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(71) Applicant: AIR PRODUCTS AND CHEMICALS, INC.
P.O. Box 538
Allentown, Pennsylvania 18105(US)

(72) Inventor: Theobald, Alan
"Ambleside" 46 Furze Lane
Purley Surrey(GB)

(74) Representative: Lucas, Brian Ronald
c/o Air Products Limited Coombe House St. George's Square
New Malden Surrey, KT3 4HH(GB)

(54) Method and cryogenic plant for producing gaseous oxygen.

(57) A method of producing gaseous oxygen comprises the steps of fractionating dry compressed air in a distillation system (9) having a high pressure column (8) operating at between 4 and 8 bars gauge and a low pressure column (15) operating at between 0.3 and 2 bars gauge. Liquid oxygen is withdrawn from the bottom of the low pressure column (8) through line (40) is pressurized by static head and/or a pump (41) and is evaporated in vessel (43) against a stream (27) of substantially pure nitrogen which has been removed from the top of the high pressure column (8) and compressed to such a pressure that it is at least partly liquified by the evaporation of the oxygen. At least part of the liquified nitrogen formed in vessel (43) is expanded and is returned to the high pressure column (8) as reflux.

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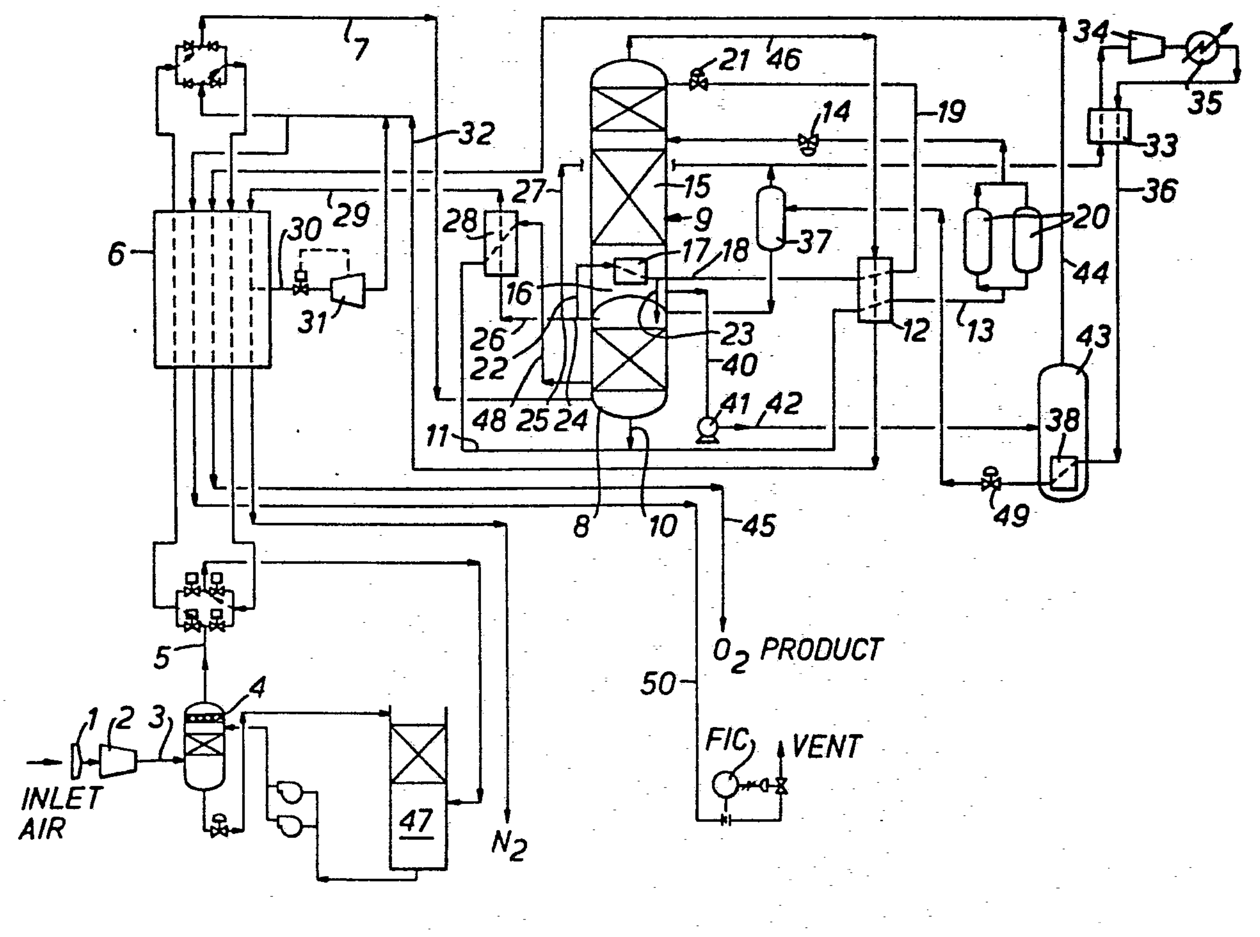

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This invention relates to a method for producing gaseous oxygen and a cryogenic plant in which said method can be carried out.

In the past large users of gaseous oxygen, such as steel producers, have required their oxygen to be supplied at little more than atmospheric pressure. Accordingly, there are a large number of cryogenic plants available which will produce gaseous oxygen at about 0.2 bars gauge.

More recently we have received enquiries for cryogenic plant capable of producing gaseous oxygen at from 1 to 4 bars gauge. In order to meet this demand we have proposed

(1) using a compressor to compress the gaseous oxygen product to the required pressure; or

(2) raising the pressure of the whole cryogenic plant from the main air compressor to the gaseous oxygen output.

Whilst both alternatives satisfy the need, the first alternative has the disadvantage that oxygen compressors are relatively expensive (typically £100,000 to £180,000) and require special safety precautions. The second alternative is relatively inexpensive in terms of capital expenditure but has the disadvantage that the power consumed by the main air compressor increases drastically.

It is an object of at least preferred embodiments of the present invention to provide a cryogenic plant which is less expensive to construct than alternative (1) and consumes less power than alternative (2).

According to the present invention there is provided a method of producing gaseous oxygen, which method comprises steps of fractionating dry compressed air in a distillation system having a high pressure column operating at between 4 and 8 bars gauge and a low pressure column operating at between 0.3 and 2 bars gauge, and wherein liquid oxygen is withdrawn from the bottom of said low pressure column, is pressurized and is evaporated against a stream of substantially pure nitrogen which has been removed from the top of said high pressure column warmed in a heat exchanger, compressed, cooled in said heat exchanger, at least partially liquified by the evaporation of said oxygen, and, at least in part, expanded and returned to said high pressure column as reflux.

Whilst the method of the present invention was specifically developed for providing gaseous oxygen at between 1 and 4 bars gauge, our preliminary investigation suggests that the method can be used for producing gaseous oxygen at much higher pressures, for example 55 bars gauge.

The liquid oxygen may be pressurized by a pump or by static head, for example by raising the height of the low pressure column so that the liquid at ground level is just above the required delivery pressure of the gaseous oxygen. Alternatively a combination of static head and pumping may be used. Cryogenic plant using the static head principle will be somewhat taller than their conventional counterparts and for most applications we anticipate that the bottom of the low pressure column will be at least 15m above ground level.

Preferably, the high pressure column is operated at between 4.5 and 7 bars gauge.

Advantageously, the low pressure column is operated at between 0.5 and 2.0 bars gauge.

In terms of cost, the nitrogen compressor required is considerably less expensive that the alternative oxygen compressor. Furthermore there are fewer potential hazards associated with its use. In terms of power consumption for a cryogenic plant designed to produce gaseous oxygen at 1 to 4 bars gauge, the power consumed by preferred embodiments of the present invention is approximately the same as that which would be consumed by a plant using a product oxygen compressor.

The present invention also provides a cryogenic plant for producing gaseous oxygen which plant comprises a high pressure column and a low pressure column for distilling air, an evaporator, a pipe for conveying, in use, liquid oxygen from the bottom of said low pressure column to said evaporator, means to ensure that, in use, the pressure of liquid oxygen at said evaporator is higher than the pressure of liquid oxygen leaving said low pressure column, a pipe for carrying gaseous oxygen from said evaporator, a heat exchanger, a pipe for conveying gaseous nitrogen from said high pressure column to said heat exchanger, a compressor, a pipe for conveying gaseous nitrogen from said heat exchanger to said compressor, a pipe for conveying compressed gaseous nitrogen to said heat exchanger, a pipe for conveying compressed gaseous nitrogen from said heat exchanger to a heat exchanger within said evaporator, an expansion valve, a pipe for conveying liquid nitrogen from said heat exchanger within said evaporator to said expansion valve and a pipe for carrying expanded liquid nitrogen from said expansion valve to the top of said high pressure column.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying flowsheet of a cryogenic plant in accordance with the present invention.

Referring to the drawing, air is passed through a filter 1 and is compressed to 5 bars gauge by a main air compressor 2. The compressed air leaves the main air compressor 2 through line 3 and after being cooled and scrubbed with water in direct contact aftercooler 4, is passed through line 5 to reversing heat exchanger 6.

As the air passes through the reversing heat exchanger 6 water and carbon dioxide freeze out and the remaining air, together with traces of uncondensed hydrocarbons, is passed through line 7 at -172^{o}C and 4.7 bars gauge to the high pressure column 8 of a double distillation column generally identified by reference numeral 9.

A vapour fraction is withdrawn from the high pressure column 8 through line 48, condensed in superheater 28, and returned through line 11. Crude liquid oxygen is withdrawn from the bottom of the high pressure column 8 through line 10 and after being joined by stream 11 is sub-cooled in sub-cooler 12 which it leaves through line 13. After passing through hydrocarbon adsorbers 20, the liquid is then expanded to approximately 0.5 bars gauge across valve 14 and enters the low pressure column 15 of the double distillation column 9. Substantially pure oxygen collects in the sump 16 of the low pressure column 15 where it cools the reflux condenser 17 associated with the high pressure column 8.

Gaseous nitrogen is removed from the top of the high pressure column 8 through line 22. Part of this nitrogen is condensed in the reboiler condenser 17 and part of the liquid is returned to the high pressure column 8 through line 23 as reflux whilst the remaining liquid is passed through line 18 to sub-cooler 12 which it leaves through line 19. This liquid is then expanded to approximately 0.4 bars gauge at valve 21 and is introduced into the top of the low pressure column 15 as reflux. The balance of the gaseous nitrogen leaving the high pressure column 8 is passed through line 24 to point 25 where the flow is divided into a first stream 26 and a second stream 27. The first stream 26 is passed through superheater 28 which it leaves through line 29 at -175°C. It is then introduced into the cold end of reversing heat exchanger 6. A side drawer 30 is expanded through expander 31 and after joining stream 32 is reintroduced into the cold end of the reversing heat exchanger 6. The balance of stream 29 leaves the reversing heat exchanger at approximately ambient temperature and is used for inter alia purging, reactivating adsorbers 22 and nitrogen product.

Second stream 27, which is at -178°C, is warmed to approximately ambient temperature in heat exchanger 33 and is then compressed to 10.3 bars gauge in compressor 34. The resulting warm nitrogen is cooled by water in heat exchanger 35 and is then further cooled in heat exchanger 33 which it leaves through line 36 at -169°C. The vapour is then condensed in heat exchanger 38 and expanded to 4.5 bars gauge at valve 49. The liquid and vapour thus formed are separated in phase separator 37 and the vapour is re-cycled to heat exchanger 33. The liquid from phase separator 37 is reintroduced into the high pressure column 8 of the double distillation column 9.

Liquid oxygen from the sump 16 of the low pressure column 15 is passed through line 40 at approximately 0.5 bars gauge to pump 41 which it leaves through line 42 at 2.1 bars gauge which is a little above the final supply pressure desired. The liquid oxygen is then vaporized in vessel 43 which is warmed by heat exchanger 38. Gaseous oxygen leaves the vessel 43 through pipe 44 and is passed through reversing heat exchanger 6 which it leaves through line 45 as product at 1.8 bars gauge and approximately ambient temperature.

Of the remaining features, impure nitrogen at approximately -193^{o}C leaves the top of the low pressure column 15 through line 46. It is then warmed in sub-cooler 12 which it leaves through line 32. After meeting the nitrogen leaving the expander 31, the mixture is divided into two streams which are each passed through reversing heat exchanger 6. One stream is vented through pipe 50 whilst the other is passed through column 47 where it cools the water used in the direct contact aftercooler 4 by evaporative cooling.

Various modifications to the plant described can be made, for example, low pressure product nitrogen from line 29 could be introduced into stream 27 immediately upstream of compressor 34 and withdrawn downstream (or from an intermediate stage) to give high pressure nitrogen product.

CLAIMS

1. A method of producing gaseous oxygen which method comprises the steps of fractionating dry compressed air in a distillation system having a high pressure column operating at between 4 and 8 bars gauge and a low pressure column operating at between 0.3 and 2 bars gauge, and wherein liquid oxygen is withdrawn from the bottom of said low pressure column, is pressurized and is evaporated against a stream of substantially pure nitrogen which has been removed from the top of said high pressure column warmed in a heat exchanger, compressed, cooled in said heat exchanger, at least partly liquified by the evaporation of said oxygen, and, at least in part, expanded and returned to said high pressure column as reflux.

2. A method as claimed in Claim 1, wherein the pressure of said oxygen is raised by a pump.

3. A method according to Claim 1 or 2, wherein said low pressure column is raised so that its bottom is at least 15m above ground level.

4. A method according to Claim 1, 2 or 3, wherein said high pressure column is operated at between 4.5 and 7 bars gauge.

5. A method according to any preceding Claim, wherein said low pressure column is operated at between 0.5 and 2.0 bars gauge.

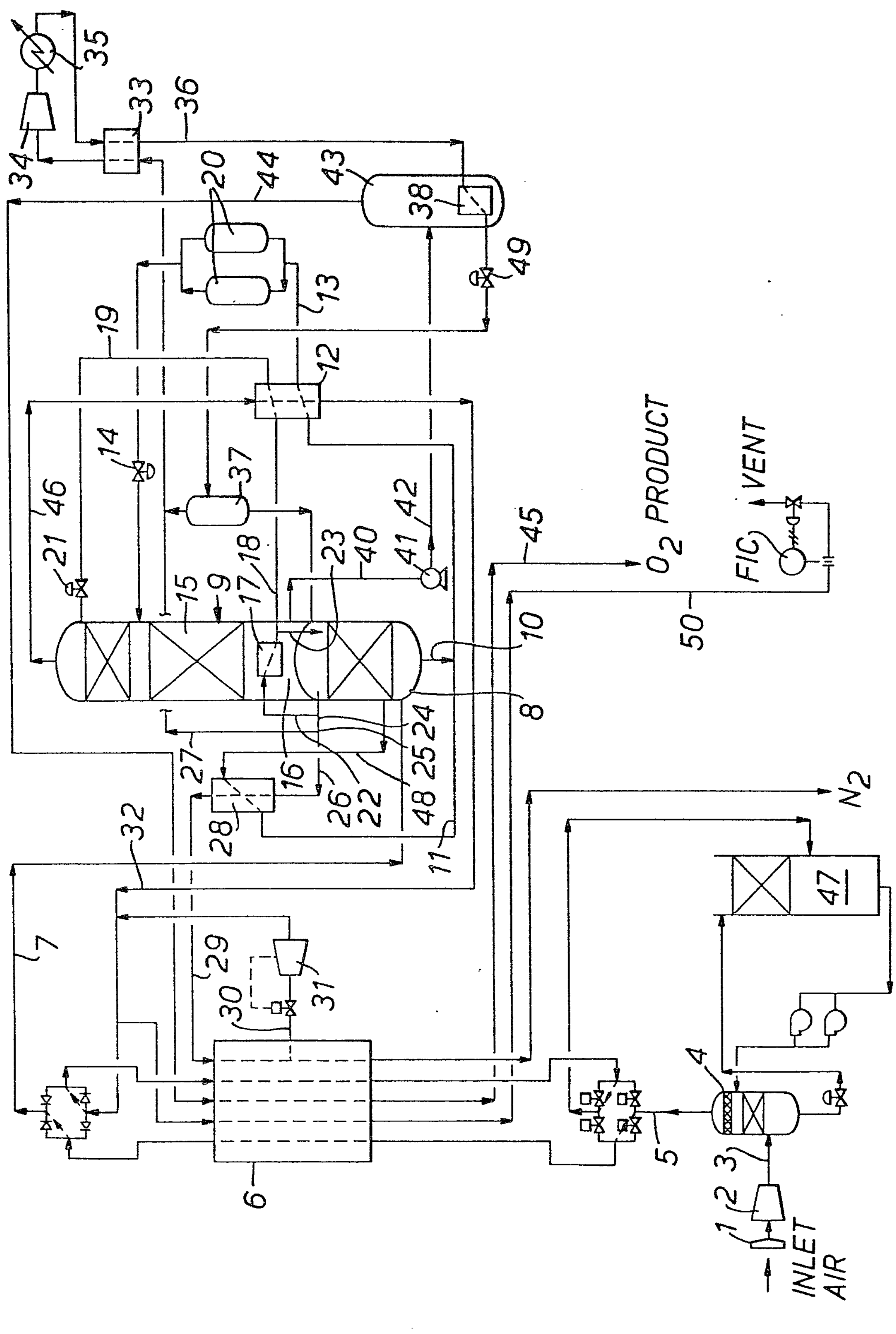
6. A cryogenic plant for producing gaseous oxygen which plant comprises a high pressure column (8) and a low pressure column (15) for distilling air, an evaporator (43), a pipe (40) for conveying, in use, liquid oxygen from the bottom of said low pressure column (15) to said evaporator (43), means (41) to ensure that, in use, the pressure of liquid oxygen at said evaporator (43) is higher than the pressure of liquid oxygen leaving said low pressure column (15), a pipe (44) for carrying gaseous oxygen from said evaporator (43), a heat

exchanger (6), a pipe (33) for conveying gaseous nitrogen from said high pressure column (8) to said heat exchanger (33), a compressor (34), a pipe for conveying gaseous nitrogen from said heat exchanger to said compressor, a pipe for conveying compressed gaseous nitrogen to said heat exchanger (34), a pipe (36) for conveying compressed gaseous nitrogen from said heat exchanger (33) to a heat exchanger (38) within said evaporator (43), an expansion valve (49), a pipe for conveying liquid nitrogen from said heat exchanger (38) within said evaporator (43) to said expansion valve (49), and a pipe for carrying expanded liquid nitrogen from said expansion valve to the top of said high pressure column.

For the Applicants

Brian Lucas

Brian Lucas
CHARTERED PATENT AGENT
EUROPEAN PATENT ATTORNEY



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Application number

European Patent Office

EUROPEAN SEARCH REPORT

EP 80 30 3721

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
X	GB - A - 1 516 478 (LINDE) * Page 1, lines 10-27; page 1, line 57 - page 2, line 32; page 2, line 72 - page 3, line 9; figures 1,2 * --	1,2,6	F 25 J 3/04
	US - A - 3 214 925 (R. BECKER) * Column 1, lines 12-19; column 1, line 57 - column 3, line 69; figures 1,2 * --	1,2,4,5	
			TECHNICAL FIELDS SEARCHED (Int.Cl. 3)
A	US - A - 3 083 544 (F. JAKOB) * Column 1, lines 11-16; column 2, line 44 - column 3, line 52; figures 1,2 * --		F 25 J 3/04 3/00
A	US - A - 3 648 471 (G.M. BAS1N et al.)		
A	US - A - 2 663 166 (C.R. ANDERSON)		
P,A	LINDE BERICHTE AUS TECHNIK UND WISSENSCHAFT, Nr. 46, Dezember 1979, Seiten 3-7 Wiesbaden, DE. H. SPRINGMANN: "Die Gewinnung von Hochdruck-Sauerstoff" * Figure 7 and its description * ----		

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	29-01-1981	SIEM