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(54) **Elevated pressure liquefier.**

(57) The energy efficiency of dual cryogenic distillation of air to produce liquid product in which refrigeration is generated by an expander scheme is improved by operating the low pressure distillation column (721) at an elevated pressure (170 to 350 kPa) vis-a-vis the prior art.

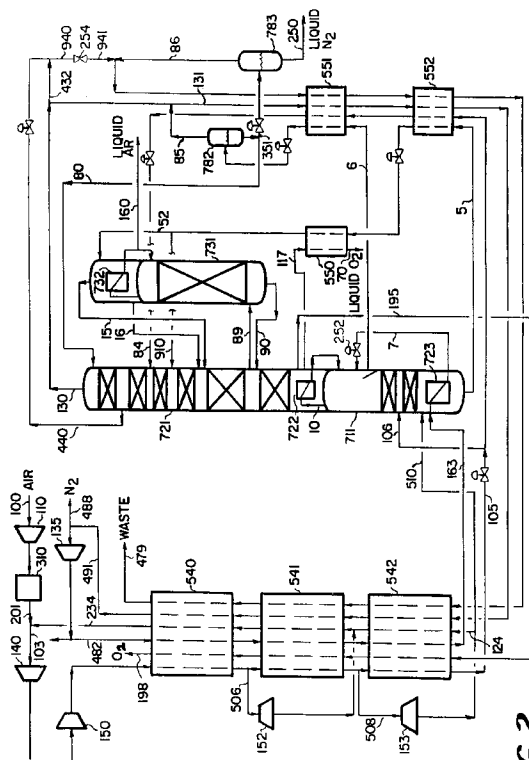


FIG. 2

The present invention is directed to a process producing large quantities of liquid product via the cryogenic distillation of air.

Liquefied atmospheric gases, including nitrogen, oxygen and argon, are finding increasing uses in industry. Such liquefied atmospheric gases provide cryogenic capabilities for various industrial processes, are more economical to transport in merchant supply and provide ready and economical sources of gaseous product from liquid storage facilities. For instance, liquid nitrogen is increasingly used to freeze food products, to cryogenically embrittle used materials for cleaning or recycle, and as a supply of gaseous nitrogen inerting medium for various industrial processes.

The conventional process for making large quantities of liquid nitrogen and/or liquid oxygen from an air feed is to include an expander scheme with the conventional multiple column distillation system. The expander scheme provides at least a portion of the large amount of refrigeration that is required to remove a large percentage of the air feed as liquid product vis-a-vis a small percentage of the air feed or no percentage of the air feed as liquid product. (As used herein, a "large percentage" of the air feed is defined as at least 15% of the air feed). This inclusion of an expander scheme with the conventional multiple column distillation system is generally referred to in the industry as a liquefier and that is how the term liquefier is used herein.

The expander scheme can be integrated with the front end processing of the air feed or with the recycling of low pressure column nitrogen overhead. Front end processing comprises compressing the air feed to an elevated pressure, removing impurities from the air feed which will freeze out at cryogenic temperatures and cooling the air feed by heat exchange against process streams. US-A-4,152,130; US-A-4,705,548; and US-A-4,715,873 for example, teach liquefiers wherein the expander scheme is integrated with the front end processing of the feed air while US-A-3,605,422 and US-A-4,894,076 teach liquefiers wherein the expander scheme is integrated with the recycling of the low pressure column nitrogen overhead.

The energy efficiency of conventional liquefiers is limited by the low operating pressure of the low pressure column (typically 17-24 psia; 115-165 kPa) in the multiple column distillation system. Air separation processes that do operate at an elevated pressure in the low pressure column (ie pressures greater than 25 psia; 170 kPa) have traditionally been restricted to gaseous product processes or small liquid making processes. GB-A-1,450,164 is an example which teaches this latter type of process.

It is an object of the present invention to improve the energy efficiency of the conventional liquefier.

The present invention is an improvement to a process producing large quantities of liquid product via the cryogenic distillation of air. The process to which the improvement pertains uses the conventional multiple column distillation system comprising a high pressure column and a low pressure column wherein, subsequent to a front end processing of the air feed, at least a portion of the air feed is fed to the high pressure column. In the high pressure column, the air feed is rectified into a high pressure nitrogen overhead and a high pressure crude liquid oxygen bottoms. At least a portion of the high pressure crude liquid oxygen bottoms is fed to the low pressure column in which the high pressure crude liquid oxygen bottoms is distilled into a low pressure nitrogen overhead and a low pressure liquid oxygen bottoms. The high pressure column and the low pressure column are thermally linked such that at least a portion of the high pressure nitrogen overhead is condensed in a reboiler/condenser against a vaporizing low pressure column oxygen-rich liquid. At least a portion of the condensed high pressure nitrogen overhead is used to provide reflux for the distillation column system. The operating pressure of the low pressure column in the conventional multiple distillation column system is typically 17-24 psia (115-165 kPa).

Along with the above described conventional multiple column distillation system, the process to which the improvement pertains generates an amount of refrigeration sufficient to remove at least 15% of the air feed as a liquid nitrogen product stream and/or a liquid oxygen product stream. At least a portion of this amount of refrigeration is generated by an expander scheme.

The improvement of the present invention is to increase the efficiency of the above described process and comprises operating the low pressure column at a pressure between 25 and 50 psia (170 and 350 kPa). In order to further increase the efficiency of the process, the improvement can further comprise expanding a nitrogen enriched gaseous product stream which is withdrawn from the low pressure column.

According to the present invention, there is provided a process for the cryogenic distillation of an air feed using a multiple column distillation system comprising a high pressure column and a low pressure column and generating an amount of refrigeration sufficient to remove at least 15% of the air feed as a liquid nitrogen product stream and/or a liquid oxygen product stream; wherein at least a portion of said amount of refrigeration is generated by an expander scheme; subsequent to a front end processing of the air feed, at least a portion of the air feed is fed to the high pressure column in which the air feed is rectified into a high pressure nitrogen overhead and a high pressure crude liquid oxygen bottoms; at least a portion of the high pressure crude liquid oxygen bottoms is fed to the low pressure column in which the high pressure crude liquid oxygen bottoms is distilled into a low pressure nitrogen overhead and a low pressure liquid oxygen bottoms; the high pressure

column and the low pressure column are thermally linked such that at least a portion of the high pressure nitrogen overhead is condensed in a reboiler/condenser against a vaporizing low pressure column oxygen-rich liquid; and at least a portion of the condensed high pressure nitrogen overhead is used to provide reflux for the distillation column system; characterized in that the low pressure column is operated at a pressure between 170 and 350 kPa (25 and 50 psia).

Desirably, a second portion of said refrigeration can be generated by withdrawing a nitrogen enriched gaseous product stream from the low pressure column and expanding said stream in an expander.

Suitably, the expander scheme is integrated with the further processing of the portion of the low pressure nitrogen overhead. In one preferred embodiment, said further processing comprises compressing said low pressure nitrogen overhead portion to an elevated pressure; cooling the compressed overhead portion nitrogen by heat exchange against one or more process streams to a temperature at or near its dew point; condensing said cooled nitrogen overhead portion in a reboiler/condenser against vaporizing high pressure crude liquid oxygen bottoms; using the condensed low pressure nitrogen overhead as additional reflux for the distillation column system and/or as at least a portion of the liquid nitrogen product stream. Advantageously, a second portion of the low pressure nitrogen overhead is warmed by heat exchange against one or more process streams and subsequently removed as a gaseous nitrogen product stream. Refrigeration can be generated by expanding said second portion of the low pressure nitrogen overhead in an expander prior to said warming thereof.

The expander scheme can be integrated with the front end processing of the air feed. Preferably, the front end processing of the air feed comprises compressing the air feed to an elevated pressure and removing impurities from the air feed which will freeze out at cryogenic temperatures; cooling the air feed by heat exchange against one or more process streams; splitting the air feed into a first split feed stream and a second split feed stream; expanding the first split feed stream in an expander and recycling the expanded first split feed stream to the air feed while providing refrigeration to the air feed by heat exchange; further cooling the second split feed stream by heat exchange against process streams; further splitting the second split feed stream into a third split feed stream and a fourth split feed stream; expanding the third split feed stream in an expander and recycling a portion of the expanded third split feed stream to the air feed while providing refrigeration to the air feed by heat exchange; further cooling the fourth split feed stream by heat exchange against process streams; introducing a portion of the fourth split feed stream into the low pressure column for rectification; and introducing the remaining portion of the fourth split feed stream and the remaining portion of the expanded third split feed stream into the high pressure column for rectification.

At least a portion of the low pressure nitrogen overhead can be warmed by heat exchange against one or more process streams and recycled to the process for further processing.

A waste stream can be withdrawn from an upper intermediate location of the low pressure column, warmed by heat exchange against one or more process streams and subsequently removed as a gaseous waste product. Refrigeration can be generated by expanding said waste stream in an expander prior to said warming thereof.

A portion of the low pressure liquid oxygen bottoms can be removed as the liquid oxygen product stream and/or a portion of said bottoms warmed by heat exchange against one or more process streams and subsequently removed as a gaseous oxygen product.

The multiple distillation column system may further comprise an argon column in which an argon containing gaseous side stream removed from a lower intermediate location of the low pressure column is rectified into an argon-rich vapor overhead and an argon-lean bottoms liquid. The argon-lean bottoms liquid is returned to the low pressure column and at least a portion of the argon-rich vapor overhead is condensed in a reboiler/condenser against vaporizing high pressure crude liquid oxygen bottoms. A portion of the condensed argon-rich vapor overhead is removed as a liquid argon product and the remaining portion of thereof is used to provide reflux for the argon column.

In the drawings:-

Figure 1 is a schematic diagram of a conventional process producing large quantities of liquid product via the cryogenic distillation of air;

Figure 2 is a schematic diagram of one embodiment of the process of the present invention; and

Figure 3 is a schematic diagram of a preferred embodiment of the process of the present invention.

Figure 1 is representative of a conventional liquefier to which the present invention pertains. Figure 1 is based on the teachings of US-A-4,705,548. Referring now to Figure 1, an ambient air feed in stream 100 is compressed in compressor 110 and cleaned of impurities which will freeze out at cryogenic temperatures in cleaning bed 310. The resultant stream 201 is combined with an air recycle stream 234 to form stream 103 which is further compressed in compressors 140 and 150 prior to being cooled by heat exchange against warming process streams in heat exchanger 540. A portion of stream 103 is removed as stream 506 and expanded

in expander 152. The remaining portion of stream 103 is further cooled by heat exchange against warming process streams in heat exchanger 541 after which a second portion of stream 103 is removed as stream 508 and expanded in expander 153. A portion of expander 153's discharge is removed as stream 124 and warmed by heat exchange against cooling process streams in heat exchanger 542 after which stream 124 is combined with expander 152's discharge and further warmed by heat exchange against cooling process streams in heat exchangers 541 and 540 to form the air recycle stream 234. The remaining portion of expander 153's discharge is fed to the bottom of high pressure column 711 as stream 510. The portion of stream 103 remaining after stream 508 is removed is further cooled by heat exchange against warming process streams in heat exchanger 542 to form stream 105. A portion of stream 105 is fed to an intermediate location of high pressure column 711 as stream 106 while the remaining portion is further cooled by heat exchange against warming process streams in heat exchangers 552 and 551 before being fed to an intermediate location of low pressure column 721 as stream 84.

The high pressure column feed streams 106 and 510 are rectified into a high pressure nitrogen overhead in stream 10 and a high pressure crude liquid oxygen bottoms in stream 5. Stream 5 is subcooled by heat exchange against warming process streams in heat exchanger 552, reduced in pressure and subsequently warmed by heat exchange against a liquid oxygen product in heat exchanger 550. A portion of stream 5 is then fed to an intermediate location of low pressure column 721 as stream 910 while the remaining portion is fed to reboiler/condenser 732 at the top of crude argon column 731 as stream 52.

An argon containing gaseous side stream 89 is removed from a lower intermediate location of the low pressure column and also fed to crude argon column 731 in which stream 89 is rectified into an argon-rich vapor overhead and an argon-lean bottoms liquid in stream 90 which is returned to the low pressure column. The argon-rich vapor overhead is condensed in reboiler/condenser 732 against the high pressure crude liquid oxygen bottoms in stream 52. A portion of the condensed argon-rich vapor overhead is removed as a liquid argon product in stream 160 while the remaining portion of the condensed argon-rich vapor overhead is used to provide reflux for the crude argon column. The portion of the high pressure crude liquid oxygen bottoms in stream 52 that is vaporized against the argon-rich vapor overhead is fed to the low pressure column in stream 15 while the portion which is not vaporized is fed to the low pressure column in stream 16.

The low pressure column feed streams 910, 84, 15 and 16 are distilled into a low pressure nitrogen overhead in stream 130 and a low pressure liquid oxygen bottoms. The high pressure column and the low pressure column are thermally linked such that at least a portion of the high pressure nitrogen overhead in stream 10 is condensed in reboiler/condenser 722 against vaporizing low pressure liquid oxygen bottoms. At least a portion of the condensed high pressure nitrogen overhead is used to provide reflux for the distillation column system.

The low pressure nitrogen overhead in stream 130 is combined with a vapor flash stream 85 from flash drum 782 to form stream 131. Stream 131 is warmed by heat exchange against process streams in heat exchangers 551, 552, 542, 541 and 540 to form stream 491. A portion of stream 491 is removed as a gaseous nitrogen product in stream 488 while the remaining portion is compressed in compressor 135 to approximately 120 psia (825 kPa) to form stream 482. Stream 482 is cooled to near its dew point by heat exchange against warming process streams in heat exchangers 540, 541 and 542. The resultant stream 163 is subsequently condensed in reboiler/condenser 723 against vaporizing high pressure crude liquid oxygen bottoms. The resultant stream 7 is expanded across valve 252 and subsequently fed as reflux to the high pressure column. A portion of the low pressure column reflux is removed from the high pressure column in stream 6. Stream 6 is subcooled by heat exchange against warming process streams in heat exchanger 551 and flashed in flash drum 782. A portion of the saturated liquid resulting from this flash is removed as a liquid nitrogen product in stream 250 while the remaining portion is used as reflux for the low pressure column in stream 80. The saturated vapor resulting from this flash in stream 85 is combined with the low pressure nitrogen overhead in stream 130 to form stream 131.

A nitrogen enriched waste stream 440 is withdrawn from an upper intermediate location of the low pressure column, warmed by heat exchange against process streams in heat exchangers 551, 552, 542, 541 and 540 and subsequently removed as a gaseous waste product in stream 479. A portion of the low pressure liquid oxygen bottoms is removed in stream 117 and subcooled in heat exchanger 550 before being removed as a liquid oxygen product in stream 70. A portion of the vaporizing low pressure liquid oxygen bottoms is removed in stream 195 and warmed by heat exchange against cooling process streams in heat exchangers 542, 541 and 540 before being removed as a gaseous oxygen product in stream 198.

The present invention improves the energy efficiency of the conventional liquefies by elevating the operating pressure of the low pressure column to a pressure between 25 and 50 psia (170-350 kPa). This elevated pressure range increases the energy efficiency of the process by reducing the irreversibility of the conventional liquefier. Irreversibility is commonly called lost work or lost exergy. In the distillation system, exergy loss

can be reduced by reducing the driving force for mass transfer. On an x-y equilibrium diagram, the driving force for mass transfer is shown by the distance between the equilibrium curve and the operating lines. At the same liquid to vapor flow ratios in the distillation column, the driving force can be reduced by elevating the column operating pressure to move the equilibrium curve closer to the operating lines. This effect is more noticeable in the low pressure column.

Exergy loss can be further reduced in the conventional liquefier by reducing the driving force for heat transfer in the front end heat exchanger(s). On a plot of temperature versus enthalpy change, the driving force for heat transfer is shown by the distance between the line for the cooling stream and the line for the warming stream. Elevating the pressure of the low pressure column in turn allows elevation of the expander scheme discharge pressure. For a typical inlet pressure of 600 psia (4.1 MPa), elevating the expander scheme discharge pressure can adjust the shape of the cooling curves to allow a smaller average heat transfer driving force.

An elevated pressure in the low pressure column also increases the density of the process gas streams, particularly the low pressure streams. Equipment sizes can be reduced for capital savings due to the lower volumetric gas flows.

The upper limit of the present invention's pressure range accounts for the fact that, as the pressure is continually elevated, the benefits of reduced irreversibility are eventually offset by the prohibitive number of additional trays that are required in the distillation system. In effect, the present invention's elevated pressure range represents an optimum trade off between reducing the irreversibility of the process at the expense of increasing the capital requirements of the process.

Figure 2 is an embodiment of the present invention as applied to the flowsheet depicted in Figure 1. Figure 2 is identical to Figure 1 (similar features of Figure 2 utilize common numbering with Figure 1) except that Figure 2 incorporates a pressure reduction scheme for the gaseous and liquid nitrogen product streams. This pressure reduction scheme equates the nitrogen product stream pressures obtained in the elevated pressure liquefier of Figure 2 with the nitrogen product streams obtained in the conventional liquefier of Figure 1. (This equating is necessary before performing an efficiency comparison between Figures 1 and 2 as is done in the Example infra). Referring to Figure 2, the pressure reduction scheme comprises combining a portion of the low pressure nitrogen overhead 432 with waste stream 440 to form a combined gaseous nitrogen product stream 940 which is subsequently reduced in pressure across valve 254 to form stream 941. The pressure reduction scheme further comprises re-flashing the initial liquid nitrogen product stream 351 obtained from flash drum 782 in a second flash drum 783 to obtain the final liquid nitrogen product stream 250. The vapor stream 86 from this second flash step is combined with stream 941. This combined stream is then warmed by heat exchange against process streams and removed as combined gaseous nitrogen product stream 479.

A preferred embodiment of the present invention which further increases the efficiency of the conventional liquefier comprises expanding a nitrogen enriched gaseous product stream which is withdrawn from the low pressure column. This preferred embodiment exploits the fact that such a product stream will be at an elevated pressure visa-vis the conventional liquefier and thus can be expanded to generate refrigeration. Figure 3 illustrates this preferred embodiment of the present invention as applied to the flowsheet depicted in Figure 2. Figure 3 is identical to Figure 2 (similar features of Figure 3 utilize common numbering with Figure 2) except that expander 154 is substituted for pressure reduction valve 254. Although not shown in Figure 3, stream 940 may first be partially warmed in one or more of the process heat exchangers prior to being expanded in expander 154.

The present invention is not only applicable to the air recycle liquefiers as described in US-A-4,152,130; US-A-4,705,548; and US-A-4,715,873 but also to any air recycle liquefier derived from these patents. It is also applicable to any nitrogen recycle liquefier such as those described in US-A-3,605,422 and US-A-4,894,076.

In order to demonstrate the efficacy of the present invention, the following example is offered.

EXAMPLE

The purpose of this example is to demonstrate the improved energy efficiency of present invention. This was accomplished by performing computer simulations for the liquefiers depicted in the flowsheets of Figures 1, 2 and 3. In the simulation of Figure 1, the pressure at the top of the low pressure column is set at a conventional pressure of 18.1 psia (125 kPa). In the simulations of Figures 2 and 3, this pressure is elevated to a pressure within the range of the present invention, namely 27.8 psia (191.5 kPa) for the Figure 2 simulation and 25.9 psia (178.5 kPa) for Figure 3's preferred embodiment simulation. In each simulation, the percentage of the air feed that is recovered as liquid nitrogen (27.1%), liquid oxygen (20.5%), liquid argon (0.9%), and gaseous nitrogen (51.0%) is kept constant. Operating conditions for these and other key streams in the simulations of Figures 1, 2 and 3 are included in the following Tables 1, 2 and 3 respectively.

Table 1

5	Steam Number	Pressure psia (kPa)	Temp. °F (°C)	Flow (% of air feed)	Composition (mole%)		
					N ₂	Ar	O ₂
	70	21.9 (151)	-300 (-184.5)	20.5	0.00	0.19	99.81
10	100	14.7 (101.5)	80 (26.5)	100.0	78.12	0.93	20.95
	103	80.5 (555)	78 (25.5)	306.0	78.12	0.93	20.95
	105	760.0 (5240)	-278 (-172)	58.5	78.12	0.93	20.95
15	124	85.0 (586)	-279 (-173)	139.0	78.12	0.93	20.95
	130	18.1 (125)	-317 (-194)	69.8	100.00	0.00	0.00
	160	15.9 (109.5)	-301 (-185)	0.9	0.11	99.39	0.50
20	163	120.0 (827.5)	-278 (-172)	37.5	100.00	0.00	0.00
	195	21.9 (151)	-290 (-179)	0.0	0.00	0.09	99.91
	198	19.9 (137)	78 (25.5)	0.0	0.00	0.09	99.91
25	201	81.0 (559)	78 (25.5)	100.0	78.12	0.93	20.95
	234	81.0 (559)	78 (25.5)	206.0	78.12	0.93	20.95
	250	18.1 (125)	-317 (-194)	27.1	100.00	0.00	0.00
30	440	18.9 (130.5)	-316 (-193.5)	11.9	99.86	0.12	0.02
	479	17.0 (117)	78 (25.5)	11.9	99.86	0.12	0.02
	488	15.2 (105)	78 (25.5)	39.1	100.00	0.00	0.00
35	506	764.0 (5268)	50 (10)	67.0	78.12	0.93	20.95
	508	762.0 (5254)	-137 (-94)	180.5	78.12	0.93	20.95
	510	85.0 (586)	-279 (-173)	41.5	78.12	0.93	20.95

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Table 2

Steam Number	Pressure psia (kPa)	Temp. °F (°C)	Flow (% of air feed)	Composition (mole %)		
				N ₂	Ar	O ₂
70	31.9 (220)	-298 (-183.5)	20.5	0.00	0.19	99.81
86	18.6 (128)	- 317 (-194)	1.1	100.00	0.00	0.00
100	14.7 (101.5)	80 (26.5)	100.0	78.12	0.93	20.95
103	109.3 (753.5)	78 (25.5)	319.1	78.12	0.93	20.95
105	760.0 (5240)	-270 (-168)	58.9	78.12	0.93	20.95
124	113.8 (784.5)	-271 (-168.5)	142.4	78.12	0.93	20.95
130	27.8 (191.5)	-310 (-190)	74.7	100.00	0.00	0.00
160	25.9 (178.5)	-292 (-180)	0.9	0.11	99.39	0.5
163	162.6 (1121)	-270 (-168)	45.0	100.00	0.00	0.00
195	31.9 (220)	-283 (-175)	0.0	0.00	0.09	99.91
198	29.9 (206)	78 (25.5)	0.0	0.00	0.09	99.91
201	109.8 (757)	78 (25.5)	100.00	78.12	0.93	20.95
234	109.8 (757)	78 (25.5)	219.1	78.12	0.93	20.95
250	18.6 (128)	-317 (-194)	27.1	100.00	0.00	0.00
432	27.8 (191.5)	-310 (-190)	38.0	100.00	0.00	0.00
440	28.9 (199.5)	-309 (-189.5)	11.9	99.76	0.19	0.05
479	17.0 (117)	78 (25.5)	51.0	99.94	0.05	0.01
488	25.2 (176)	78 (25.5)	0.0	100.00	0.00	0.00
506	764.0 (5268)	50 (10)	76.7	78.12	0.93	20.95
508	762.0 (5254)	-140 (-95.5)	183.5	78.12	0.93	20.95
510	113.8 (784.5)	-271 (-168.5)	41.1	78.12	0.93	20.95
940	27.8 (191.5)	-310 (-190)	49.9	99.94	0.05	0.01
941	18.7 (129)	-313 (-191.5)	49.9	99.94	0.05	0.01

Table 3

	Steam Number	Pressure psia (kPa)	Temp. °F (°C)	Flow (% of air feed)	Composition (mole %)		
					N ₂	Ar	O ₂
5	70	31.8 (219.5)	-298.5 (-183.5)	20.5	0.00	0.19	99.81
10	100	14.7 (101.5)	80 (26.5)	100.0	78.12	0.93	20.95
	103	109.1 (752)	78 (25.5)	312.9	78.12	0.93	20.95
	105	760.0 (5240)	-270 (-128)	57.0	78.12	0.93	20.95
15	124	113.6 (783.5)	-272 (-169)	136.9	78.12	0.93	20.95
	130	25.9 (178.5)	-311 (-190.5)	74.9	100.00	0.00	0.00
	160	23.7 (163.5)	-294 (-181)	0.9	0.11	99.39	0.5
20	163	164.0 (1131)	-269 (-167)	45.0	100.00	0.00	0.00
	195	31.8 (219.5)	-283 (-175)	0.0	0.00	0.09	99.91
	198	29.8 (205.5)	78 (25.5)	0.0	0.00	0.09	99.91
25	201	109.6 (755.5)	78 (25.5)	100.0	78.12	0.93	20.95
	234	109.6 (755.5)	78 (25.5)	212.9	78.12	0.93	20.95
	250	18.6 (128)	-317 (-194)	27.1	100.00	0.00	0.00
30	432	25.9 (178.5)	-311 (190.5)	38.2	100.00	0.00	0.00
	440	26.7 (184)	-311 (-190.5)	11.9	99.86	0.11	0.03
	479	17.0 (117)	78 (25.5)	51.0	99.96	0.03	0.01
35	488	23.0 (158.5)	78 (25.5)	0.0	100.00	0.00	0.00
	506	764.0 (5268)	50 (10)	76.1	78.12	0.93	20.95
	508	762.0 (5254)	-140 (-95.5)	179.9	78.12	0.93	20.95
40	510	113.6 (783.5)	-272 (-169)	43.0	78.12	0.93	20.95
	940	25.9 (178.5)	-311 (-190.5)	50.1	99.96	0.03	0.01
	941	18.7 (129)	-317 (-194)	50.1	99.96	0.03	0.01

The following Table 4 compares the power consumption in the simulations of Figures 1, 2 and 3. This comparison shows that the present invention achieved a 1.0% efficiency improvement when applied to Figure 1's conventional liquefier while a preferred embodiment of the present invention achieved a 2.1% efficiency improvement when applied to Figure 1's conventional liquefier.

Table 4

Simulation	Power
Figure 1	1.000
Figure 2	0.990
Figure 3	0.979

It is important to note that the efficiency improvement of the present invention will be significantly more

pronounced where the product streams are required at an elevated pressure. Assume, for example, that the 39.1 % of the air feed which is removed as the high purity gaseous nitrogen product in stream 488 in Figure 1 is required at Figure 2's elevated low pressure column pressure of 27.8 psia (191.5 kPa) less 2.6 psia (18 kPa) to account for the pressure drop across the heat exchangers. In this scenario, Figure 1 would incur an additional compression requirement for compressing stream 488 from 15.2 psia (105 kPa) to 25.2 psia (174 kPa) while Figure 2 would incur an additional compression requirement only for compressing stream 86 (a mere 1.1% of the air feed) from 18.6 psia (128 kPa) to 27.8 psia (191.5 kPa). (Also in this scenario for Figure 2, streams 432 and 86 totalling 39.1% of the air feed would not be combined with waste stream 440 as is currently shown in Figure 2. Instead, stream 432 would remain a part of stream 130 and, after compressing stream 86 from 18.6 psia (128 kPa) to 27.8 psia (191.5 kPa), streams 86 would be combined with stream 130. After being warmed in the heat exchangers and undergoing a 2.6 psia (18 kPa) pressure drop, the total amount of flow previously contained in streams 432 and 86 [ie 39.1% of the air feed] would then be removed as the high purity gaseous nitrogen product in stream 488 at a pressure of 25.2 psia (174 kPa). This much larger additional compression requirement for Figure 1 would increase Figure 2's efficiency improvement over Figure 1 from the above 1.0% to approximately 2.9%.

In summary, the present invention is an effective method for increasing the energy efficiency of a conventional liquefier.

Claims

1. A process for the cryogenic distillation of an air feed using a multiple column distillation system comprising a high pressure column and a low pressure column and generating an amount of refrigeration sufficient to remove at least 15% of the air feed as a liquid nitrogen product stream and/or a liquid oxygen product stream; wherein at least a portion of said amount of refrigeration is generated by an expander scheme; subsequent to a front end processing of the air feed, at least a portion of the air feed is fed to the high pressure column in which the air feed is rectified into a high pressure nitrogen overhead and a high pressure crude liquid oxygen bottoms; at least a portion of the high pressure crude liquid oxygen bottoms is fed to the low pressure column in which the high pressure crude liquid oxygen bottoms is distilled into a low pressure nitrogen overhead and a low pressure liquid oxygen bottoms; the high pressure column and the low pressure column are thermally linked such that at least a portion of the high pressure nitrogen overhead is condensed in a reboiler/condenser against a vaporizing low pressure column oxygen-rich liquid; and at least a portion of the condensed high pressure nitrogen overhead is used to provide reflux for the distillation column system; characterized in that the low pressure column is operated at a pressure between 170 and 350 kPa (25 and 50 psia).
2. A process as claimed in Claim 1, wherein a nitrogen enriched gaseous product stream is withdrawn from the low pressure column and refrigeration is generated by expanding the nitrogen enriched gaseous product stream in an expander.
3. A process as claimed in Claim 1 or Claim 2, wherein at least a portion of the low pressure nitrogen overhead is warmed by heat exchange against one or more process streams and recycled to the process for further processing.
4. A process as claimed in Claim 3, wherein the expander scheme is integrated with the further processing of the portion of the low pressure nitrogen overhead.
5. A process as claimed in Claim 4, wherein said further processing comprises:
 - (a) compressing said low pressure nitrogen overhead portion to an elevated pressure;
 - (b) cooling the compressed overhead portion nitrogen by heat exchange against one or more process streams to a temperature at or near its dew point;
 - (c) condensing said cooled nitrogen overhead portion in a reboiler/condenser against vaporizing high pressure crude liquid oxygen bottoms;
 - (d) using the condensed low pressure nitrogen overhead as additional reflux for the distillation column system and/or as at least a portion of the liquid nitrogen product stream.
6. A process as claimed in Claim 5, wherein a second portion of the low pressure nitrogen overhead is warmed by heat exchange against one or more process streams and subsequently removed as a gaseous

nitrogen product stream.

7. A process as claimed in any one of the preceding claims, wherein a waste stream is withdrawn from a upper intermediate location of the low pressure column, warmed by heat exchange against one or more process streams and subsequently removed as a gaseous waste product.
8. A process as claimed in Claim 6 or Claim 7, wherein refrigeration is generated by expanding said waste stream in an expander prior to said warming thereof and/or by expanding said second portion of the low pressure nitrogen overhead in an expander prior to said warming thereof.
9. A process as claimed in any one of the preceding claims, wherein the expander scheme is integrated with the front end processing of the air feed.
10. A process as claimed in Claim 9, wherein the front end processing of the air feed comprises:
 - (a) compressing the air feed to an elevated pressure and removing impurities from the air feed which will freeze out at cryogenic temperatures;
 - (b) cooling the air feed by heat exchange against one or more process streams;
 - (c) splitting the air feed into a first split feed stream and a second split feed stream;
 - (d) expanding the first split feed stream in an expander and recycling the expanded first split feed stream to the air feed while providing refrigeration to the air feed by heat exchange;
 - (e) further cooling the second split feed stream by heat exchange against process streams;
 - (f) further splitting the second split feed stream into a third split feed stream and a fourth split feed stream;
 - (g) expanding the third split feed stream in an expander and recycling a portion of the expanded third split feed stream to the air feed while providing refrigeration to the air feed by heat exchange;
 - (h) further cooling the fourth split feed stream by heat exchange against process streams;
 - (i) introducing a portion of the fourth split feed stream into the low pressure column for rectification; and
 - (j) introducing the remaining portion of the fourth split feed stream and the remaining portion of the expanded third split feed stream into the high pressure column for rectification.
11. A process as claimed in any one of the preceding claims, wherein a portion of the low pressure liquid oxygen bottoms is removed as the liquid oxygen product stream.
12. A process as claimed in any one of the preceding claims, wherein a portion of the low pressure liquid oxygen bottoms is warmed by heat exchange against one or more process streams and subsequently removed as a gaseous oxygen product.
13. A process as claimed in any one of the preceding claims, wherein:
 - (a) the multiple distillation column system further comprises an argon column;
 - (b) an argon containing gaseous side stream is removed from a lower intermediate location of the low pressure column and fed to the argon column in which the argon containing gaseous side stream is rectified into an argon-rich vapor overhead and an argon-lean bottoms liquid;
 - (c) the argon-lean bottoms liquid is returned to the low pressure column;
 - (d) at least a portion of the argon-rich vapor overhead is condensed in a reboiler/condenser against vaporizing high pressure crude liquid oxygen bottoms;
 - (e) a portion of the condensed argon-rich vapor overhead is removed as a liquid argon product; and
 - (f) the remaining portion of the condensed argon-rich vapor overhead is used to provide reflux for the argon column.

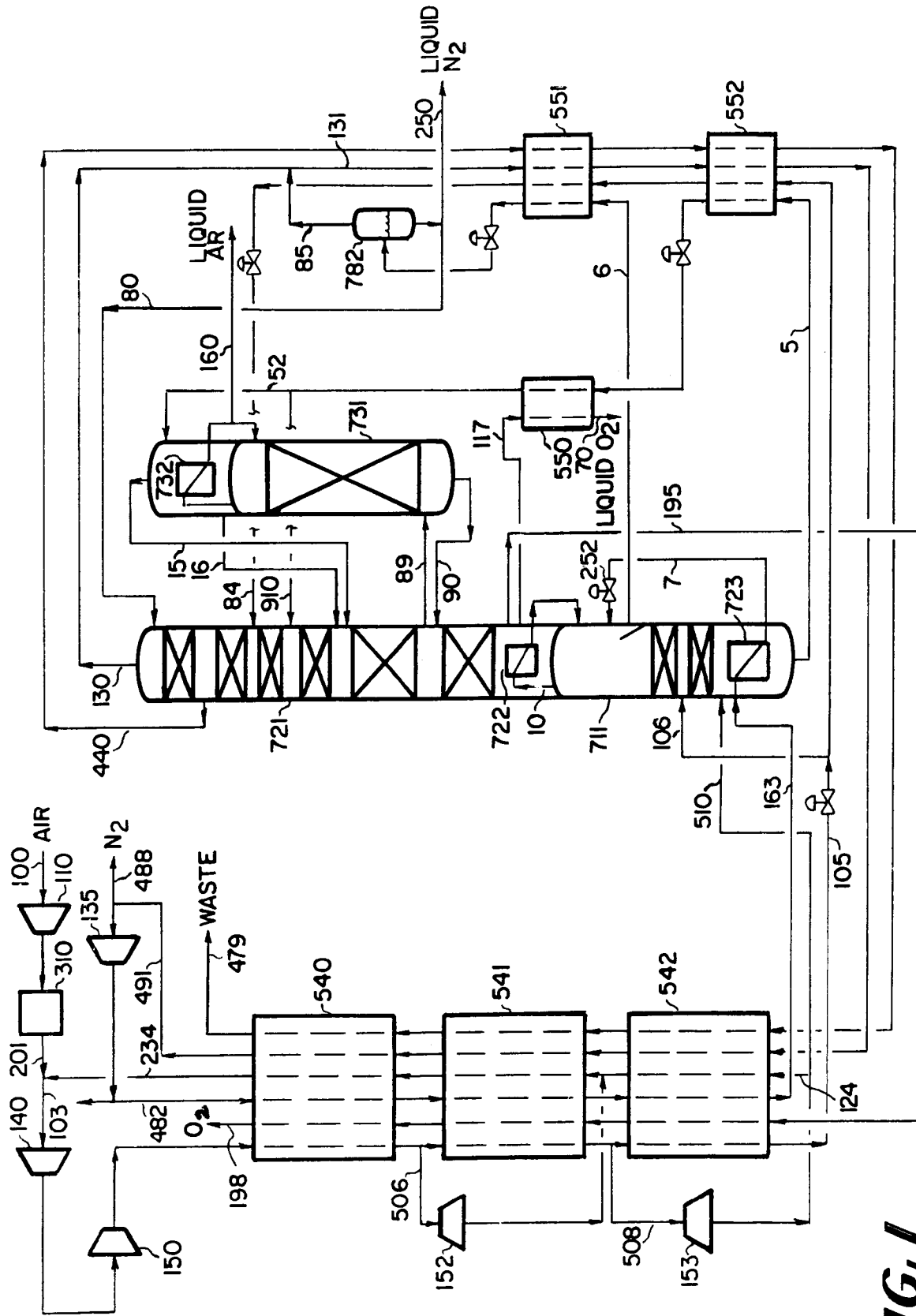


FIG. 1

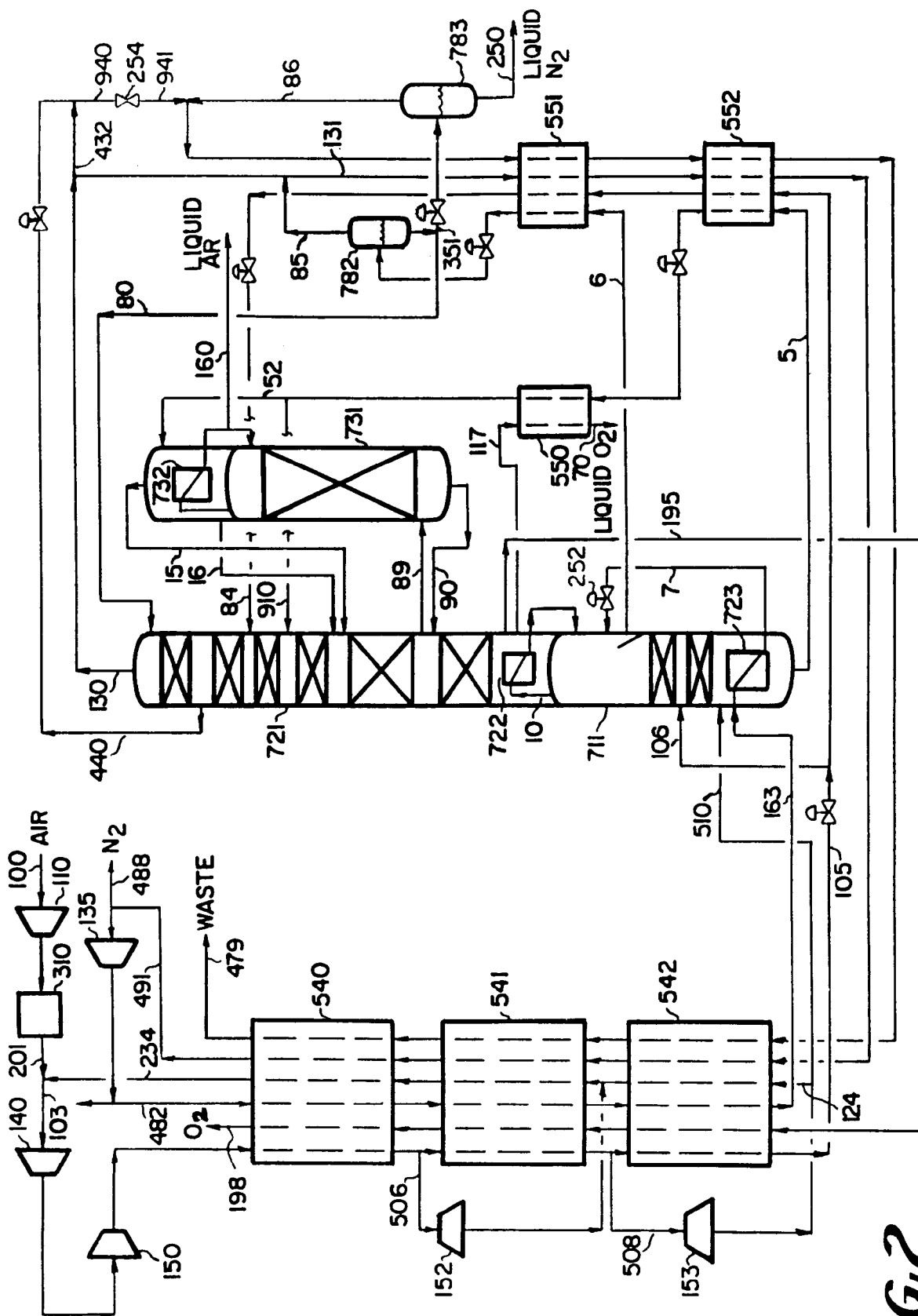


FIG. 2

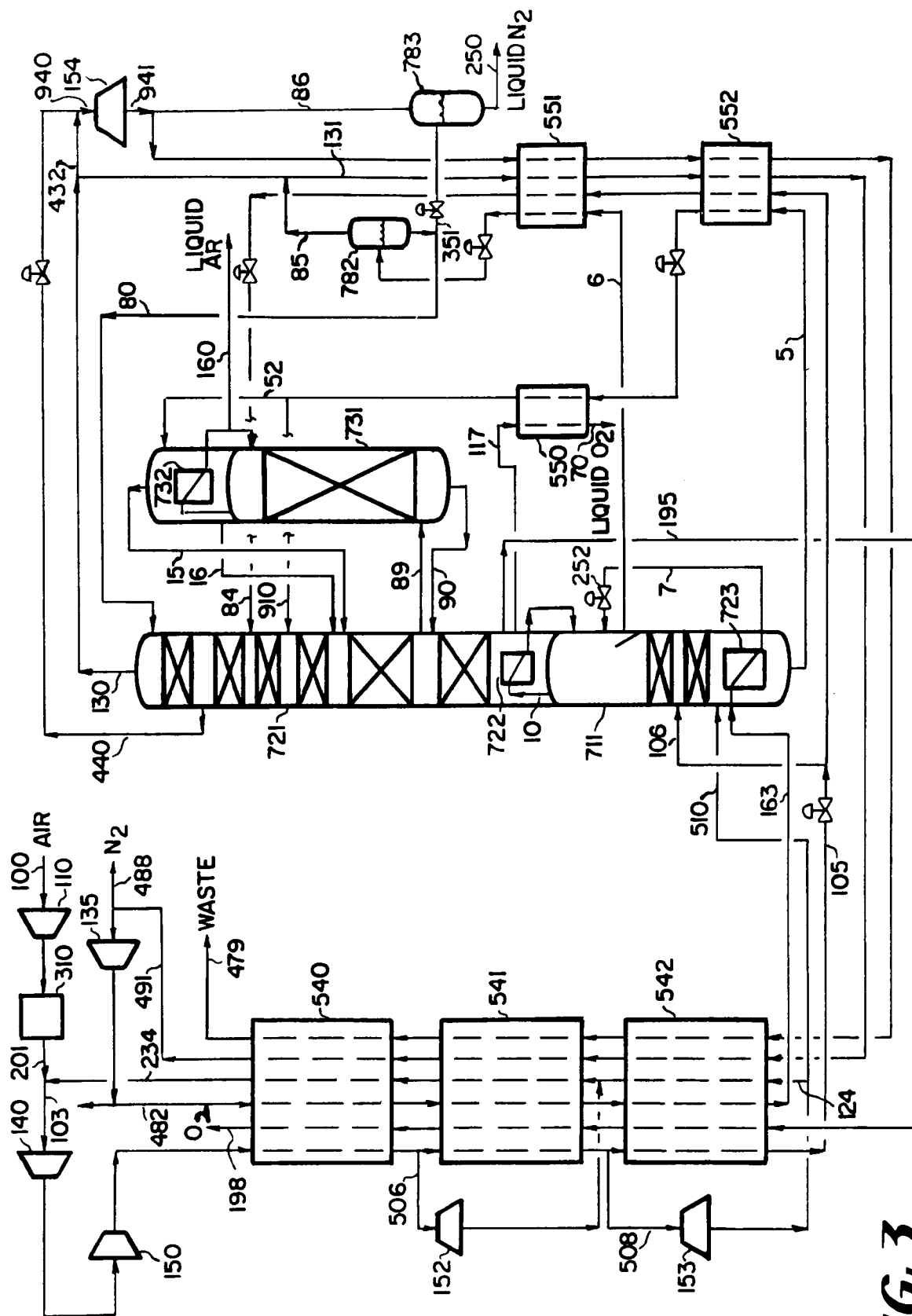


FIG. 3



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 93 30 5480

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.5)
D,A	US-A-4 705 548 (AIR PRODUCTS AND CHEMICALS, INC.) * the whole document * ---	1,3-5,7, 9-11,13	F25J3/04 F25J3/02
P,A	EP-A-0 527 501 (LINDE AKTIENGESELLSCHAFT) 17 February 1993 * the whole document * ---	1,3-7,9, 11-13	
A	EP-A-0 384 688 (THE BOC GROUP PLC) * the whole document * ---	1,3,5,9, 11,12	
A	DE-A-4 030 749 (LINDE AG) * the whole document * -----	1,3-5,7, 9,11-13	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			F25J
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 23 SEPTEMBER 1993	Examiner STEVNSBORG N.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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