressed in the first air compressor.
2. Process of any preceding claim, wherein the expansion of the gas, preferably air, from the third pressure to the fourth pressure is performed in at least one valve or in at least one turbine (14), the fourth pressure preferably being subcritical.
 3. Process of any preceding claim wherein the temperature of the at least one fraction (8) before expansion is lower than the sum of the vaporization temperature of the liquid oxygen and the minimum temperature approach in the heat exchanger in which the fraction vaporises.
 4. Process of any preceding claim, wherein the inlet temperature of the at least one fraction (8) immediately before expansion is below ambient temperature.
 5. Process of any preceding claim wherein the second gaseous air portion (5) represents at least 90% of the gaseous feed air entering the column system.
 6. Process of any preceding claim wherein the heat exchanger comprises two sections, one section (E01LP) in which the second gaseous air portion is cooled by warming the nitrogen (13) to be expanded in the turbine (T03) and another section (E01HP) in which the liquid oxygen (21) and condensed air (8) vaporize by cooling the air to be condensed.
 7. Process of any of claim 1 to 4 wherein the heat exchanger comprises two sections, one section (E01LP) in which the gaseous nitrogen (3) to be sent to the second compressor is warmed, all the air at the first outlet pressure is cooled and the nitrogen to be expanded in the turbine (T03) is warmed and another section (E01HP) in which the liquid oxygen and condensed nitrogen vaporizes by cooling the nitrogen to be condensed after compression in the second and third compressors.
 8. Process according to any preceding claim comprising expanding only one fraction (8) of the cooled and condensed gas from the third pressure to a fourth pressure and completely vaporizing the expanded gas, preferably air, in the heat exchanger at the fourth pressure.
 9. Process according to any one of the preceding claims, in which the production of final product or products in liquid form is not greater than 5% mol of the feed air, preferably no more than 2% mol of the feed air.
 10. Process according to any preceding claim wherein part (7) of the condensed or pseudo condensed gas, preferably air is expanded in a further expansion device (T05) and sent to the column system in liquid form.
 11. Process according to any preceding claim wherein the fourth pressure is substantially equal to the second pressure.
 12. Process according to any preceding claim wherein the turbine (T03) is coupled to a generator (G).
 13. Process according to any of preceding claims 1 to 6 or 8 to 11 comprising sending the first gaseous portion of the air at the first pressure to the second compressor, and compressing the first gaseous portion of the air to a second pressure which is the outlet pressure of the second compressor (C05-2),
 - i) dividing the first gaseous portion of the air at the second pressure into a first part and a second part, compressing the first part in a first booster compressor (C05-2) to a fourth pressure, compressing the second part in a second booster compressor (T03C) to the fourth pressure, the third compressor being comprised of the first and second booster compressors, cooling and condensation or pseudo condensation at the fourth pressure of the first and second parts compressed respectively in the first and second booster compressors or
 - ii) sending all the first gaseous portion of the air at the second pressure to the third compressor (C05-2), sending a portion of the vaporised air to the third compressor to be compressed to the third pressure, sending another portion of the vaporised air to a booster compressor (T03C) to be compressed to the third pressure and mixing the two portions to form the stream to be cooled and condensed or pseudo condensed at the third pressure in the heat exchanger (E01HP), sending the second gaseous air portion (5) under the first outlet pressure to the system of columns, without further compression, and separation of the at least part of the air, preferably the second gaseous air portion, in the system of columns, wherein the first booster compressor (C05-3, T03C) is coupled to the turbine (T03).

14. Process according to Claim 13 wherein the expanded at least one fraction of air (8) is warmed and sent to the inlets of the first and second booster compressors (C05-2, C05-3, T03C).

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15. Air separation apparatus using distillation in a cryogenic column system comprising a first column (K01) operating at a pressure and a second column (K02) operating at a lower pressure than the first column, a first air compressor (C01), a second compressor (C05-1), a third compressor (C05-2, C05-3, T03C) and a heat exchanger (E01LP, E01HP), means for sending all the feed air to be compressed in the first air compressor to a first outlet pressure which not more than one bar higher than and preferably substantially equal to the pressure at which the first column operates, means for sending a gas (3) which is a first gaseous portion of the air at the first pressure or a stream of nitrogen to the second compressor, means for sending gas compressed in the second compressor to the third compressor, means for sending gas compressed in the third compressor be cooled and condensed or pseudo condensed at the third pressure in the heat exchanger, means for sending at least part of the air, preferably a second gaseous air portion under the first outlet pressure to the system of columns, without further compression, and separation of the at least part of the air, preferably the second gaseous air portion, in the system of columns, means for withdrawing liquid oxygen (21) from the second column, pressurizing of the liquid oxygen and vaporizing of the liquid oxygen by heat exchange in the heat exchanger, expansion means for expanding at least one fraction of the cooled and condensed gas from at least the third pressure to a fourth pressure, means for sending the expanded fraction from the expansion means to the heat exchanger and then to the inlet of the third compressor, a turbine (T03) and means for removing a gaseous nitrogen stream (13) from the first column, means for sending the gaseous nitrogen to be warmed in the heat exchanger, means for sending the warmed gaseous nitrogen to expand in the turbine, means for sending the expanded gaseous nitrogen to the heat exchanger to be warmed and means for sending the warmed nitrogen to the atmosphere.

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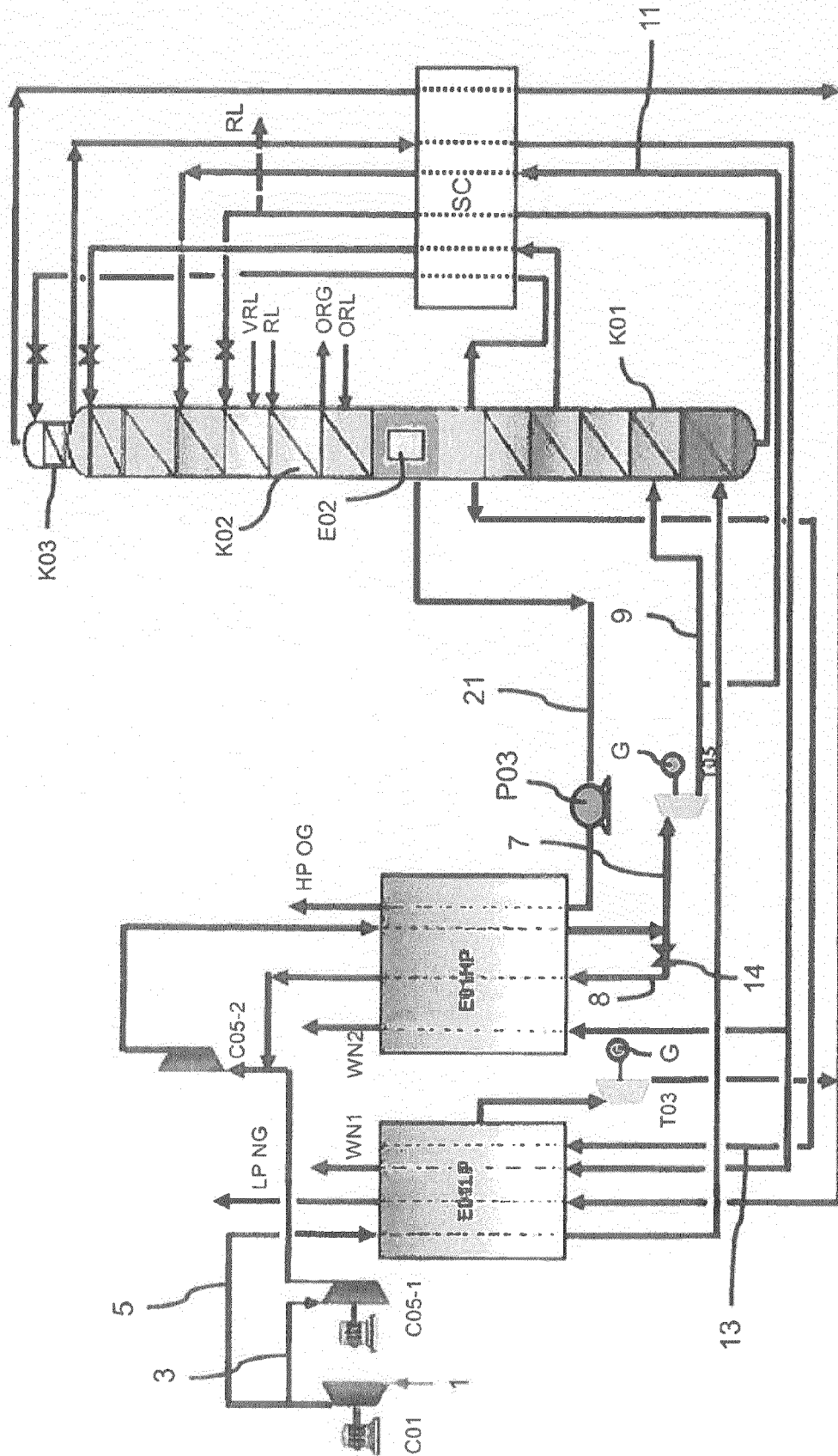


Figure 1

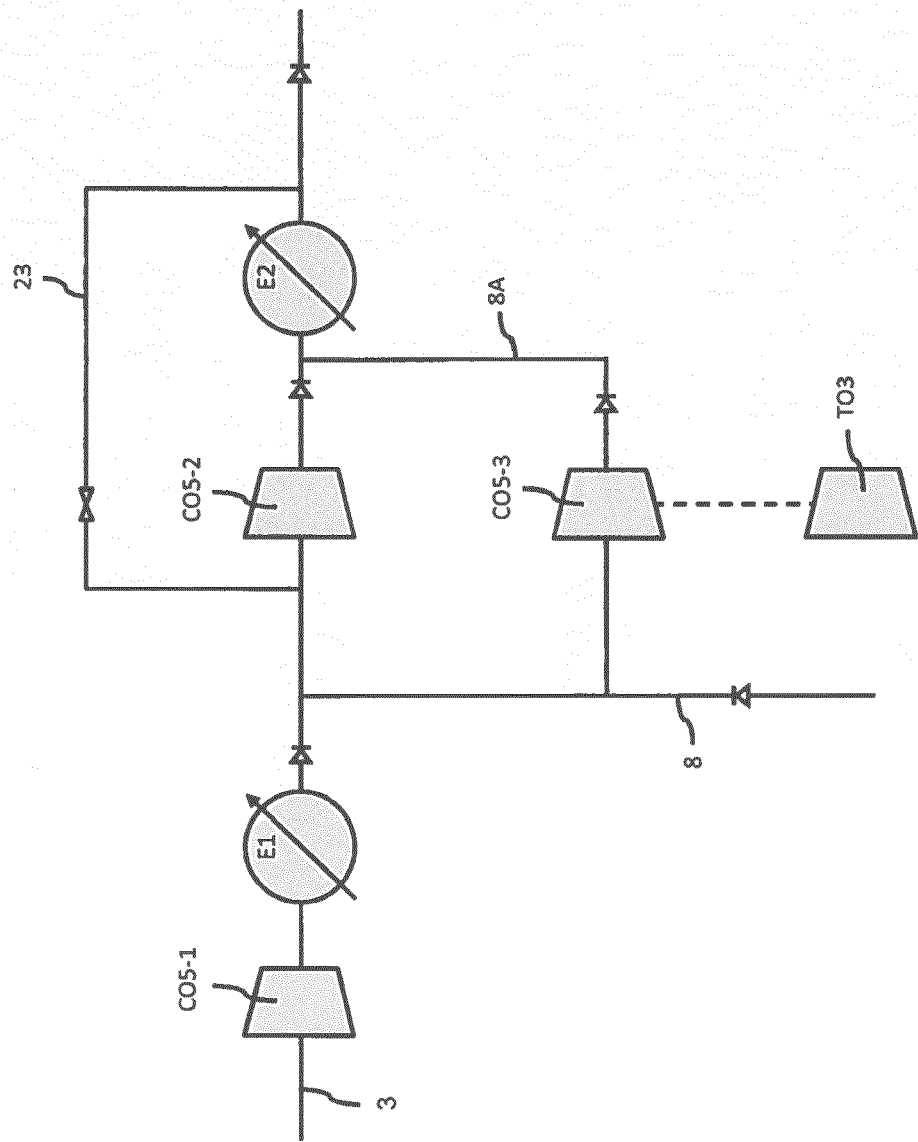


Figure 2

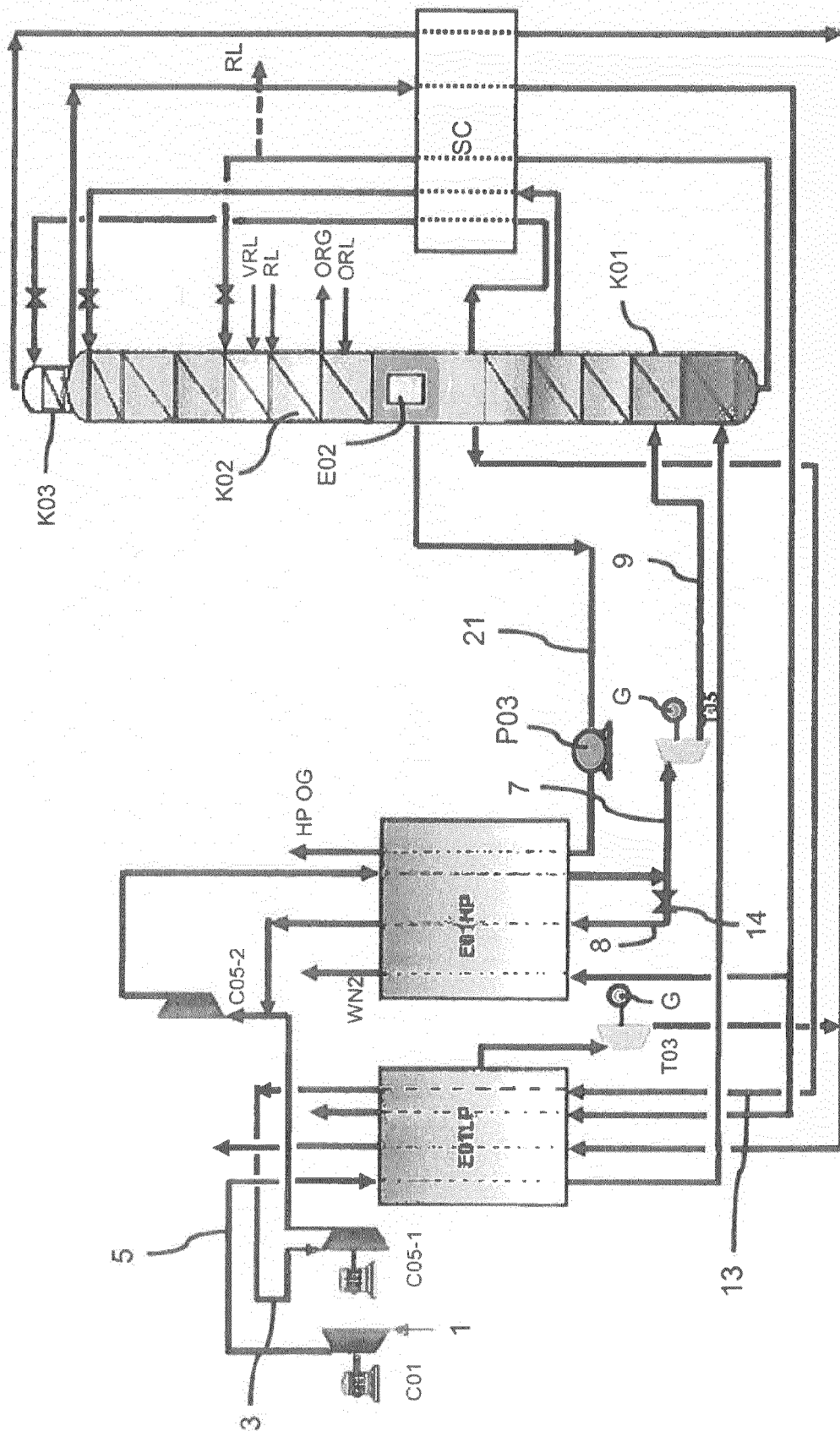
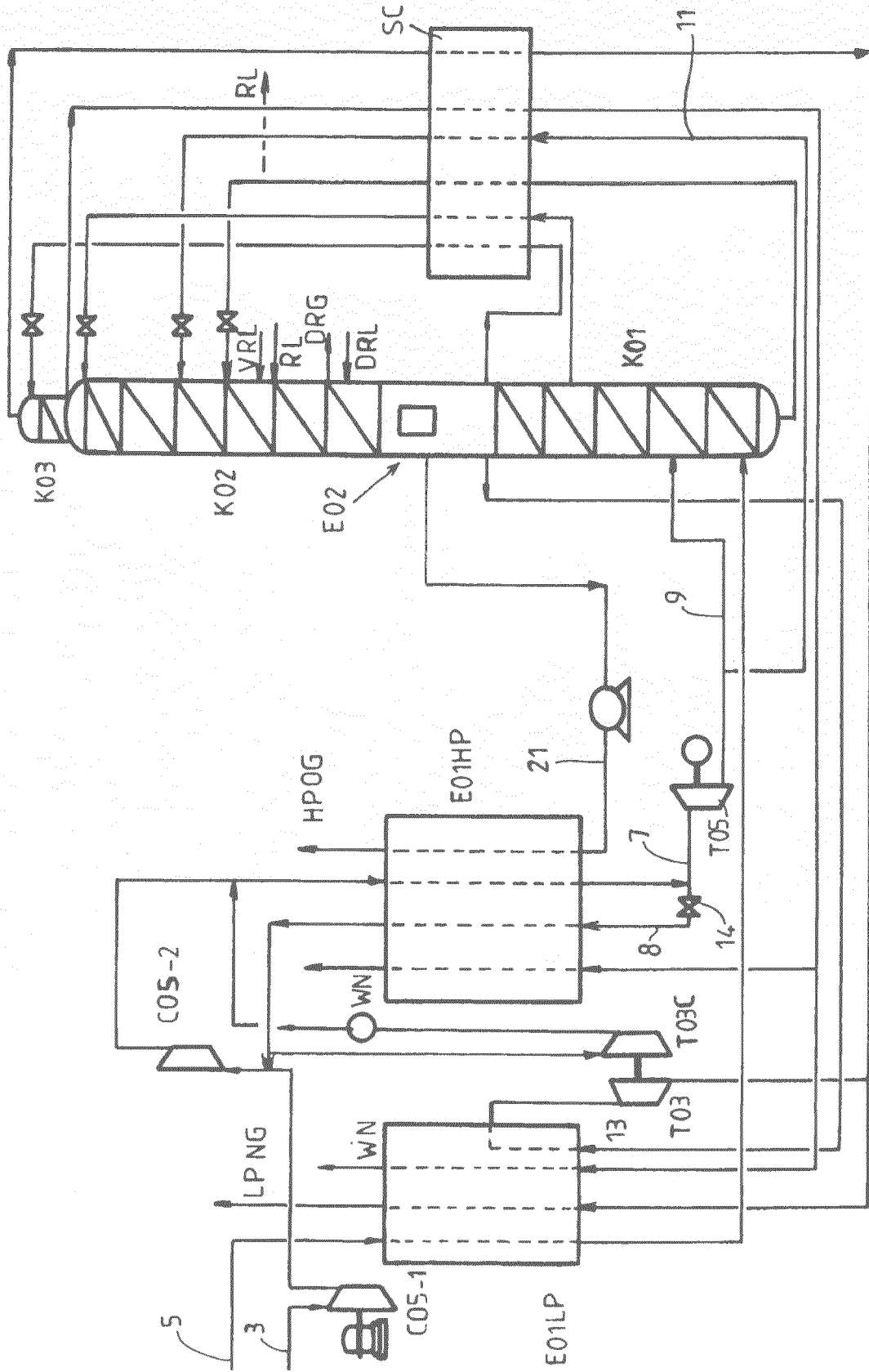


Figure 3

FIG. 4





EUROPEAN SEARCH REPORT

Application Number

EP 22 19 2944

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EPO FORM 1503 03.82 (P04C01)

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	US 2020/132367 A1 (TRANIER JEAN-PIERRE [FR]) 30 April 2020 (2020-04-30) * paragraphs [0075] - [0024], [0033], [0066], [0067], [0075] - [0084]; figure 3 *	1-6, 8-15	INV. F25J3/04
Y	US 4 345 925 A (CHEUNG HARRY) 24 August 1982 (1982-08-24) * column 7, lines 1-19; figure 2 *	1-6, 8-15	
Y	US 2020/355429 A1 (ZHAO BOWEI [CN] ET AL) 12 November 2020 (2020-11-12) * figure 2 *	6, 13, 14	
Y	US 4 617 037 A (OKADA HIDETAKE [JP] ET AL) 14 October 1986 (1986-10-14) * figure 3 *	13, 14	
			TECHNICAL FIELDS SEARCHED (IPC)
			F25J
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		9 February 2023	Göritz, Dirk
CATEGORY OF CITED DOCUMENTS		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	
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			



Application Number

EP 22 19 2944

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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:

6 (completely); 1-5, 8-15 (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

EP 22 19 2944

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: 6 (completely); 1-5, 8-15 (partially)

Air separation process by distillation in a cryogenic column system comprising a first column operating at a pressure and a second column operating at a lower pressure than the first column, comprising the steps of:

- i) compression of all the feed air in a first air compressor to a first outlet pressure which not more than one bar higher than and preferably substantially equal to the pressure at which the first column operates,
 - ii) sending a gas which is a first gaseous portion of the air at the first pressure to a second compressor, compressing the gas to a second pressure which is the outlet pressure of the second compressor, compressing the gas at the second pressure to a third pressure which is the outlet pressure of a third compressor
 - iii) cooling and condensation or pseudo condensation at the third pressure of at least a portion of the gas compressed in the third compressor in a heat exchanger,
 - iv) sending a second gaseous air portion under the first outlet pressure to the system of columns, without further compression, and separating of the second gaseous air portion in the system of columns,
 - v) withdrawing liquid oxygen from the second column, pressurizing of the liquid oxygen and vaporizing of the liquid oxygen by heat exchange in the heat exchanger, and
 - vi) expanding at least one fraction of the cooled and condensed gas from at least the third pressure to a fourth pressure, at least partially vaporizing the expanded air in the heat exchanger at the fourth pressure, the fourth pressure being between the first pressure and the third pressure at which the gas condenses or pseudo-condenses in step iii), sending at least a portion of the vaporised air to the third compressor to be compressed to the third pressure
- characterized in that at least 50% of the refrigeration for the process is provided by removing a gaseous nitrogen stream from the first column, warming the gaseous nitrogen in the heat exchanger, expanding the warmed gaseous nitrogen in a turbine, warming the expanded gaseous nitrogen in the heat exchanger and sending it to the atmosphere, wherein the expanded gaseous nitrogen corresponds to between 5 and 10% mol of the feed air compressed in the first air compressor.

2. claims: 7 (completely); 1-5, 8-15 (partially)

Air separation process by distillation in a cryogenic column system comprising a first column operating at a pressure and a second column operating at a lower pressure than the first column, comprising the steps of:



LACK OF UNITY OF INVENTION SHEET B

Application Number

EP 22 19 2944

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:

- i) compression of all the feed air in a first air compressor to a first outlet pressure which not more than one bar higher than and preferably substantially equal to the pressure at which the first column operates,
 - ii) sending a gas which is a stream of nitrogen to a second compressor, compressing the gas to a second pressure which is the outlet pressure of the second compressor, compressing the gas at the second pressure to a third pressure which is the outlet pressure of a third compressor
 - iii) cooling and condensation or pseudo condensation at the third pressure of at least a portion of the gas compressed in the third compressor in a heat exchanger,
 - iv) sending at least part of the air to the system of columns, without further compression, and separating of the at least part of the air in the system of columns,
 - v) withdrawing liquid oxygen from the second column, pressurizing of the liquid oxygen and vaporizing of the liquid oxygen by heat exchange in the heat exchanger, and
 - vi) expanding at least one fraction of the cooled and condensed gas from at least the third pressure to a fourth pressure, at least partially vaporizing the expanded gas in the heat exchanger at the fourth pressure, the fourth pressure being between the first pressure and the third pressure at which the gas condenses or pseudo-condenses in step iii), sending at least a portion of the vaporised gas to the third compressor to be compressed to the third pressure
- characterized in that at least 50% of the refrigeration for the process is provided by removing a gaseous nitrogen stream from the first column, warming the gaseous nitrogen in the heat exchanger, expanding the warmed gaseous nitrogen in a turbine, warming the expanded gaseous nitrogen in the heat exchanger and sending it to the atmosphere, wherein the expanded gaseous nitrogen corresponds to between 5 and 10% mol of the feed air compressed in the first air compressor.

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

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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.

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