(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 163 576 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
12.04.2023 Bulletin 2023/15

(21) Application number: **22199455.1**

(22) Date of filing: **04.10.2022**

(51) International Patent Classification (IPC):
F25J 3/04 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F25J 3/04218; F25J 3/0409; F25J 3/04103; F25J 3/04206; F25J 3/04309; F25J 3/04381; F25J 3/04387; F25J 3/04412; F25J 3/04957;
F25J 2230/24; F25J 2240/10; F25J 2250/40; F25J 2250/50

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **06.10.2021 US 202117495456**
30.08.2022 EP 22192944

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

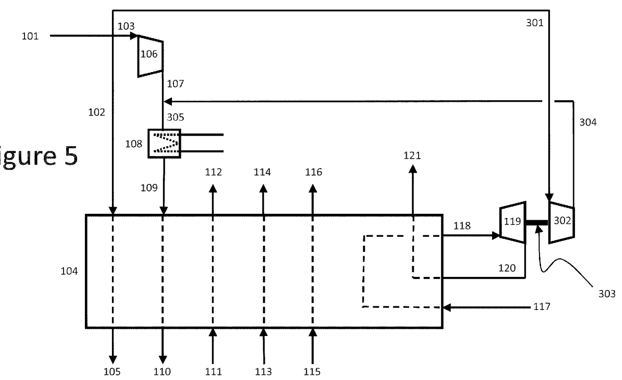
(72) Inventors:
- **TURNEY, Michael A.**
  HOUSTON, 77024 (US)
- **TURNEY, Lindsey**
  HOUSTON, 77024 (US)
- **GUILLARD, Alain**
  SANTA ANA (US)
- **FARA, Baptiste**
  60439 FRANKFURT AM MAIN (DE)
- **TRANIER, Jean-Pierre**
  78350 LES LOGES EN JOSAS (FR)
- **BRIGLIA, Alain**
  75007 PARIS (FR)
- **DAY, Eric**
  Eric, 77024 (US)
- **XUE, Feng-Jie**
  HANGZHOU, 310012 (CN)

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

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

(57) An air separation process having a first booster air compressor comprising a first outlet stream and a second booster air compressor comprising a second outlet stream,wherein the first booster air compressor and the second booster air compressor are in parallel, and the second booster air compressor is driven by a nitrogen turboexpander, the first outlet stream and the second outlet stream being at least partially condensed by heat exchange with a vaporizing oxygen stream.

Figure 5



EP 4 163 576 A1

Description

[0001] The present invention relates to an apparatus and a process for the separation of air by cryogenic distillation.

[0002] Processes as known in the art are presented in Figures 1 through 4. A main air compressor (not shown) compresses air to provide feed air stream **101** which is split into main feed air stream **102** and secondary feed air stream **103.** Main feed air stream **102** is introduced into main heat exchanger **104** wherein it is cooled, thereby producing cold feed air stream **105.** Secondary feed air stream **103** is introduced into first booster air compressor **106** thereby producing boosted air feed stream **107.** Secondary feed air stream **103** has a first inlet pressure, and boosted air feed stream **107** has a first outlet pressure. Boosted air feed stream **107** is introduced into aftercooler **108,** thereby producing cooled compressed air feed stream **109.** The pressure of cooled compressed air feed stream **109** is determined by the oxygen vaporizing pressure in first heat exchanger **203.** For efficient heat transfer the air condensing temperature in first heat exchanger **203** must be only slightly (~2C to 3C) warmer than the temperature of the vaporizing oxygen. Cooled compressed air feed stream **109** is then introduced into main heat exchanger **104** wherein it is cooled, thereby producing cool boosted feed air stream **110.**

[0003] Cold feed air stream **105** is introduced into HP column **201.** Cool boosted feed air stream **110** is introduced into first heat exchanger **203,** wherein it exchanges heat with liquid oxygen stream **214,** thereby producing at least partially condensed cold boosted feed air stream **204.** Second heat exchanger **203** vaporizes liquid oxygen stream **214** against at least partially condensing air stream **110** at a pressure provided by first booster air compressor **106.** The pressure of liquid oxygen stream **214** vaporized in second heat exchanger **203** is boosted by static head by positioning second heat exchanger **203** at a lower elevation than the liquid oxygen supply sump **217** of LP column **202.** Alternatively, the pressure of liquid oxygen stream **214** may be boosted by a liquid oxygen pump. (not shown). For this process the gaseous oxygen product pressure is in the range of 1.1 bara to 3 bara and preferably in the range of 1.2 bara and 2 bara.

[0004] Cold boosted feed air stream **204** may be split into two portions, primary cold boosted feed air stream **205** and secondary cold boosted fed air stream **206.** Primary cold boosted feed air stream **205** is introduced into HP column **201.** Secondary cold boosted fed air stream **206** is introduced into LP column **202.**

[0005] In one embodiment, as illustrated in Figure 1 and Figure 2, HP column **201** produces at least four output streams, rich liquid stream **208,** first nitrogen reflux stream **210,** second nitrogen reflux stream **212,** and HP gaseous nitrogen stream **117.** Rich liquid stream **208** passes through second heat exchanger **207,** thereby producing cold rich liquid stream **209,** which is introduced into LP column **202.** First nitrogen reflux stream **210** passes through second heat exchanger **207,** thereby producing cold first reflux stream **211,** which is introduced into LP column **202.** Second nitrogen reflux stream **212** passes through second heat exchanger **207,** thereby producing cold second reflux stream **213,** which is introduced into LP column **202.**

[0006] LP column **202** produces at least three output streams, liquid oxygen stream **214,** cold waste nitrogen stream **215,** and cold gaseous nitrogen stream **216.** Liquid oxygen stream **214** passes through first heat exchanger **203,** thereby producing gaseous oxygen product stream **115.** Gaseous oxygen product stream **115** may have a pressure between 1.1 and 3 bara, preferably between 1.2 and 2 bara. Cold waste nitrogen stream **215** passes through second heat exchanger **207,** thereby producing waste nitrogen stream **113.** Cold gaseous nitrogen stream **216** passes through second heat exchanger **207,** thereby producing gaseous nitrogen product stream **111.**

[0007] Gaseous nitrogen product stream **111** is introduced into main heat exchanger **104,** thereby producing warmed gaseous nitrogen product **112.** Waste nitrogen product stream **113** is introduced into main heat exchanger **104,** thereby producing warmed waste nitrogen product **114.** Gaseous oxygen product stream **115** is introduced into main heat exchanger **104,** thereby producing warmed gaseous oxygen product **116.**

[0008] HP gaseous nitrogen stream **117** is introduced into main heat exchanger **104,** thereby producing warmed HP gaseous nitrogen stream **118.** Warmed HP gaseous nitrogen stream **118** is then introduced into turboexpander **119,** thereby producing LP gaseous nitrogen stream **120.** Turboexpander **119** may have an inlet pressure of between 4 and 10 bara, and an outlet pressure of between atmospheric pressure and 2 bara. Turboexpander **119** may have a loading or braking device to act as a sink for the expander's energy. As a brake, turboexpander **119** may utilize a booster, a generator or oil (not shown). Typically, a booster brake is preferred to put as much energy back into the system as possible, with less overall losses and equipment cost. LP gaseous nitrogen stream **120** is then introduced into main heat exchanger **104** thereby producing warmed LP gaseous nitrogen stream **121.**

[0009] In another embodiment, as illustrated in Figure 3 and Figure 4, HP column **201** produces at least 3 output streams rich liquid stream **208,** nitrogen reflux stream **212,** and HP gaseous nitrogen stream **117.** Rich liquid stream **208** passes through second heat exchanger **207,** thereby producing cold rich liquid stream **209,** which is introduced into LP column **202.** Nitrogen reflux stream **212** passes through second heat exchanger **207,** thereby producing cold reflux stream **213,** which is introduced into LP column **202.**

[0010] LP column **202** produces at least two output streams, liquid oxygen stream **214,** cold waste nitrogen stream **215,** Liquid oxygen stream **214** passes through first heat exchanger **203,** thereby producing gaseous oxygen product stream **115.** Gaseous oxygen product stream **115** may have a pressure between 1.1 and 3 bara, preferably between 1.2 and 2 bara. Cold waste nitrogen stream **215** passes through second heat exchanger **207,** thereby producing waste nitrogen stream **113.** Waste nitrogen product stream **113** is introduced into main heat exchanger **104,** thereby producing warmed waste nitrogen product **114.** Gaseous oxygen product stream **115** is introduced into main heat exchanger **104,** thereby producing warmed gaseous oxygen product **116.**

[0011] HP gaseous nitrogen stream **117** is introduced into main heat exchanger **104,** thereby producing warmed HP gaseous nitrogen stream **118.** Warmed HP gaseous nitrogen stream **118** is then introduced into turboexpander **119,** thereby producing LP gaseous nitrogen stream **120.** Turboexpander **119** may have an inlet pressure of between 4 and 10 bara, and an outlet pressure of between atmospheric pressure and 2 bara. Turboexpander **119** may have a loading or braking device to act as a sink for the expander's energy. As a brake, turboexpander **119** may utilize a booster, a generator or oil (not shown). Typically, a booster brake is preferred to put as much energy back into the system as possible, with less overall losses and equipment cost. LP gaseous nitrogen stream **120** is then introduced into main heat exchanger **104** thereby producing warmed LP gaseous nitrogen stream **121.**

[0012] An air separation process having a first booster air compressor comprising a first outlet stream and a second booster air compressor comprising a second outlet stream. Wherein the first booster air compressor and the second booster air compressor are in parallel, and the second booster air compressor is driven by a nitrogen turboexpander. The first outlet stream and/or the second outlet stream may be at least partially condensed by heat exchange with a vaporizing low pressure oxygen stream, and the low-pressure gaseous oxygen pressure is in the range of 1.1 bara to 3 bara.

[0013] According to an object of the invention, there is provided a process for the separation of air by cryogenic distillation comprising:

i) Cooling compressed air in a heat exchanger
ii) Sending cooled and compressed air from the heat exchanger to a distillation column system comprising a first column operating at a first pressure and a second column operating at a second pressure lower than the first pressure, including sending at least part of the air to first column
iii) Removing a liquid oxygen stream from the second column, vaporizing it against feed air to produce a gaseous stream
iv) Removing a gaseous nitrogen stream from the first column, warming it in the heat exchanger and expanding it in a turbine
v) Dividing a portion of the compressed air into first and second parts
vi) Compressing the first part of the compressed air portion at a first inlet pressure in a first booster air compressor to form a first outlet stream at a first outlet pressure,
vii) Compressing the second part of the compressed air at the first inlet pressure in a second booster air compressor to form a second outlet stream at the first outlet pressure, wherein the second booster air compressor is driven by the turbine and the first outlet stream and the second outlet stream are combined to form a combined stream and sent to the heat exchanger to be cooled before being sent to the distillation column system .

[0014] According to optional aspects of the invention:

- the combined stream is introduced into a common after-cooler upstream of the heat exchanger.
- the turbine has an inlet pressure in the range of 4 to 10 bara
- the turbine has outlet pressure in the range of atmospheric pressure to 2 bara.
- the combined stream is at least partially condensed by heat exchange with the liquid oxygen stream.
- the low-pressure gaseous oxygen pressure of the vaporised stream formed by vaporizing the liquid oxygen stream is in the range of 1.1 bara to 3 bara, preferably in the range of 1.2 bara and 2 bara .
- a stream of air at the inlet pressure of the first and second booster compressors is cooled in the heat exchanger at that pressure and sent to the first column.
- the liquid oxygen is pressurized by a pump before being vaporised.
- the inlet and outlet temperatures of the first and second booster compressors are higher than the inlet temperature of the heat exchanger.
- the first booster compressor is not coupled to the turbine.
- the first booster compressor is driven by a motor.

[0015] According to another aspect of the invention, there is provided an apparatus for the separation of air by cryogenic distillation comprising: a heat exchanger, a distillation column system comprising a first column operating at a first pressure and a second column operating at a second pressure lower than the first pressure, means for cooling compressed air in the heat exchanger, means for sending cooled and compressed air from the heat exchanger to the distillation column system, including sending at least part of the air to first column, means for removing a liquid oxygen stream from the second column, means for vaporizing the liquid oxygen stream against feed air to produce a gaseous stream, a turbine, means for removing a gaseous nitrogen stream from the first column, warming it in the heat exchanger and expanding it in the turbine, means for dividing a portion of the compressed air into first and second parts, first and second booster air compressors, means for sending the first part of the compressed air portion at a first inlet pressure to be compressed in the first booster air compressor to form a first outlet stream at a first outlet pressure, means for sending the second part of the compressed air at the first inlet pressure to be compressed in the second booster air compressor to form a second outlet stream at the first outlet pressure, wherein the second booster air compressor is driven by the turbine and means for combining the first outlet stream and the second outlet stream to form a combined stream and means for sending the combined stream to the heat exchanger to be cooled before being sent to the distillation column system .

[0016] The apparatus may include:

- the means for vaporizing the liquid oxygen Is a dedicated heat exchanger.
- the means for vaporizing the liquid oxygen is the heat exchanger.

Figure 1 is a schematic representation of the main heat exchanger with a low-pressure nitrogen stream, as utilized in one system as known in the art.

Figure 2 is a schematic representation of an overall system with a low-pressure nitrogen stream, as utilized in one system as known in the art.

Figure 3 is a schematic representation of the main heat exchanger without a low-pressure nitrogen stream, as utilized in one system as known in the art.

Figure 4 is a schematic representation of an overall system without a low-pressure nitrogen stream, as utilized in one system as known in the art.

Figure 5 is a schematic representation of the main heat exchanger with a low-pressure nitrogen stream, in accordance with the present invention.

Figure 6 is a schematic representation of an overall system with a low-pressure nitrogen stream, in accordance with the present invention.

Figure 7 is a schematic representation of the main heat exchanger without a low-pressure nitrogen stream, in accordance with the present invention.

Figure 8 is a schematic representation of an overall system without a low-pressure nitrogen stream, in accordance with the present invention.

Figure 9 is a schematic representation of the compressor and booster set-up of a process in accordance with the present invention

Figure 10 is a schematic representation of an overall system with a low-pressure nitrogen stream, in accordance with the present invention.

Element Numbers

[0017]

101 = feed air stream
102 = main feed air stream (first portion)
103 = secondary feed air stream (second portion)
104 = main heat exchanger
105 = cold feed air stream
106 = first booster air compressor
107 = boosted air feed stream
108 = aftercooler
109 = cooled compressed air feed stream
110 = cool boosted feed air stream
111 = gaseous nitrogen product
112 = warmed gaseous nitrogen product
113 = waste nitrogen
114 = warmed waste nitrogen
115 = gaseous oxygen product
116 = warmed gaseous oxygen product
117 = HP gaseous nitrogen
118 = warmed HP gaseous nitrogen
119 = turboexpander
120 = LP gaseous nitrogen
121 = warmed LP gaseous nitrogen
201 = HP column
202 = LP column
203 = first heat exchanger
204 = cold boosted feed air stream
205 = primary cold boosted feed air stream (first portion)
206 = secondary cold boosted feed air stream (second portion)
207 = second heat exchanger
208 = rich liquid (rich in oxygen)
209 = cold rich liquid
210 = first (nitrogen) reflux stream
211 = cold first reflux stream
212 = second (nitrogen) reflux stream
213 = cold second reflux stream
214 = gaseous oxygen stream
215 = cold waste nitrogen stream
216 = cold gaseous nitrogen
301 = tertiary feed air stream (third portion)
302 = second booster air compressor
303 = drive connection (between turboexpander and secondary feed air compressor)
304 = compressed tertiary feed air stream
305 = combined boosted feed air stream

Description of Embodiments

[0018] Illustrative embodiments of the invention are described below. While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

[0019] It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

[0020] Turning to Figures 5 through 8, a system in accordance with the present invention is presented. A main air compressor (not shown) compresses air to provide feed air stream **101** which is split into main feed air stream **102** and secondary feed air stream **103,** and tertiary feed air stream **301.** Main feed air stream **102** is introduced into main heat exchanger **104** wherein it is cooled, thereby producing cold feed air stream **105.** Secondary feed air stream **103** is introduced into first booster air compressor **106** thereby producing boosted air feed stream **107.** Secondary feed air stream **103** has a first inlet pressure, and boosted air feed stream **107** has a first outlet pressure. Tertiary feed air stream **301** is introduced into second booster air compressor **302,** thereby producing compressed tertiary feed air stream **304.** Tertiary feed air stream **301** has a second inlet pressure and compressed tertiary feed air stream **304** has a second outlet pressure. The first inlet pressure and the second inlet pressure are the same, which is defined herein as being within 1 bar of each other, or within 0,5 bar of each other, or within 0,25 bar of each other. The first outlet pressure and the second outlet pressure are the same, which is defined herein as being within 1 bar of each other or within 0,5 bar of each other, or within 0,25 bar of each other.

[0021] Boosted air feed stream **107** is combined with compressed tertiary feed air stream **304,** thereby producing combined boosted feed air stream **305.** Thus, first booster air compressor **106** and second booster air compressor **302** are in parallel, having the same, or approximately the same, inlet pressures and outlet pressures. The term "the same, or approximately the same' means as close to the same as is reasonable given the conditions.

[0022] First booster air compressor **106,** may control this common discharge pressure, in order to fully vaporize the oxygen stream. The load on turboexpander **119** will determine the relative flowrates between first booster air compressor **106** and second booster air compressor **302.** Combined boosted feed air stream **305** is introduced into aftercooler **108,** thereby producing cooled compressed air feed stream **109.** Cooled compressed air feed stream **109** is then introduced into main heat exchanger **104** wherein it is cooled, thereby producing cool boosted feed air stream **110.**

[0023] Cold feed air stream **105** is introduced into HP column **201.** Cool boosted feed air stream **110** is introduced into first heat exchanger **203,** wherein it exchanges heat with liquid oxygen stream **214,** thereby producing at least partially condensed cold boosted feed air stream **204 and vaporised gaseous oxygen 115. The vaporised gaseous oxygen, at substantially the pressure of the LP column 202, is further warmed in heat exchanger 104.** Cold boosted feed air stream **204** is split into two portions, primary cold boosted feed air stream **205** and secondary cold boosted fed air stream **206.** Primary cold boosted feed air stream **205** is introduced into HP column **201 in liquid form.** Secondary cold boosted fed air stream **206** is expanded (not shown) and introduced into LP column **202.**

[0024] In one embodiment, as illustrated in Figure 5 and Figure 6, HP column **201** produces at least four output streams, rich liquid stream **208,** first nitrogen reflux stream **210,** second nitrogen reflux stream **212,** and HP gaseous nitrogen stream **117.** Rich liquid stream **208** passes through second heat exchanger **207,** thereby producing cold rich liquid stream **209,** which is introduced into LP column **202.** First nitrogen reflux stream **210** passes through second heat exchanger **207,** thereby producing cold first reflux stream **211,** which is introduced into LP column **202.** Second nitrogen reflux stream **212** passes through second heat exchanger **207,** thereby producing cold second reflux stream **213,** which is introduced into LP column **202.**

[0025] LP column **202** produces at least three output streams, liquid oxygen stream **214,** cold waste nitrogen stream **215,** and cold gaseous nitrogen stream **216.** Liquid oxygen stream **214** passes through first heat exchanger **203,** thereby producing gaseous oxygen product stream **115.** Gaseous oxygen product stream **115** may have a pressure between 1.1 and 3 bara, preferably between 1.2 and 2 bara. Cold waste nitrogen stream **215** passes through second heat exchanger **207,** thereby producing waste nitrogen stream **113.** Cold gaseous nitrogen stream **216** passes through second heat exchanger **207,** thereby producing gaseous nitrogen product stream **111.**

[0026] Gaseous nitrogen product stream **111** is introduced into main heat exchanger **104,** thereby producing warmed gaseous nitrogen product **112.** Waste nitrogen product stream **113** is introduced into main heat exchanger **104,** thereby producing warmed waste nitrogen product **114.** Gaseous oxygen product stream **115** is introduced into main heat exchanger **104,** thereby producing warmed gaseous oxygen product **116.**

[0027] HP gaseous nitrogen stream **117** is introduced into main heat exchanger **104,** thereby producing warmed HP gaseous nitrogen stream **118.** Warmed HP gaseous nitrogen stream **118** is then introduced into turboexpander **119,** thereby producing LP gaseous nitrogen stream **120.** LP gaseous nitrogen stream **120** is then introduced into main heat exchanger **104** thereby producing warmed LP gaseous nitrogen stream **121.** Second booster air compressor **302** and turboexpander **119** may be connected with a common drive 303.

[0028] In another embodiment, as illustrated in Figure 7 and Figure 8, HP column **201** produces at least 3 output streams rich liquid stream **208,** nitrogen reflux stream **212,** and HP gaseous nitrogen stream **117.** Rich liquid stream **208** passes through second heat exchanger **207,** thereby producing cold rich liquid stream **209,** which is introduced into LP column **202.** Nitrogen reflux stream **212** passes through second heat exchanger **207,** thereby producing cold reflux stream **213,** which is introduced into LP column **202.**

[0029] LP column **202** produces at least two output streams, liquid oxygen stream **214,** cold waste nitrogen stream **215,** Liquid oxygen stream **214** passes through first heat exchanger **203,** thereby producing gaseous oxygen product stream **115.** Gaseous oxygen product stream **115** may have a pressure between 1.1 and 3 bara, preferably between 1.2 and 2 bara. Cold waste nitrogen stream **215** passes through second heat exchanger **207,** thereby producing waste nitrogen stream **113.** Waste nitrogen product stream **113** is introduced into main heat exchanger **104,** thereby producing warmed waste nitrogen product **114.** Gaseous oxygen product stream **115** is introduced into main heat exchanger **104,** thereby producing warmed gaseous oxygen product **116.**

[0030] HP gaseous nitrogen stream **117** is introduced into main heat exchanger **104,** thereby producing warmed HP gaseous nitrogen stream **118.** Warmed HP gaseous nitrogen stream **118** is then introduced into turboexpander **119,** thereby producing LP gaseous nitrogen stream **120.** Turboexpander **119** may have an inlet pressure of between 4 and 10 bara, and an outlet pressure of between atmospheric pressure and 2 bara. Turboexpander **119** may have a loading or braking device to act as a sink for the expander's energy. As a brake, turboexpander **119** may utilize a booster, a generator or oil (not shown). Typically, a booster brake is preferred to put as much energy back into the system as possible, with less overall losses and equipment cost. LP gaseous nitrogen stream **120** is then introduced into main heat exchanger **104** thereby producing warmed LP gaseous nitrogen stream **121.** Second booster air compressor **302** and turboexpander **119** may be connected with a common drive **303.**

[0031] Figure 9 shows detail of a compressor and booster setup of a process according to the invention. Air 3 to be condensed in heat exchanger E01HP is compressed In a first booster C05-1 , cooled in a cooler E1 and then compressed in two boosters in parallel C05-2, C05-3 from the second pressure to the third pressure. A single booster is replaced by two boosters in parallel, the booster C05-3 being driven by expander T03.

[0032] The cooler E2 is common to the two boosters C05-2 and C05-3.

[0033] Line 23 is an anti-surge system for both boosters.

[0034] In Figure 10, 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.

[0035] The second column feeds argon enriched vapor ORG to an argon column (not shown).

[0036] 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 divided in two. One part of the air is compressed in the second stage of the booster compressor C05-02 to a third pressure, which may be a supercritical pressure. This part of 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. Condensed or pseudo condensed air 7 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.

[0037] Optionally condensed or pseudo condensed air can be divided in two. A part (not shown) 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 downstream of booster compressor C05-1 and then compressed once again in compressor stage C05-2.

[0038] Another part of air stream 3 is compressed in booster T03C having the same inlet pressure and outlet pressure as booster C05-2. The boosted air streams are combined upstream of heat exchanger E01HP forming a stream 7.

[0039] The turbine T05 may be coupled to a generator or to booster T03C.

[0040] 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.

[0041] 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.

[0042] 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.

[0043] 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 %.

[0044] 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.

[0045] 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.

[0046] Nitrogen enriched liquid from top of the first column is sent directly to the second column K02.

[0047] 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.

[0048] 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.

[0049] 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.

Claims

1. A process for the separation of air by cryogenic distillation comprising:

i) Cooling compressed air in a heat exchanger (104, E01LP, E01HP)

ii) Sending cooled and compressed air from the heat exchanger to a distillation column system comprising a first column (201, K01) operating at a first pressure and a second column (202, K02) operating at a second pressure lower than the first pressure, including sending at least part of the air to first column

iii) Removing a liquid oxygen stream (214, 21) from the second column, vaporizing it against feed air (110, 7) to produce a gaseous stream

iv) Removing a gaseous nitrogen stream from the first column, warming it in the heat exchanger and expanding it in a turbine (119, T03)

v) Dividing a portion of the compressed air into first and second parts

vi) Compressing the first part of the compressed air portion at a first inlet pressure in a first booster air compressor (106, C05-2) to form a first outlet stream at a first outlet pressure,

vii) Compressing the second part of the compressed air at the first inlet pressure in a second booster air compressor (302, C05-3, T03C) to form a second outlet stream at the first outlet pressure, wherein the second booster air compressor is driven by the turbine and the first outlet stream and the second outlet stream are combined to form a combined stream (109, 110, 7) and sent to the heat exchanger to be cooled before being sent to the distillation column system .

2. The process of Claim 1, wherein the combined stream (109, 110, 7) is introduced into a common after-cooler (108, E2) upstream of the heat exchanger.

3. The process of Claim 1 or 2, wherein the turbine (119, T03) has an inlet pressure in the range of 4 to 10 bara and outlet pressure in the range of atmospheric pressure to 2 bara.

4. The process of any preceding claim wherein the combined stream (109, 110, 7) is at least partially condensed by heat exchange with the liquid oxygen stream.

5. The process of Claim 4 wherein the low-pressure gaseous oxygen pressure of the vaporised stream (115) formed by vaporizing the liquid oxygen stream is in the range of 1.1 bara to 3 bara, preferably in the range of 1.2 bara and 2 bara.

6. The process of Claim 5 wherein a stream of air (102) at the inlet pressure of the first and second booster compressors is cooled in the heat exchanger at that pressure and sent to the first column.

7. The process of any preceding claim wherein the liquid oxygen (21) is pressurized by a pump before being vaporised.

8. The process of any preceding claim wherein the inlet and outlet temperatures of the first and second booster compressors (106, 302, C05-2, C05-3) are higher than the inlet temperature of the heat exchanger (104, E01HP).

9. The process of any preceding claim wherein the first booster compressor (106, C05-2) is not coupled to the turbine (T).

10. The process of Claim 9 wherein the first booster compressor (106, C05-2) is driven by a motor.

11. Apparatus for the separation of air by cryogenic distillation comprising: a heat exchanger, a distillation column system comprising a first column (201, K01) operating at a first pressure and a second column (202, K02) operating at a second pressure lower than the first pressure, means for cooling compressed air in the heat exchanger, means for sending cooled and compressed air from the heat exchanger to the distillation column system, including sending at least part of the air to first column, means for removing a liquid oxygen stream (214, 21) from the second column, means for vaporizing the liquid oxygen stream against feed air to produce a gaseous stream, a turbine (119, T03), means for removing a gaseous nitrogen stream (117, 13) from the first column, warming it in the heat exchanger and expanding it in the turbine, means for dividing a portion of the compressed air into first and second parts, first and second booster air compressors (106, 302, C05-2, C05-3), means for sending the first part (103) of the compressed air portion at a first inlet pressure to be compressed in the first booster air compressor to form a first outlet stream (107) at a first outlet pressure, means for sending the second part (301) of the compressed air at the first inlet pressure to be compressed in the second booster air compressor to form a second outlet stream (304) at the first outlet pressure, wherein the second booster air compressor is driven by the turbine and means for combining the first outlet stream and the second outlet stream to form a combined stream (305, 7) and means for sending the combined stream to the heat exchanger to be cooled before being sent to the distillation column system.

12. Apparatus according to Claim 11 wherein the means for vaporizing the liquid oxygen Is a dedicated heat exchanger (203).

13. Apparatus according to Claim 11 wherein the means for vaporizing the liquid oxygen is the heat exchanger (104, E01HP).

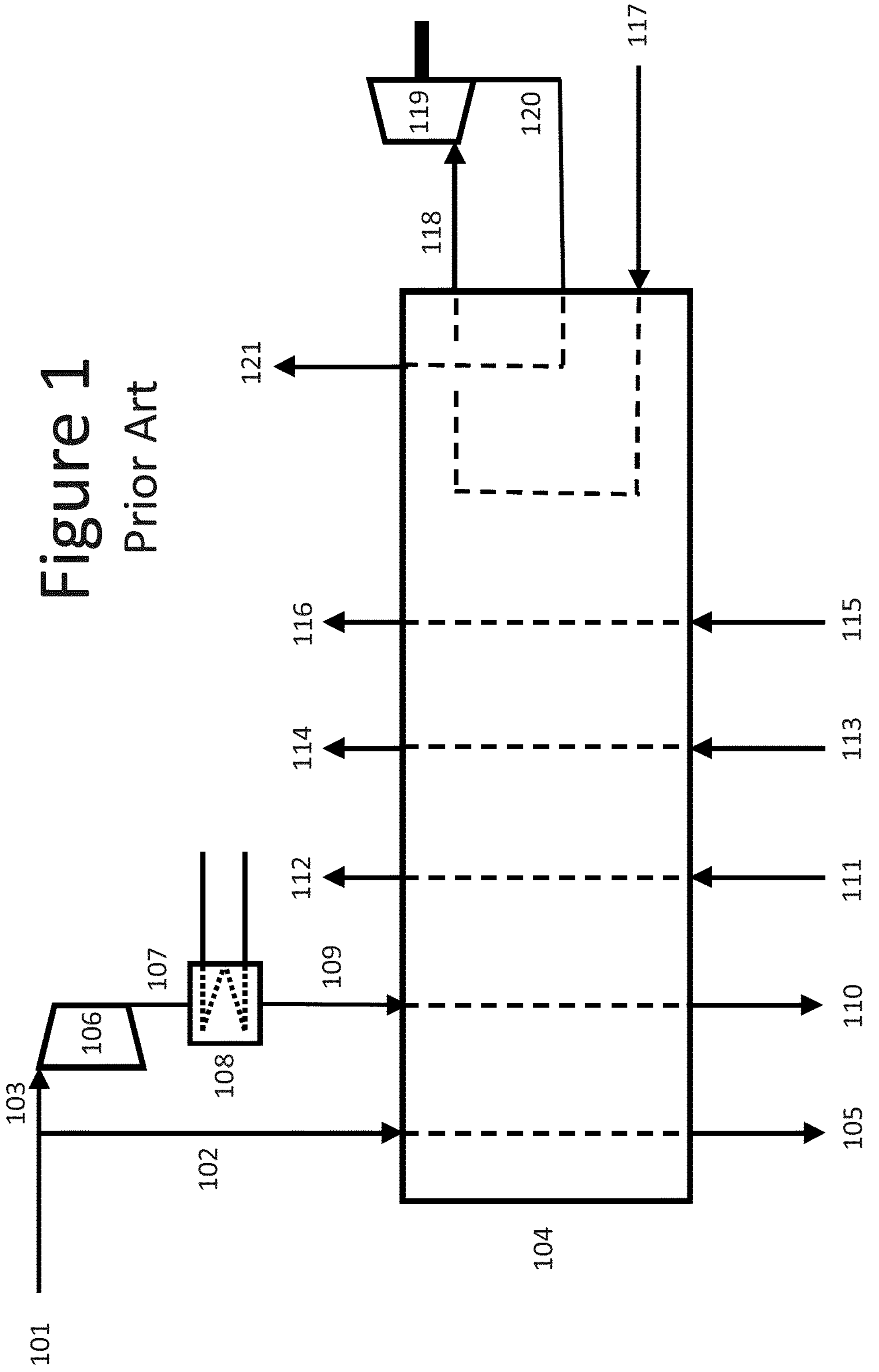


Figure 1
Prior Art

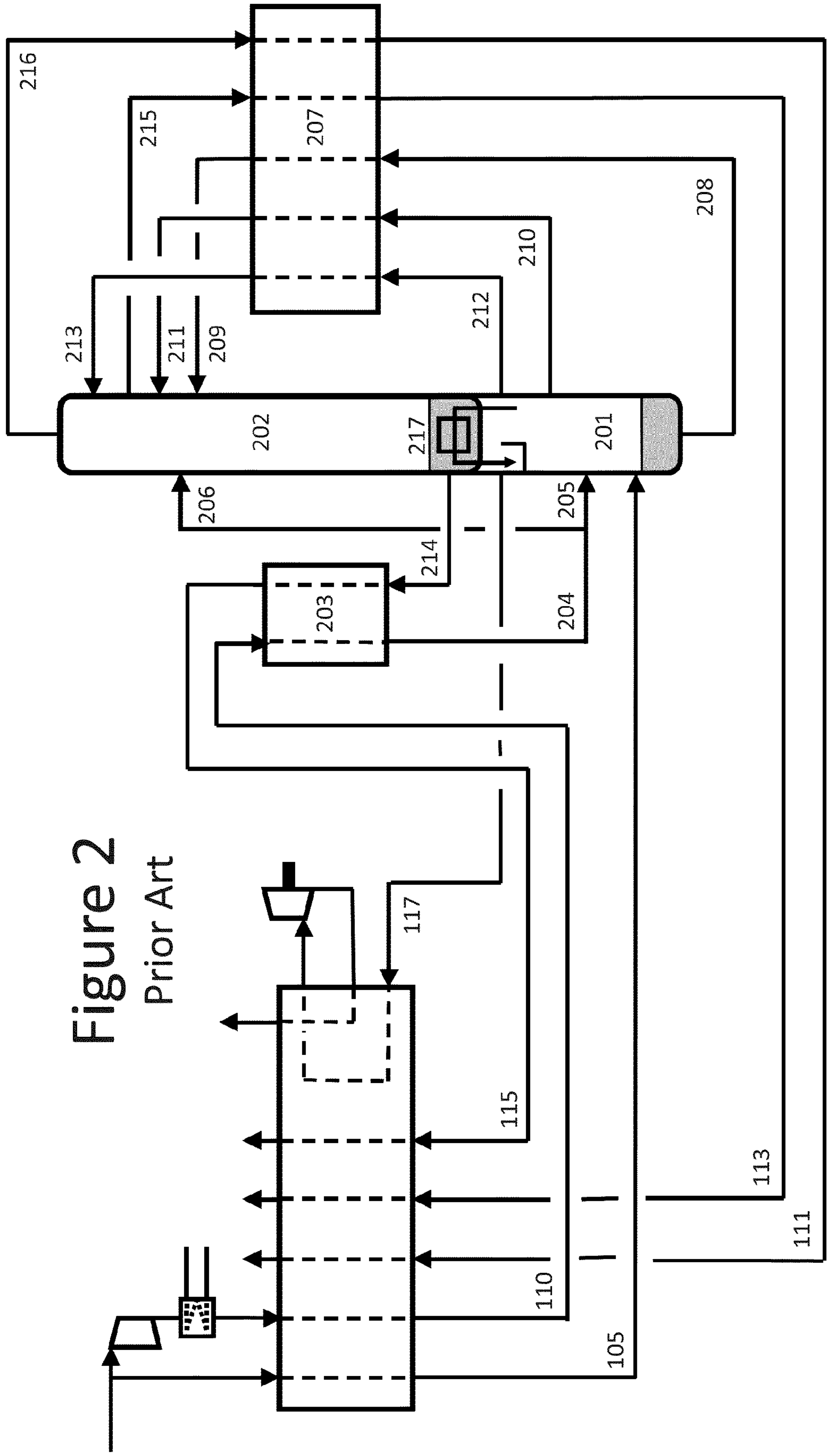


Figure 2
Prior Art

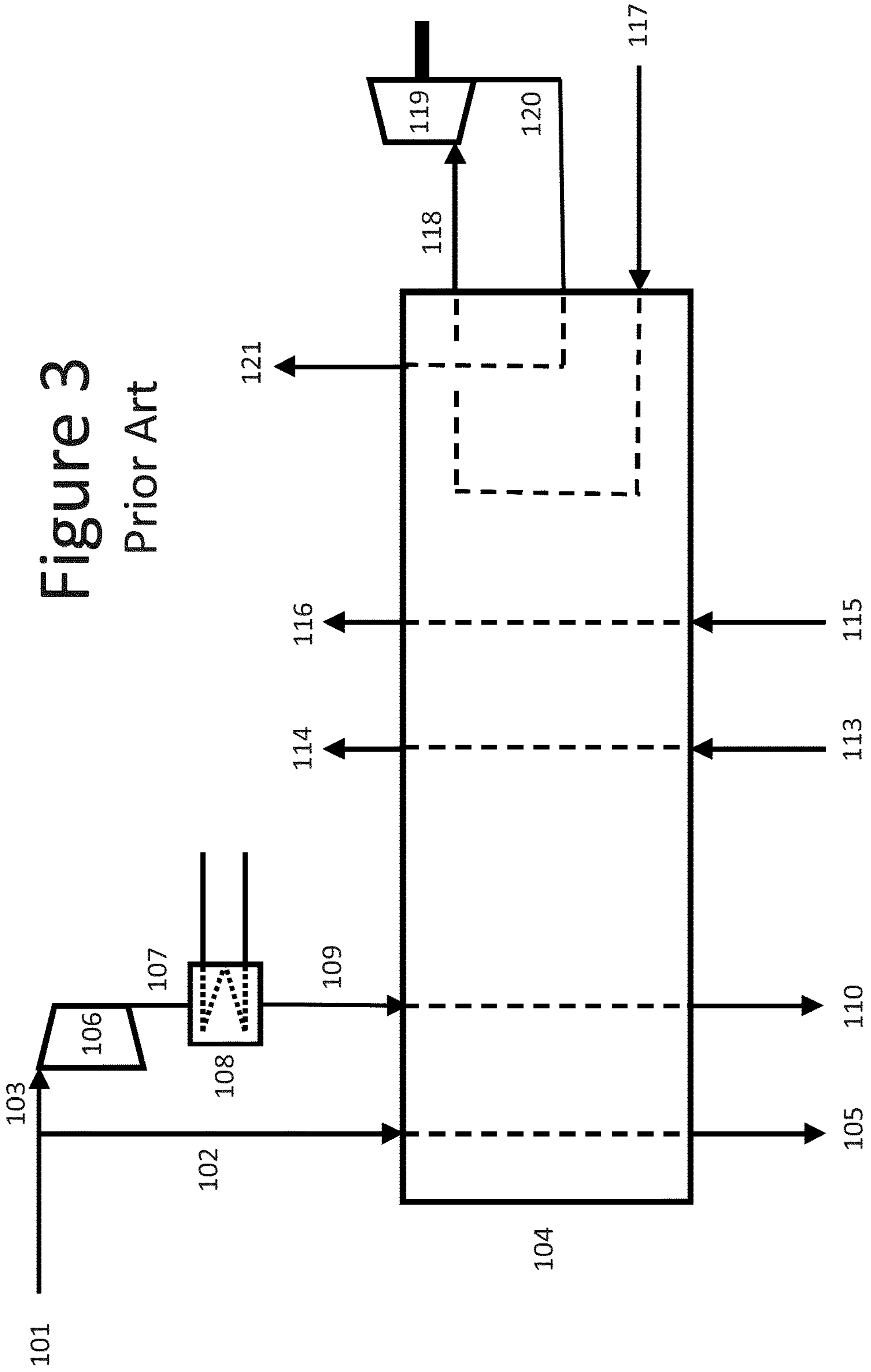


Figure 3
Prior Art

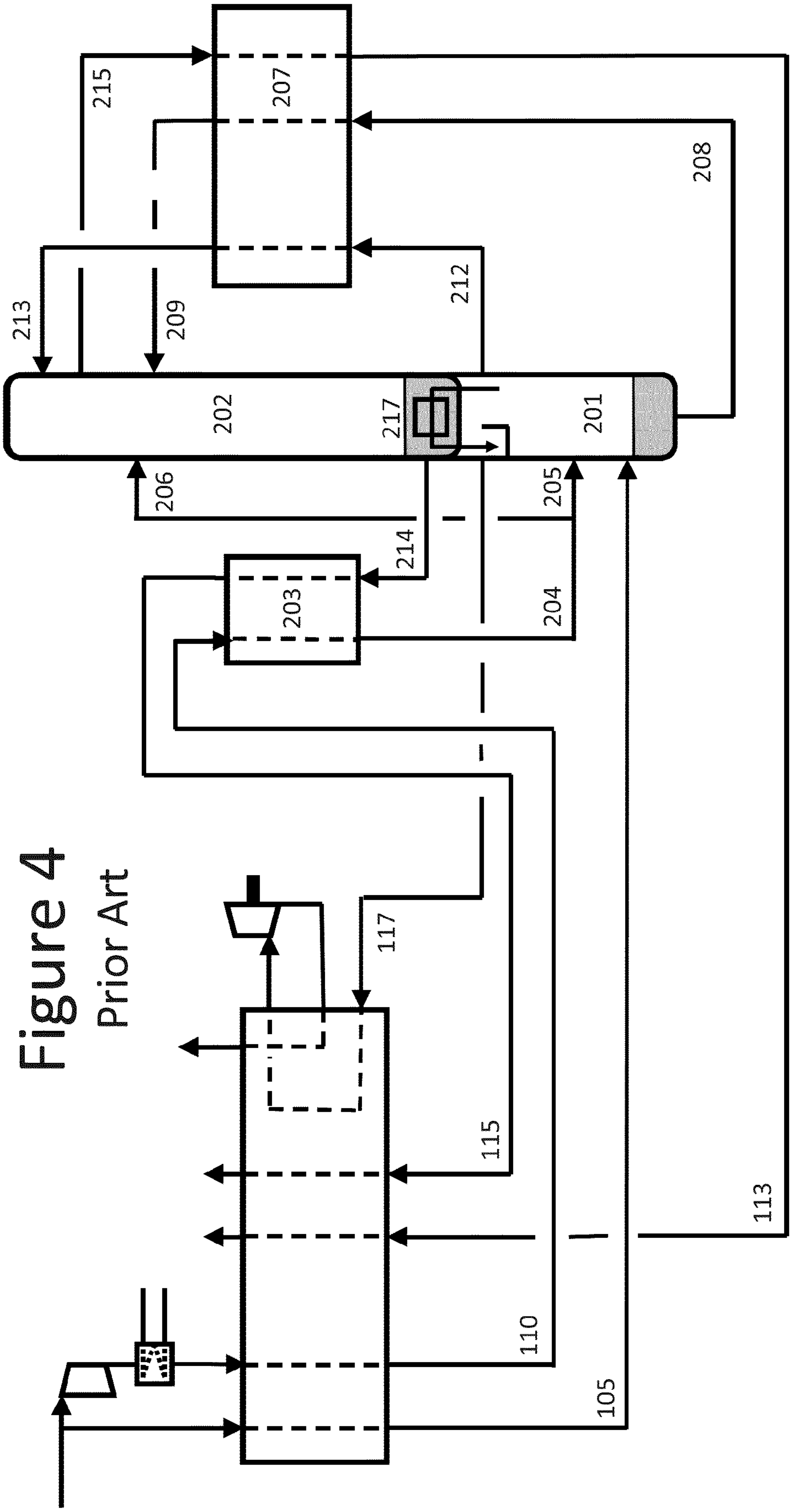


Figure 4
Prior Art

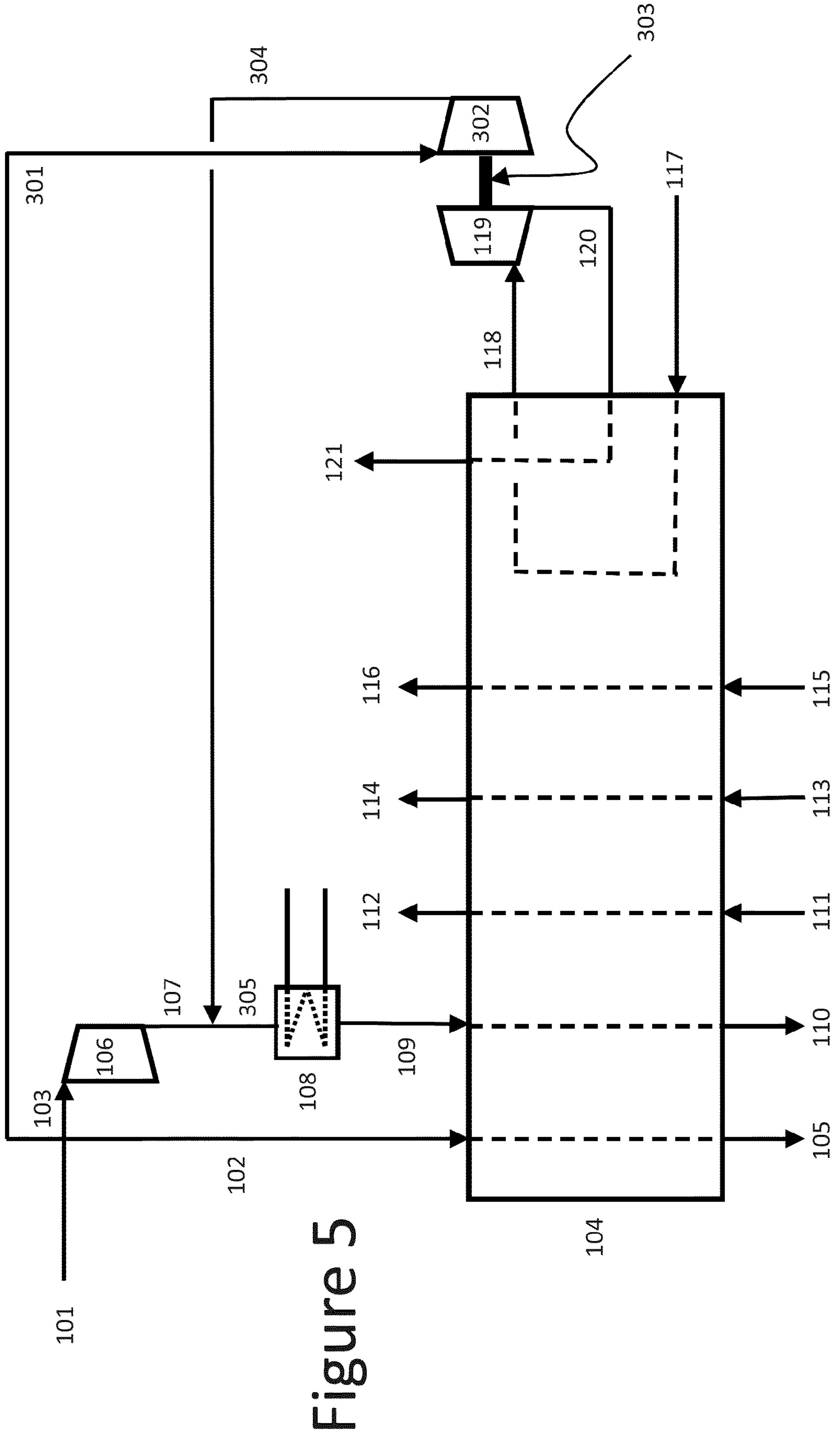

101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
301
302
303
304
305

Figure 5

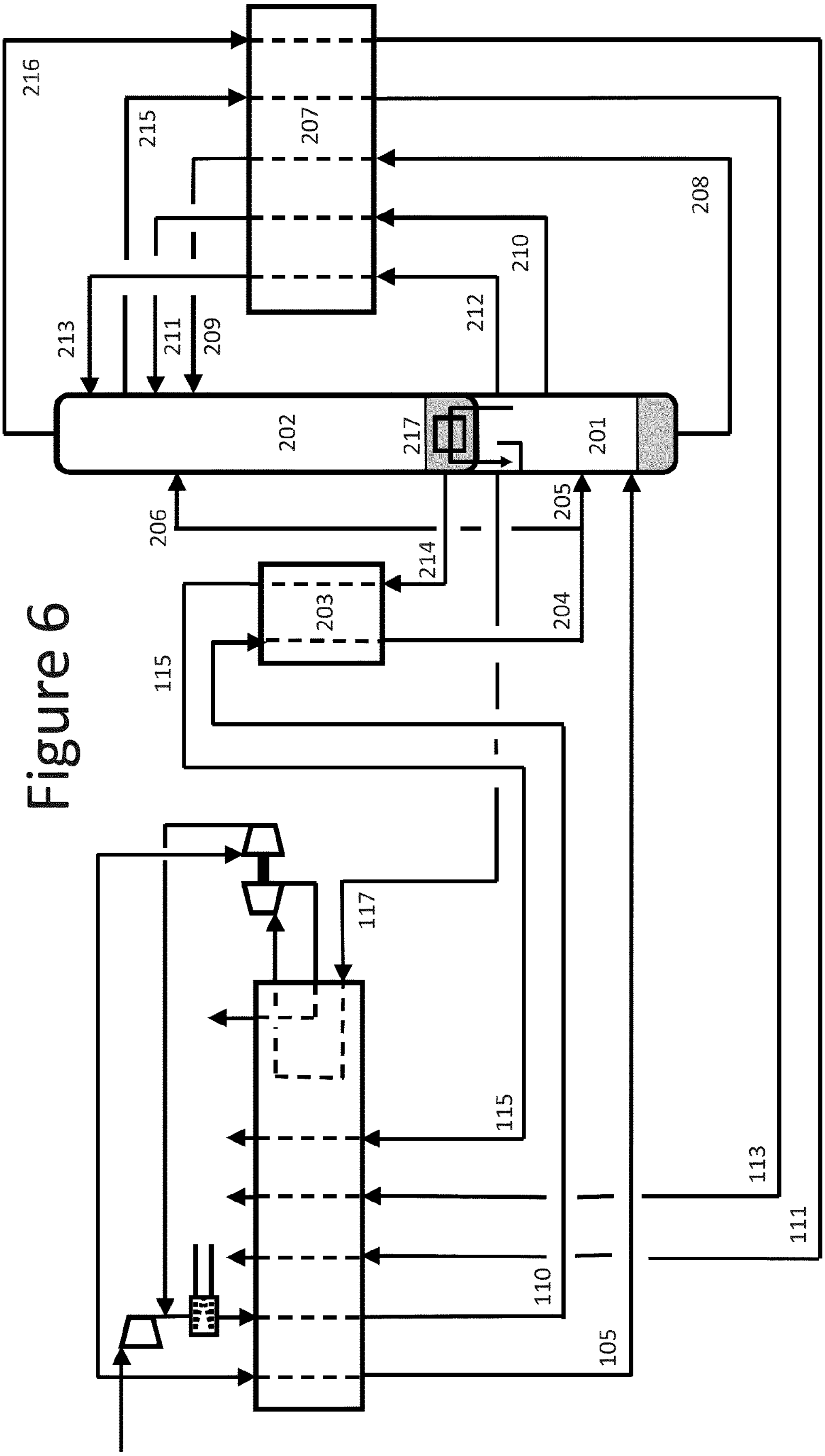

216
215
207
208
210
213
211
209
212
202
217
201
206
205
214
203
204
115
117
115
113
111
110
105

Figure 6

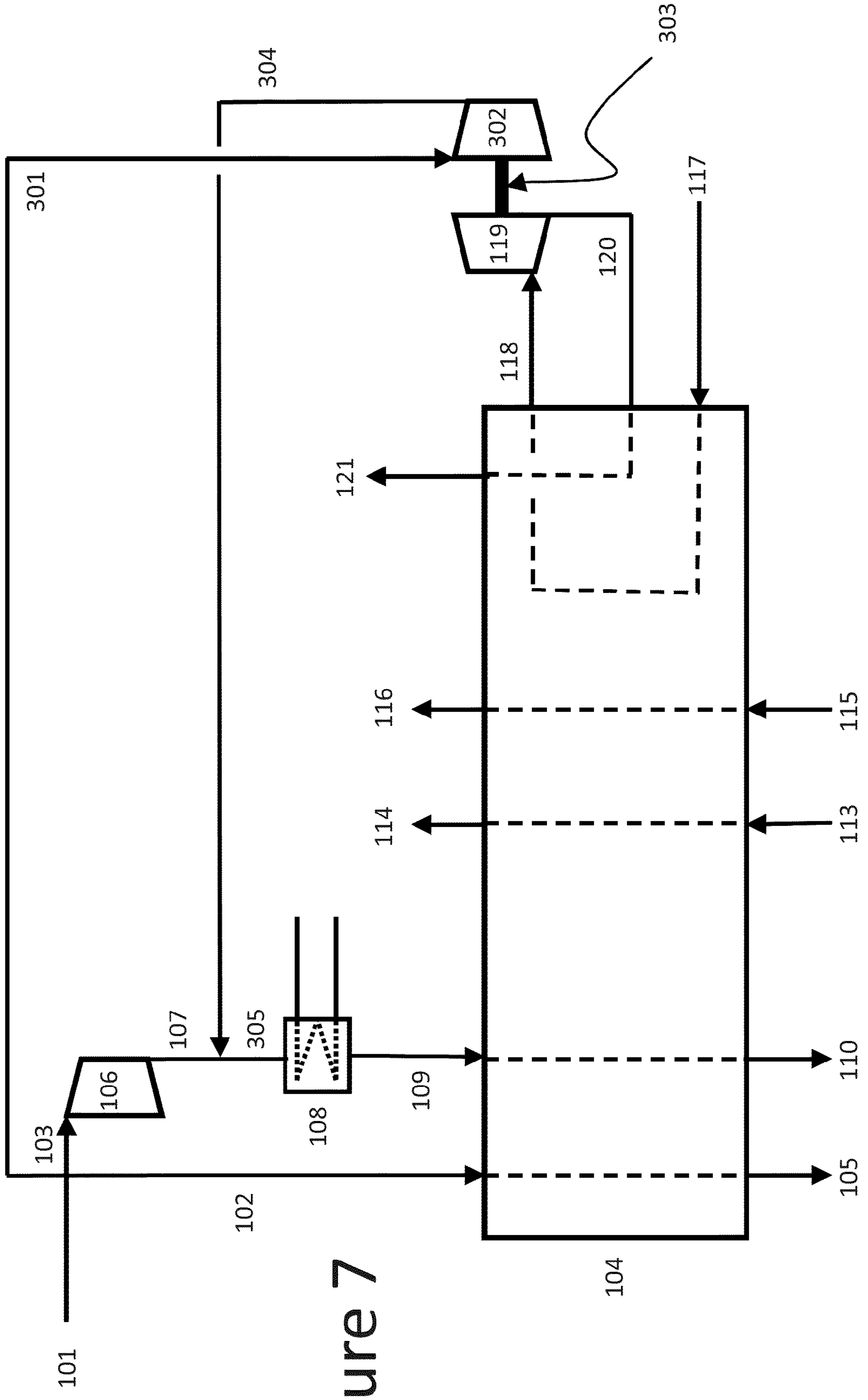
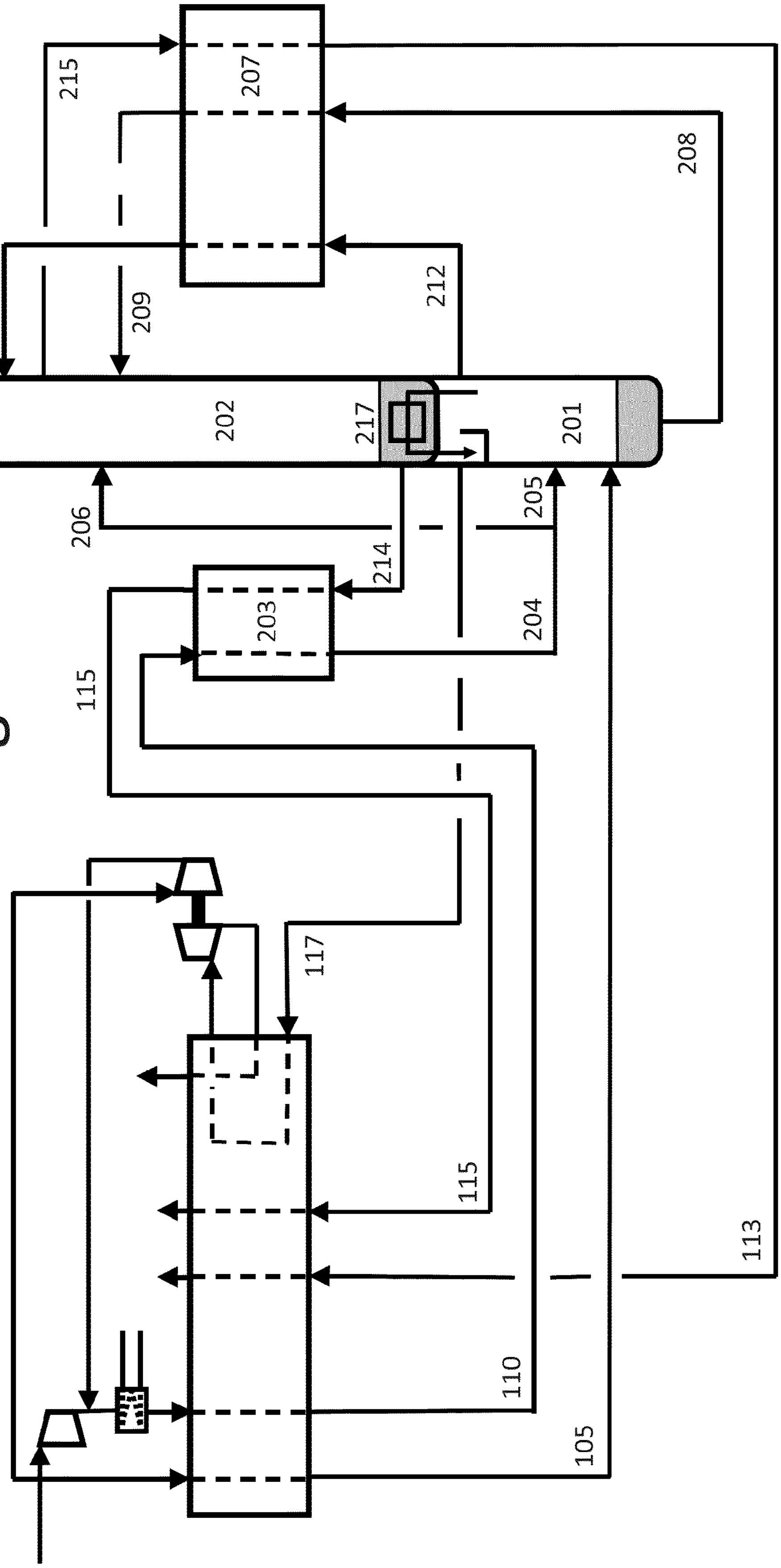

303
304
302
301
117
119
120
118
121
116
115
114
113
107
305
106
110
109
108
103
105
102
104
101

Figure 7



215
207
208
213
209
212
202
217
201
206
205
214
203
204
115
117
115
113
110
105

Figure 8

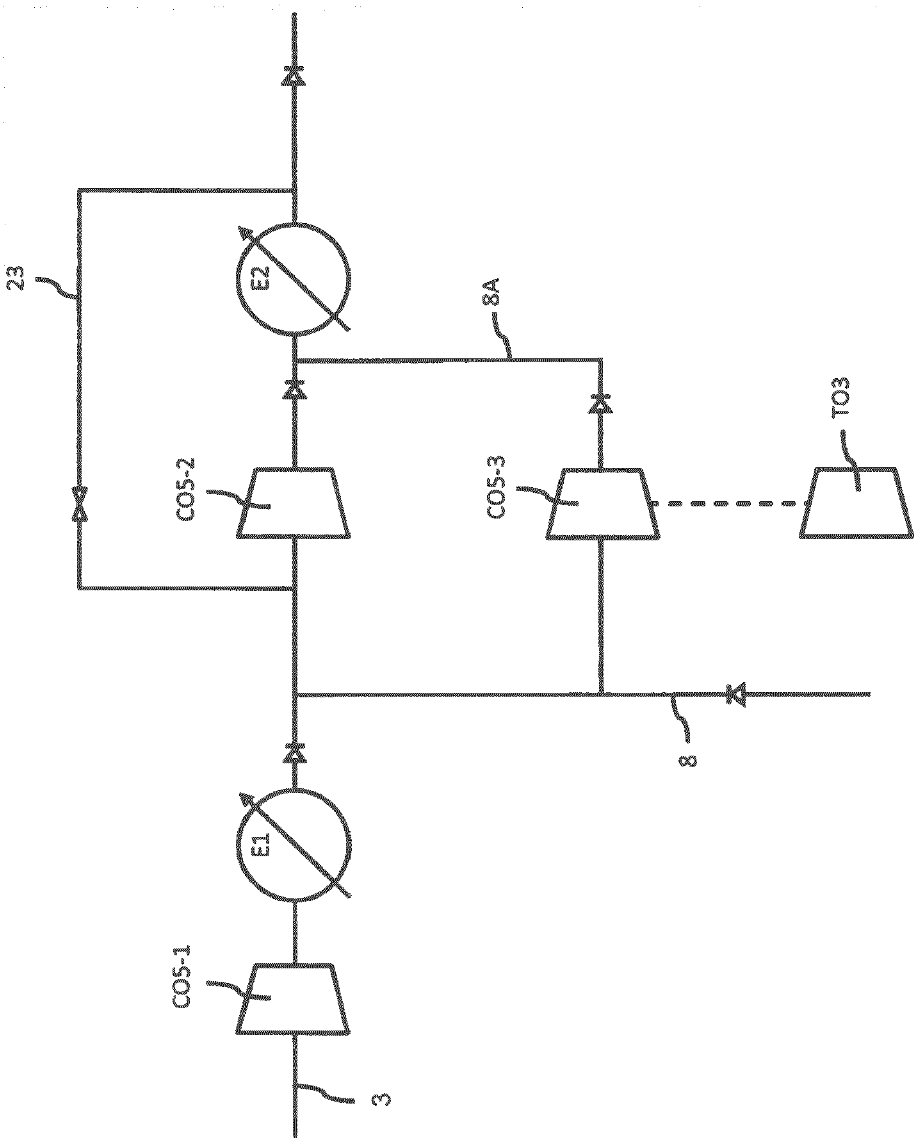


Figure 9

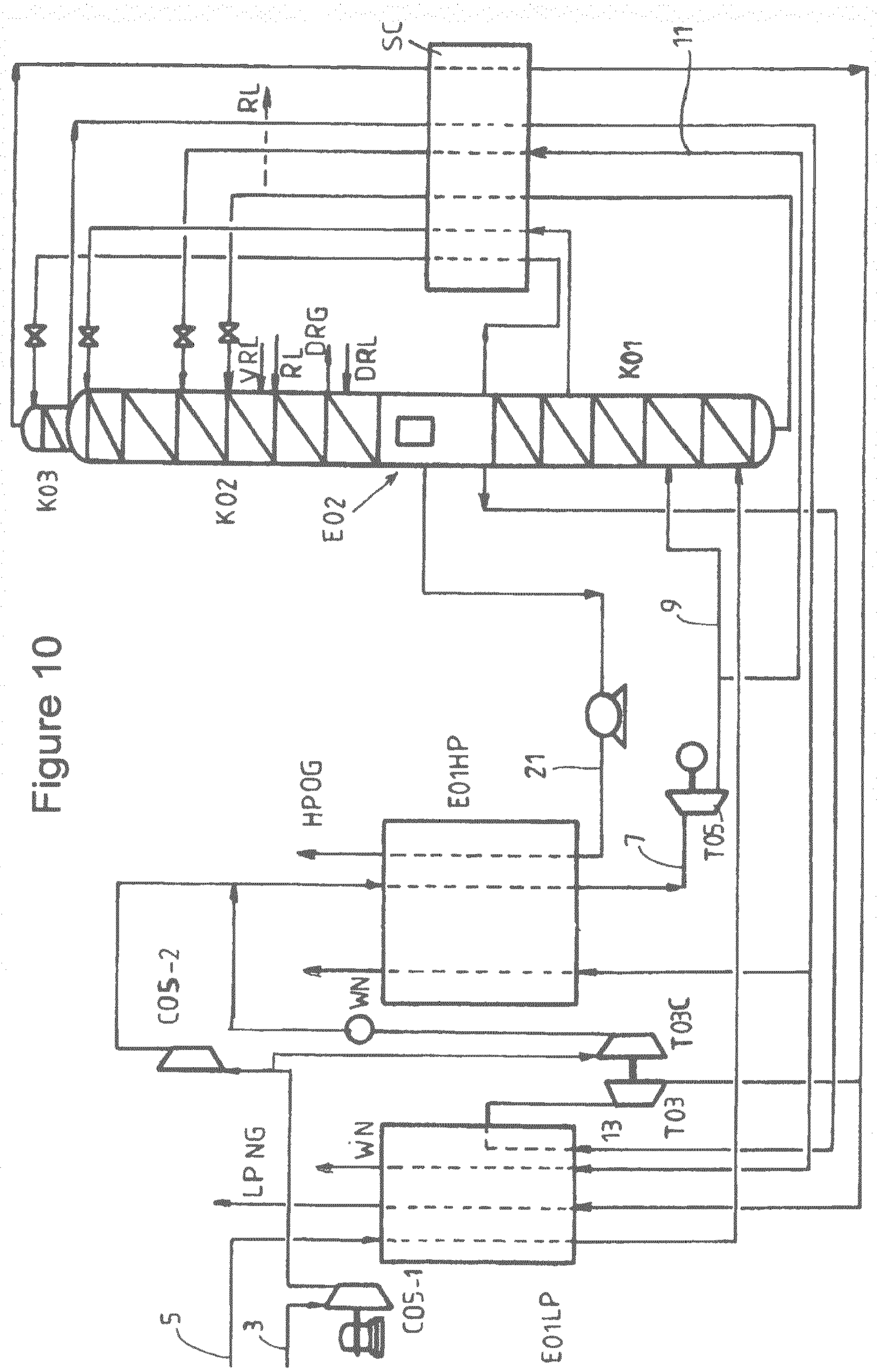

SC
11
RL
VRL
RL
DRG
DRL
K01
K03
K02
E02
9
21
E01HP
HPOG
7
T05
CO5-2
WN
T03C
T03
13
WN
LP NG
CO5-1
5
3
E01LP

Figure 10

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 22 19 9455

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 Y	US 2020/355429 A1 (ZHAO BOWEI [CN] ET AL) 12 November 2020 (2020-11-12) * figure 2 *	1-4,7-9, 11-13 5,6,10	INV. F25J3/04
X Y A	US 2016/231053 A1 (ASSE ALEXIS [FR] ET AL) 11 August 2016 (2016-08-11) * figures 1-3 *	1,3,4,7, 9,11-13 10 2,5,6,8	
Y	US 4 817 394 A (ERICKSON DONALD C [US]) 4 April 1989 (1989-04-04) * column 4, lines 59-68; figures 2,3 * * column 5, lines 38-50 * * column 6, lines 1-5 *	5,6,10	
Y	US 4 133 662 A (WAGNER NORBERT) 9 January 1979 (1979-01-09) * column 1, paragraph 33-38; figure 1 *	5,6	
Y	CN 112 414 003 A (AIR LIQUIDE) 26 February 2021 (2021-02-26) * figures *	10	

TECHNICAL FIELDS SEARCHED (IPC)

F25J

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	9 February 2023	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

EPO FORM 1503 03.82 (P04C01)

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

EP 22 19 9455

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.

09-02-2023

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2020355429 A1	12-11-2020	CN 111406192 A	10-07-2020
		EP 3719427 A1	07-10-2020
		KR 20200088399 A	22-07-2020
		US 2020355429 A1	12-11-2020
		WO 2019104524 A1	06-06-2019
US 2016231053 A1	11-08-2016	CN 105579801 A	11-05-2016
		EP 3047221 A2	27-07-2016
		FR 3010778 A1	20-03-2015
		US 2016231053 A1	11-08-2016
		WO 2015040306 A2	26-03-2015
US 4817394 A	04-04-1989	EP 0400046 A1	05-12-1990
		JP H03505911 A	19-12-1991
		US 4817394 A	04-04-1989
		WO 8907229 A1	10-08-1989
US 4133662 A	09-01-1979	AU 500646 B2	31-05-1979
		BR 7608165 A	22-11-1977
		DE 2557453 A1	30-06-1977
		FR 2335809 A1	15-07-1977
		GB 1511977 A	24-05-1978
		JP S5289565 A	27-07-1977
		JP S5634784 B2	12-08-1981
		US 4133662 A	09-01-1979
		ZA 761237 B	23-02-1977
CN 112414003 A	26-02-2021	NONE	

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82