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(54) **Process and apparatus for the cryogenic separation of air**

(57) Air is separated in a cryogenic distillation system operating a dual reboiler/condenser cycle. Refrigeration for the system is usually provided by expanding

a process stream. In the present invention, refrigeration is provided by introducing from an external source at least one refrigerant.

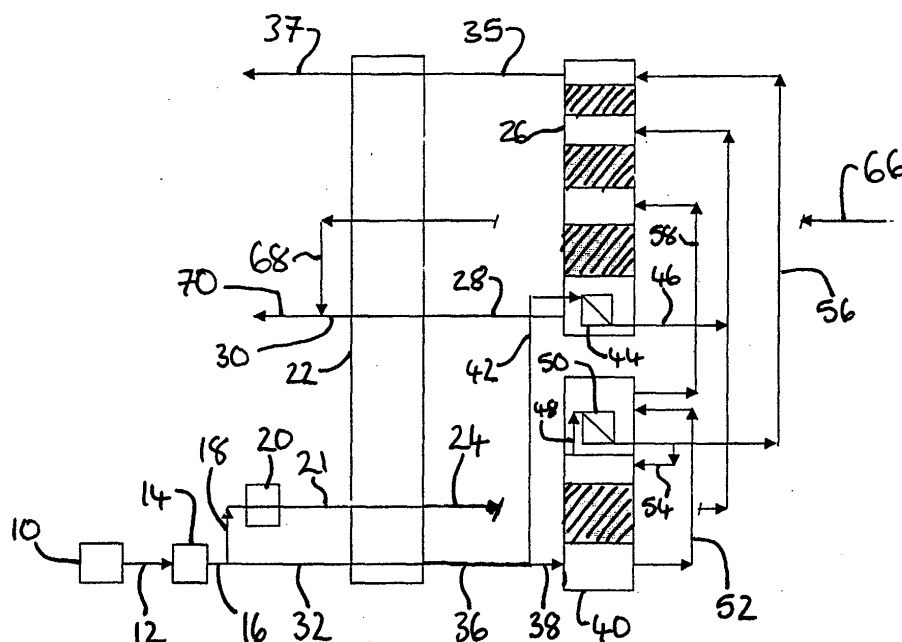


FIGURE 2

Description

[0001] The present invention relates generally to the cryogenic separation of air into gaseous nitrogen ("GAN") and gaseous oxygen ("GOX") and, in particular but not necessarily exclusively, it relates to the production of GOX at low pressure and low purity.

[0002] There is a considerable market, particularly in the glass and metallurgical industries, for low purity, e.g. from 80 to 98 vol %, low pressure, e.g. from 1.5 to 5.0 bar absolute (0.15 to 0.5 MPa), GOX. The GOX is used in processes requiring oxygen-enriched combustion in which the required pressure of the oxygen at the point of use is near atmospheric.

[0003] An O₂ vacuum swing absorption ("VSA") process is commonly used for applications requiring 90 to 93 vol % O₂. However, up to 98 vol % O₂ GOX is often required and such high purities cannot be supplied economically by the VSA process. Cryogenic distillation processes are economic for both low and higher purity oxygen requirements. There are many prior public disclosures of processes using cryogenic distillation of air to produce a GOX product. A number of the disclosed processes use a liquid cryogen from an external source to provide at least part of the refrigeration duty for the process.

[0004] US-A-5408831 (Guillard *et al*) and US-A-5505052 (Ekins *et al*) both disclose single reboiler/condenser cycles for the production of GOX in which at least a portion of the refrigeration duty for the processes is provided by at least one refrigerant from an external source. For example, in Guillard *et al*, both liquid oxygen ("LOX") and liquid nitrogen ("LIN") are used and, in Ekins *et al*, both LOX and liquid argon ("LAR") are used.

[0005] US-A-6539748 (Prentice *et al*) discloses the use of LOX from an external source to provide refrigeration in a single reboiler/condenser cycle process for the production of low purity GOX. A stream of LOX refrigerant from an external source is injected into the main heat exchanger at a pressure greater than that of the LOX entering the main heat exchanger from the distillation system. In the exemplified embodiment, the resultant vaporised LOX refrigerant is then combined with the vaporised LOX taken from the distillation system to provide a combined GOX product.

[0006] Low pressure GOX may be produced in a double cryogenic distillation column system using a dual reboiler/condenser cycle. Examples of existing dual reboiler/condenser cycle processes are disclosed in US-A-3210951 (Gaumer), US-A-4410343 (Ziemer) and US-A-4702757 (Kleinberg). The processes disclosed in each of these references produce refrigeration by expansion of a process stream.

[0007] An example of an existing system is depicted in Figure 1. Air is compressed in an air compressor 10 to produce a stream 12 of compressed air which is then purified in a temperature swing absorption purifier 14 to produce a stream 16 of purified compressed air. Stream 16 is then divided into two portions. The first portion 18 is further compressed in a compressor 20 and then fed as stream 21 to the warm end of the main heat exchanger 22 where it is condensed by indirect heat exchange against vaporising LOX to produce a stream 24 of liquid air ("LAIR"). The LAIR is then fed to the lower pressure ("LP") column 26 of the distillation system where it is separated into nitrogen overhead and LOX. A stream 28 of LOX is removed and fed to the cold end of the main heat exchanger 22 where it is vaporised by indirect heat exchange against the feed air to produce a stream 30 of low pressure GOX. The second portion 32 is fed to the warm end of the main heat exchanger 22 where it is cooled by indirect heat exchange against vaporising LOX to produce a stream 34 of cooled compressed feed air. A stream 35 of gaseous nitrogen ("GAN") is removed from the LP column 26 and warmed in the main heat exchanger 22 to produce a stream 37 of waste GAN.

[0008] At an intermediate point within the main heat exchanger 22, stream 34 is divided into two parts, the first part 36 is divided into two substreams. The first substream 38 is fed to the higher pressure ("HP") column 40 of the distillation column system at a high pressure for separation into nitrogen-rich overhead vapour and crude liquid oxygen ("CLOX"). The second substream 42 is partially condensed in a first reboiler/condenser 44 located in the sump of the LP column 26 to produce a stream 46 of partially condensed air which is then fed to the bottom of the HP column 40.

[0009] A stream 48 of nitrogen-rich overhead vapour from the HP column 40 is condensed in a second reboiler/condenser 50 against vaporising CLOX removed via stream 52 from the HP column 40. The condensed nitrogen-rich overhead is fed as streams 54 and 56 to the HP column 40 and LP column 26 respectively to provide reflux for the separations. Vaporised CLOX is fed via stream 58 to the LP column 26.

[0010] Refrigeration for the process is provided by an expansion turbine 60. The second part 62 of the cooled compressed air is fed to the expander 60 where it is work expanded to produce a stream 64 of expanded air that is then fed to the LP column 26. As the expander sends part of the medium pressure air directly to the LP column 26, it reduces the air flow available to the HP column 40 and the second reboiler/condenser 50. Consequentially, distillation is impaired with reduced boil-up of LOX in the sump of the LP column 26 and reduced reflux down the LP column 26.

[0011] The benefit of the dual reboiler/condenser cycle is that high pressure air is at a lower pressure than in a conventional cycle as LOX in the LP column 26 is vaporised by condensing air rather than nitrogen. This difference in air pressure results in reduced power unless the air flow to produce a given flow of GOX increases. The effect of impaired distillation is to increase the air flow and hence the power advantage of the dual reboiler/condenser cycle with an expander is small when compared to a conventional cycle and unlikely to be sufficient to justify the additional

complexity and cost of this cycle. The Inventors are unaware of any teaching in the prior art that the substantial power benefits of a dual reboiler/condenser cycle process can be almost fully realised if external refrigerant is employed instead of an expander to meet the refrigeration requirements of the process.

[0012] One objective of preferred embodiments of the present invention is to provide a process and apparatus for the production of low pressure GOX, in particular at low purity, with reduced power consumption (and, thus, with reduced operating cost) without any significant increase in capital cost.

[0013] According to a first aspect of the present invention, there is provided a process for cryogenically separating air in a cryogenic distillation system comprising a higher pressure ("HP") distillation column and a lower pressure ("LP") distillation column, a first reboiler/condenser, a second reboiler/condenser and heat exchange means, said process comprising:

separating feed air in the HP column into nitrogen-rich overhead vapour and crude liquid oxygen ("CLOX");
separating at least a portion of said CLOX or crude oxygen vapour derived therefrom in the LP column to produce nitrogen overhead vapour and liquid oxygen ("LOX");
at least partially condensing air by indirect heat exchange against LOX in said first reboiler/condenser to produce oxygen vapour and at least partially condensed air;
at least partially condensing at least a portion of said nitrogen-rich overhead vapour by indirect heat exchange against an oxygen-rich liquid in said second reboiler/condenser to produce oxygen-rich vapour and at least partially condensed nitrogen-rich overhead vapour;
vaporising LOX from said LP column by indirect heat exchange against compressed air in said heat exchange means to produce gaseous oxygen ("GOX") and cooled compressed air; and
using at least a portion of said at least partially condensed nitrogen-rich overhead vapour and/or at least a portion of said at least partially condensed air as reflux in the distillation system;

wherein at least a portion of the required refrigeration duty for the process is provided by introducing into the distillation system from an external source at least one refrigerant. The or at least refrigerant is preferably selected from liquid nitrogen ("LIN") or LOX.

[0014] One advantage of preferred embodiments of the present invention is that it is not necessary to provide refrigeration for the process by expansion of a process stream. The use of an expander incurs significant capital and operational cost and can increase energy consumption.

In preferred processes, the overall refrigeration requirement of the process is met without expansion of a process stream thereby eliminating these penalties in cost and energy consumption. In such embodiments, the liquid and vapour flow in the HP column is increased, compared to prior art processes having expanders. For a given flow of GOX, the increase in air flow in the present invention is substantially zero when compared to the air flow in a conventional single reboiler/condenser cycle. Therefore, the power advantage of dual reboiler/condenser cycles using imported refrigerant such as LIN and/or LOX to provide refrigeration is large when compared to conventional dual reboiler/condenser cycles using expansion to provide refrigeration. This power advantage is sufficient to justify the additional complexity and cost of this cycle.

[0015] The or each refrigerant may be introduced into any suitable location in the cryogenic section of the plant. Where the or at least one refrigerant is LOX, at least a portion of the required refrigeration duty for the process may be provided by feeding LOX from an external source to the sump of the LP column. Alternatively, at least a portion of the required refrigeration duty for the process may be provided by vaporising LOX from an external source by indirect heat exchange against compressed air in the heat exchange means to produce cooled compressed air and vaporised refrigerant. It would also be possible to provide at least a portion of the refrigeration duty by carrying out both of these steps in combination. Where LOX refrigerant is vaporised in the main exchange means, the resultant GOX may be combined with the GOX produced by vaporising LOX from the LP column to produce combined GOX product.

[0016] Where the or at least one refrigerant is LIN, LIN from an external source may be introduced into the distillation column system at a location having a high nitrogen concentration. For example, LIN from an external source may be fed to the top of the LP column, the top of the HP column or to the top of both columns.

[0017] Both LIN and LOX from external sources may be used simultaneously to provide at least a portion of the refrigeration duty required by the process. However, in preferred embodiments, only one refrigerant is used.

[0018] The first reboiler/condenser is usually located in the sump of the LP column. In such embodiments, the process comprises at least partially condensing air by indirect heat exchange against LOX produced in the LP column to produce said oxygen vapour and said at least partially condensed air.

[0019] The second reboiler/condenser may be located at an intermediate location in the LP column in which case the process comprises at least partially condensing the nitrogen-rich overhead vapour by indirect heat exchange against oxygen-rich liquid descending the LP column to produce said oxygen-rich vapour and said at least partially condensed nitrogen-rich overhead vapour. Alternatively, the second reboiler/condenser may be located outside the LP

column. In such cases, the process may comprise at least partially condensing the nitrogen-rich overhead vapour by indirect heat exchange against CLOX produced in the HP column to produce said crude oxygen vapour and said at least partially condensed nitrogen-rich overhead vapour.

[0020] A portion of the required refrigeration duty may be provided by expansion of a process stream. However, in preferred embodiments, there is no expansion of a process stream to provide refrigeration. An advantage of these preferred embodiments is that the capital and operational costs of dual reboiler/condenser cycles may be reduced if there are no expansion turbines present in the system.

[0021] The feed air may comprise at least a portion of the cooled compressed air. Alternatively or additionally, the feed air may comprise at least a portion of the at least partially condensed air. Feed air to the HP column is preferably cooled compressed air with LAIR being fed to the LP column. However, in other embodiments, the all of the cooled compressed feed air is at least partially condensed in the first reboiler/condenser and then fed to the HP column. Also, LAIR can be fed to the HP column or split between the HP and LP columns.

[0022] Reflux for the LP and HP columns may be provided by any suitable liquid stream in the process. In particular, both the HP column and the LP column may be refluxed with at least partially condensed nitrogen-rich overhead vapour.

[0023] In preferred embodiments, low purity GOX, e.g. GOX having an oxygen concentration from about 80 to about 98 vol %, preferably about 95 vol %, is produced. The pressure of the GOX is preferably from about 1.5 to about 5.0 bar absolute (0.15 to 0.5 MPa). Preferably, the pressure is from about 1.7 to about 2.3 bar absolute (0.17 to 0.23 MPa). Nitrogen overhead vapour may be removed from the HP column, warmed in the main heat exchanger and collected as a GAN product.

[0024] According to a second aspect of the present invention, there is provided apparatus for cryogenically separating air comprising:

an HP distillation column for separating feed air into nitrogen-rich overhead vapour and CLOX;
 an LP distillation column in fluid flow communication with said HP column for separating at least a portion of said CLOX or crude oxygen vapour derived therefrom to produce nitrogen overhead vapour and LOX;
 a first reboiler/condenser for at least partially condensing air by indirect heat exchange against LOX to produce oxygen vapour and at least partially condensed air;
 a second reboiler/condenser in fluid flow communication with said HP column for at least partially condensing at least a portion of said nitrogen-rich overhead vapour by indirect heat exchange against an oxygen-rich liquid to produce oxygen-rich vapour and at least partially condensed nitrogen-rich overhead vapour;
 heat exchange means in fluid flow communication with said LP column for vaporising LOX from said LP column by indirect heat exchange against compressed air to produce GOX and cooled compressed air;
 at least one reflux conduit means in fluid flow communication with said HP column and/or said LP column for feeding at least a portion of said at least partially condensed air and/or at least a portion of said at least partially condensed nitrogen-rich overhead vapour as reflux to the distillation system; and
 at least one refrigerant conduit means in fluid flow communication with said distillation system for introducing into said distillation system from an external source at least one refrigerant.

[0025] The apparatus may be adapted and/or constructed to operate any of the preferred processes described above.

[0026] In particular, where the or at least one refrigerant is LOX, the or at least one refrigerant conduit means is adapted to carry LOX and, preferably, is in fluid flow communication with the sump of the LP column. Additionally or alternatively, the or at least one refrigerant conduit means may be in fluid flow communication with the cold end of the heat exchange means. In such embodiments, the apparatus may further comprise GOX conduit means for combining the GOX produced by vaporising LOX from the LP column and GOX produced by vaporising the LOX refrigerant.

[0027] Where the or at least one refrigerant is LIK, the or at least one refrigerant conduit means is adapted to carry LIN and, preferably, is in fluid flow communication with a location of the distillation system having high nitrogen concentration. Suitable examples of such locations include the top of the LP column and the top of the HP column.

[0028] The first reboiler/condenser is usually located in the sump of the LP column. The second reboiler/condenser may be located at an intermediate location in the LP column or may be located outside the LP column. In the latter case, the apparatus may further comprise conduit means for feeding crude oxygen vapour from the second reboiler/condenser to the LP column.

[0029] The apparatus may further comprise conduit means for feeding at least a portion of the partially condensed air as feed air to the HP column. The apparatus may further comprise, either additionally or alternatively, conduit means for feeding at least a portion of the cooled compressed air as feed air to the HP column.

[0030] The following is a description, by way of example only and with reference to the accompanying drawings, of presently preferred embodiments of the invention. In the drawings:

Figure 1 is a flow diagram of an existing dual reboiler/condenser cycle process for the production of low purity GOX;

Figure 2 is a flow diagram of one embodiment of the present invention using LOX as an external refrigerant and in which the second reboiler/condenser is located outside the LP column;

Figure 3 is a flow diagram of another embodiment of the present invention using LOX as an external refrigerant and in which the second reboiler/condenser is located at an intermediate location of the LP column;

Figure 4 is a flow diagram of a different arrangement of the embodiment depicted in Figure 2 using LOX as an external refrigerant;

Figure 5 is a flow diagram of a different arrangement of the embodiment depicted in Figure 2 using LIN as an external refrigerant; and

Figure 6 is a flow diagram of a different arrangement of the embodiments depicted in Figure 5 using LIN as an external refrigerant.

[0031] The process depicted in Figure 1 is discussed above.

[0032] The flow diagrams depicted in Figures 2 to 6 have many features in common with the flow diagram depicted in Figure 1. The numerical legends used in Figure 1 have been used in Figures 2 to 6 to identify the common features. The parts of the flow diagrams in Figures 2 to 6 that are common with those depicted in Figure 1 are discussed above in the discussion of Figure 1. The following is limited to discussion of the differences between the process depicted in Figure 1 and those processes shown in Figures 2 to 6.

[0033] In the flow diagram depicted in Figure 2, refrigeration is not provided by expansion of a process stream as in Figure 1. Instead, a small stream 66 of LOX is introduced into the cryogenic section of the plant. The LOX stream 66 is vaporised in the main heat exchanger 22 by indirect heat exchange against streams 32 and 21 of compressed air to produce a stream 68 of GOX which is then combined with GOX stream 30 to produce a stream 70 of combined GOX product. The compressed air stream 36 is cooled to about its dew point and the LOX stream 28 removed from the LP column 26 is pressurised either by static head or using a pump (not shown).

[0034] In the flow diagram depicted in Figure 3, the second reboiler/condenser 50 is located at an intermediate location in the LP column 26 rather than outside the LP column 26 as in the embodiment depicted in Figure 2. CLOX is, therefore, fed directly to the LP column as stream 72. Refrigeration is not provided by expansion of a process stream as in Figure 1. Instead, as in Figure 2, a stream 66 of LOX is introduced into the cryogenic section of the plant. The LOX stream 66 is vaporised in the main heat exchanger 22 by indirect heat exchange against streams 32 and 21 of compressed air to produce a stream 68 of GOX which is then combined with GOX stream 30 to produce a stream 70 of combined GOX product. As in Figure 2, the compressed air stream 36 is cooled to about its dew point and the LOX stream 28 removed from the LP column 26 is pressurised either by static head or using a pump (not shown).

[0035] In the flow diagram depicted in Figure 4, the stream 66 of LOX from an external source is fed to the sump of the LP column 26 rather than to the main heat exchanger 22 to provide refrigeration for the process.

[0036] In the flow diagram depicted in Figure 5, rather than feeding LOX from an external source to the main heat exchanger 22 as in Figure 2, a stream 74 of LIN from an external source is fed to the top of the HP column 40 to provide refrigeration for the process.

[0037] In the flow diagram depicted in Figure 6, the LIN stream 74 is fed from an external source to the top of the LP column 26 to provide refrigeration for the process.

[0038] The variations regarding the external refrigerant depicted in Figures 4 to 6 can also be applied to the embodiment of the process depicted in Figure 3.

EXAMPLE

[0039] Computer simulations have been carried out to compare the energy consumption of known single reboiler/condenser cycles (S1-S4) with dual reboiler/condenser cycles (D1-D3). The simulations were run on the basis of a GOX production of 3500 Nm³/h (contained) at 95 vol % O₂. The results are depicted in Table 1.

Table 1

Cycle	S1	S2	S3	S4	D1	D2	D3
HP air stream fully condensed in MHE	N/A	YES	YES	YES	YES	YES	YES
Air Booster	NO	YES	YES	YES	YES	YES	YES
Expander	NO	NO	YES	YES	NO	YES	YES
Vac Can	YES	YES	YES	NO	YES	YES	NO

Table 1 (continued)

Cycle	S1	S2	S3	S4	D1	D2	D3
Air condensed in reboiler 44	N/A	N/A	N/A	N/A	Partial cond.*	Partial cond.*	Partial cond.*
O ₂ recovery	0.207	0.208	0.208	0.207	0.207	0.205	0.204
MAC/booster power (kW)	1423	1397	1464	1441	1244	1326	1344
%	100	98.2	102.9	101.3	87.4	93.2	94.4

(*Partial cond. means partial condensation)

[0040] Cycle S2 is a single reboiler cycle with imported LOX for refrigeration (i.e. no expander). Cycle S3 is the same cycle as cycle S2 except it uses an expander to provide refrigeration instead of imported LOX. There is a MAC/booster power increase of over 4%.

[0041] Cycle D2 is a conventional dual reboiler cycle using an expander for refrigeration. The MAC/booster power for this cycle is about 5% lower than observed in cycle S2. Cycle D1 is a dual reboiler cycle according to the present invention (i.e. uses imported LOX rather than an expander to provide refrigeration). The MAC/booster power for this cycle is about 11% lower than that for cycle S2 and about 6% lower than that for about conventional dual reboiler cycle D2.

[0042] The results indicate that the use of a dual reboiler/condenser cycle with LOX refrigeration (D1) reduces MAC/booster power consumption when compared to a standard single reboiler/condenser cycle (S1) by about 13%. This reduction in power consumption is significant as it reduces the overall cost of GOX production considerably. The estimated capital cost for the D2 and D3 processes is approximately the same as that for the standard single reboiler/condenser cycle S1. However, the estimated capital cost for the D1 process is about 2% less than that for S1. Therefore, preferred embodiments of the present invention not only reduce the cost of GOX production but also reduce the capital cost.

[0043] Throughout the specification, the term "means" in the context of means for carrying out a function, is intended to refer to at least one device adapted and/or constructed to carry out that function.

[0044] It will be appreciated that the invention is not restricted to the details described above with reference to the preferred embodiments but that numerous modifications and variations can be made without departing from the spirit and scope of the invention as defined in the following claims.

Claims

1. A process for cryogenically separating air in a cryogenic distillation system comprising a higher pressure ("HP") distillation column and a lower pressure ("LP") distillation column, a first reboiler/condenser, a second reboiler/condenser and heat exchange means, said process comprising:

separating feed air in the HP column into nitrogen-rich overhead vapour and crude liquid oxygen ("CLOX");
 separating at least a portion of said CLOX or crude oxygen vapour derived therefrom in the LP column to produce nitrogen overhead vapour and liquid oxygen ("LOX");
 at least partially condensing air by indirect heat exchange against LOX in said first reboiler/condenser to produce oxygen vapour and at least partially condensed air;
 at least partially condensing at least a portion of said nitrogen-rich overhead vapour by indirect heat exchange against an oxygen-rich liquid in said second reboiler/condenser to produce oxygen-rich vapour and at least partially condensed nitrogen-rich overhead vapour;
 vaporising LOX from said LP column by indirect heat exchange against compressed air in said heat exchange means to produce gaseous oxygen ("GOX") and cooled compressed air; and
 using at least a portion of said at least partially condensed nitrogen-rich overhead vapour and/or at least a portion of said at least partially condensed air as reflux in the distillation system;

wherein at least a portion of the required refrigeration duty for the process is provided by introducing into the distillation system from an external source at least one refrigerant.

2. A process as claimed in Claim 1, wherein the or at least one refrigerant is selected from liquid nitrogen ("LIN") or

LOX.

3. A process as claimed in Claim 1 or Claim 2, wherein the or at least one refrigerant is LOX.

4. A process as claimed in Claim 3 wherein at least a portion of the required refrigeration duty for the process is provided by feeding LOX from an external source to the sump of the LP column.

5. A process as claimed in any of Claims 1 to 4 wherein at least a portion of the required refrigeration duty for the process is provided by vaporising LOX from an external source by indirect heat exchange against compressed air in the heat exchange means to produce cooled compressed air and vaporised LOX refrigerant.

6. A process as claimed in Claim 5 further comprising combining at least a portion of said vaporised LOX refrigerant with said GOX produced by vaporising LOX from the LP column to produce combined GOX product.

7. A process as claimed in any of the preceding claims wherein the or at least one refrigerant is LIN.

8. A process as claimed in Claim 7, wherein LIN from an external source is introduced into the distillation system at a location having high nitrogen concentration.

9. A process as claimed in Claim 7 or Claim 8, wherein LIN from an external source is introduced into the distillation system at the top of the LP column.

10. A process as claimed in any of Claims 7 to 9, wherein LIN from an external source is introduced into the distillation system at the top of the HP column.

11. A process as claimed in any of the preceding claims wherein the first reboiler/condenser is located in the sump of the LP column, said process comprising at least partially condensing air by indirect heat exchange against LOX produced in the LP column to produce said oxygen vapour and said at least partially condensed air.

12. A process as claimed in any of the preceding claims wherein the second reboiler/condenser is located at an intermediate location in the LP column, said process comprising at least partially condensing said nitrogen-rich overhead vapour by indirect heat exchange against oxygen-rich liquid descending the LP column to produce said oxygen-rich vapour and said at least partially condensed nitrogen-rich overhead vapour.

13. A process as claimed any of Claims 1 to 11 wherein the second reboiler/condenser is located outside the LP column, said process comprising at least partially condensing said nitrogen-rich overhead vapour by indirect heat exchange against CLOX produced in the HP column to produce said crude oxygen vapour and said at least partially condensed nitrogen-rich overhead vapour.

14. A process as claimed in any of the preceding claims wherein said feed air comprises at least a portion of said cooled compressed air.

15. A process as claimed in any of the preceding claims wherein said feed air comprises at least a portion of said at least partially condensed air.

16. A process as claimed in any of the preceding claims wherein GOX is produced having a purity from about 80 to about 98 vol %.

17. A process as claimed in any of the preceding claims wherein there is no expansion of a process stream to provide refrigeration.

18. Apparatus for cryogenically separating air comprising:

an HP distillation column for separating feed air into nitrogen-rich overhead vapour and CLOX;
an LP distillation column in fluid flow communication with said HP column for separating at least a portion of said CLOX or crude oxygen vapour derived therefrom to produce nitrogen overhead vapour and LOX;
a first reboiler/condenser for at least partially condensing air by indirect heat exchange against LOX to produce oxygen vapour and at least partially condensed air;

a second reboiler/condenser in fluid flow communication with said HP column for at least partially condensing at least a portion of said nitrogen-rich overhead vapour by indirect heat exchange against an oxygen-rich liquid to produce oxygen-rich vapour and at least partially condensed nitrogen-rich overhead vapour;
 heat exchange means in fluid flow communication with said LP column for vaporising LOX from said LP column by indirect heat exchange against compressed air to produce GOX and cooled compressed air;

at least one reflux conduit means in fluid flow communication with said HP column and/or said LP column for feeding at least a portion of said at least partially, condensed air and/or at least a portion of said at least partially condensed nitrogen-rich overhead vapour as reflux to the distillation system; and

at least one refrigerant conduit means in fluid flow communication with said distillation system for introducing into said distillation system from an external source at least one refrigerant.

19. Apparatus as claimed in Claim 18 wherein the or at least one refrigerant conduit means is adapted to carry LOX and is in fluid flow communication with the sump of the LP column.

20. Apparatus as claimed in Claim 18 or Claim 19 wherein the or at least one refrigerant conduit means is adapted to carry LOX and is in fluid flow communication with the cold end of the heat exchange means.

21. Apparatus as claimed in Claim 20 further comprising GOX conduit means for combining said GOX produced by vaporising LOX from the LP column and GOX produced by vaporising said LOX refrigerant.

22. Apparatus as claimed in any of Claims 18 to 21 wherein the or at least one refrigerant conduit means is adapted to carry LIN and is in fluid flow communication with a location of the distillation system having high nitrogen concentration.

23. Apparatus as claimed in Claim 22 wherein the or at least one refrigeration conduit means is in fluid flow communication with the top of the LP column.

24. Apparatus as claimed in Claim 22 or Claim 23 wherein the or at least one refrigeration conduit means is in fluid flow communication with the top of the HP column.

25. Apparatus as claimed in any of Claims 18 to 24 wherein the first reboiler/condenser is located in the sump of said LP column.

26. Apparatus as claimed in any of Claims 18 to 25 wherein the second reboiler/condenser is located at an intermediate location in said LP column.

27. Apparatus as claimed in any of Claims 18 to 25 wherein the second reboiler/condenser is located outside said LP column.

28. Apparatus as claimed in Claim 27 further comprising conduit means for feeding crude oxygen vapour from said second reboiler/condenser to said LP column.

29. Apparatus as claimed in any of Claim 18 to 28 further comprising conduit means for feeding at least a portion of said partially condensed air as feed air to said HP column.

30. Apparatus as claimed in any of Claims 18 to 29 further comprising conduit means for feeding at least a portion of said cooled compressed air as feed air to said HP column.

Amended claims in accordance with Rule 86(2) EPC.

1. A process for cryogenically separating air in a cryogenic distillation system comprising a higher pressure ("HP") distillation column and a lower pressure ("LP") distillation column, a first reboiler/condenser, a second reboiler/condenser and heat exchange means, said process comprising:

separating feed air in the HP column into nitrogen-rich overhead vapour and crude liquid oxygen ("CLOX");
 separating at least a portion of said CLOX or crude oxygen vapour derived therefrom in the LP column to

produce nitrogen overhead vapour and liquid oxygen ("LOX");
 at least partially condensing air by indirect heat exchange against LOX in said first reboiler/condenser to produce oxygen vapour and at least partially condensed air;
 at least partially condensing at least a portion of said nitrogen-rich overhead vapour by indirect heat exchange
 5 against an oxygen-rich liquid in said second reboiler/condenser to produce oxygen-rich vapour and at least partially condensed nitrogen-rich overhead vapour;
 vaporising LOX from said LP column by indirect heat exchange against compressed air in said heat exchange means to produce gaseous oxygen ("GOX") and cooled compressed air; and
 10 using at least a portion of said at least partially condensed nitrogen-rich overhead vapour and/or at least a portion of said at least partially condensed air as reflux in the distillation system;

wherein the required refrigeration duty for the process is provided by introducing into the distillation system from an external source at least one refrigerant.

15 **2.** A process as claimed in Claim 1, wherein the or at least one refrigerant is selected from liquid nitrogen ("LIN") or LOX.

3. A process as claimed in Claim 1 or Claim 2, wherein the or at least one refrigerant is LOX.

20 **4.** A process as claimed in Claim 3 wherein at least a portion of the required refrigeration duty for the process is provided by feeding LOX from an external source to the sump of the LP column.

25 **5.** A process as claimed in any of Claims 1 to 4 wherein at least a portion of the required refrigeration duty for the process is provided by vaporising LOX from an external source by indirect heat exchange against compressed air in the heat exchange means to produce cooled compressed air and vaporised LOX refrigerant.

6. A process as claimed in Claim 5 further comprising combining at least a portion of said vaporised LOX refrigerant with said GOX produced by vaporising LOX from the LP column to produce combined GOX product.

30 **7.** A process as claimed in any of the preceding claims wherein the or at least one refrigerant is LIN.

8. A process as claimed in Claim 7, wherein LIN from an external source is introduced into the distillation system at a location having high nitrogen concentration.

35 **9.** A process as claimed in Claim 7 or Claim 8, wherein LIN from an external source is introduced into the distillation system at the top of the LP column.

40 **10.** A process as claimed in any of Claims 7 to 9, wherein LIN from an external source is introduced into the distillation system at the top of the HP column.

11. A process as claimed in any of the preceding claims wherein the first reboiler/condenser is located in the sump of the LP column, said process comprising at least partially condensing air by indirect heat exchange against LOX produced in the LP column to produce said oxygen vapour and said at least partially condensed air.

45 **12.** A process as claimed in any of the preceding claims wherein the second reboiler/condenser is located at an intermediate location in the LP column, said process comprising at least partially condensing said nitrogen-rich overhead vapour by indirect heat exchange against oxygen-rich liquid descending the LP column to produce said oxygen-rich vapour and said at least partially condensed nitrogen-rich overhead vapour.

50 **13.** A process as claimed any of Claims 1 to 11 wherein the second reboiler/condenser is located outside the LP column, said process comprising at least partially condensing said nitrogen-rich overhead vapour by indirect heat exchange against CLOX produced in the HP column to produce said crude oxygen vapour and said at least partially condensed nitrogen-rich overhead vapour.

55 **14.** A process as claimed in any of the preceding claims wherein said feed air comprises at least a portion of said cooled compressed air.

15. A process as claimed in any of the preceding claims wherein said feed air comprises at least a portion of said

at least partially condensed air.

16. A process as claimed in any of the preceding claims for the production of GOX.

17. A process as claimed in any of the preceding claims wherein GOX is produced having a purity from about 80 to about 98 vol %.

18. A process as claimed in any of the preceding claims wherein GOX is produced at a pressure of from about 0.15 MPa to about 0.5 MPa.

19. A process as claimed in any of the preceding claims wherein there is no expansion of a process stream to provide refrigeration.

20. A process as claimed in any of the preceding claims comprising using at least partially condensed air as reflux to the HP column and/or the LP column.

21. A process as claimed in any of the preceding claims comprising using condensed nitrogen-rich overhead vapour as reflux at the top of the HP column.

22. Apparatus for cryogenically separating air comprising:

an HP distillation column for separating feed air into nitrogen-rich overhead vapour and CLOX;
 an LP distillation column in fluid flow communication with said HP column for separating at least a portion of said CLOX or crude oxygen vapour derived therefrom to produce nitrogen overhead vapour and LOX;
 a first reboiler/condenser for at least partially condensing air by indirect heat exchange against LOX to produce oxygen vapour and at least partially condensed air;
 a second reboiler/condenser in fluid flow communication with said HP column for at least partially condensing at least a portion of said nitrogen-rich overhead vapour by indirect heat exchange against an oxygen-rich liquid to produce oxygen-rich vapour and at least partially condensed nitrogen-rich overhead vapour;
 heat exchange means in fluid flow communication with said LP column for vaporising LOX from said LP column by indirect heat exchange against compressed air to produce GOX and cooled compressed air;
 at least one reflux conduit means in fluid flow communication with said HP column and/or said LP column for feeding at least a portion of said at least partially condensed air and/or at least a portion of said at least partially condensed nitrogen-rich overhead vapour as reflux to the distillation system; and
 at least one refrigerant conduit means in fluid flow communication with said distillation system for introducing into said distillation system from an external source at least one refrigerant,

wherein the apparatus is without an expansion turbine to expand a process stream to provide refrigeration.

23. Apparatus as claimed in Claim 22 wherein the or at least one refrigerant conduit means is adapted to carry LOX and is in fluid flow communication with the sump of the LP column.

24. Apparatus as claimed in Claim 22 or Claim 23 wherein the or at least one refrigerant conduit means is adapted to carry LOX and is in fluid flow communication with the cold end of the heat exchange means.

25. Apparatus as claimed in Claim 24 further comprising GOX conduit means for combining said GOX produced by vaporising LOX from the LP column and GOX produced by vaporising said LOX refrigerant.

26. Apparatus as claimed in any of Claims 22 to 25 wherein the or at least one refrigerant conduit means is adapted to carry LIN and is in fluid flow communication with a location of the distillation system having high nitrogen concentration.

27. Apparatus as claimed in Claim 26 wherein the or at least one refrigeration conduit means is in fluid flow communication with the top of the LP column.

28. Apparatus as claimed in Claim 26 or Claim 27 wherein the or at least one refrigeration conduit means is in fluid flow communication with the top of the HP column.

29. Apparatus as claimed in any of Claims 22 to 28 wherein the first reboiler/condenser is located in the sump of said LP column.

30. Apparatus as claimed in any of Claims 22 to 29 wherein the second reboiler/condenser is located at an intermediate location in said LP column.

31. Apparatus as claimed in any of Claims 22 to 29 wherein the second reboiler/condenser is located outside said LP column.

32. Apparatus as claimed in Claim 31 further comprising conduit means for feeding crude oxygen vapour from said second reboiler/condenser to said LP column.

33. Apparatus as claimed in any of Claim 22 to 32 further comprising conduit means for feeding at least a portion of said partially condensed air as feed air to said HP column.

34. Apparatus as claimed in any of Claims 22 to 33 further comprising conduit means for feeding at least a portion of said cooled compressed air as feed air to said HP column.

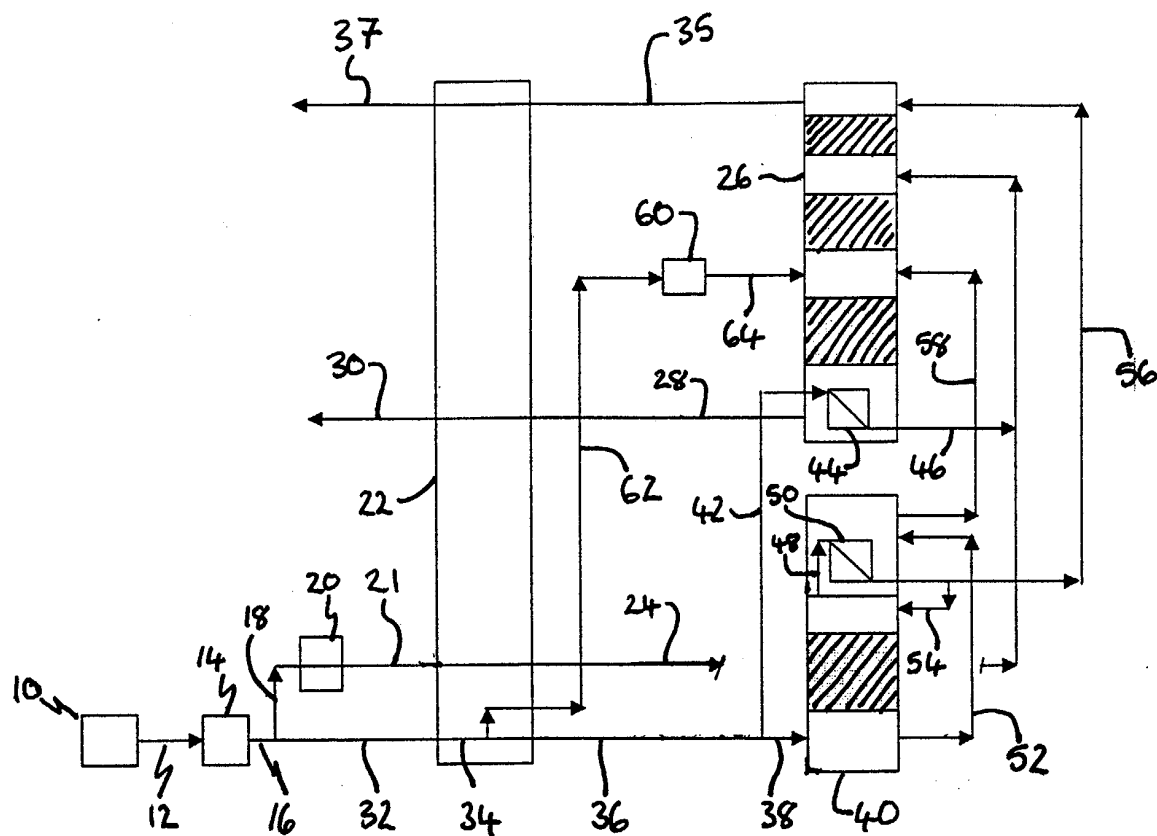


FIGURE 1

(PRIOR ART)

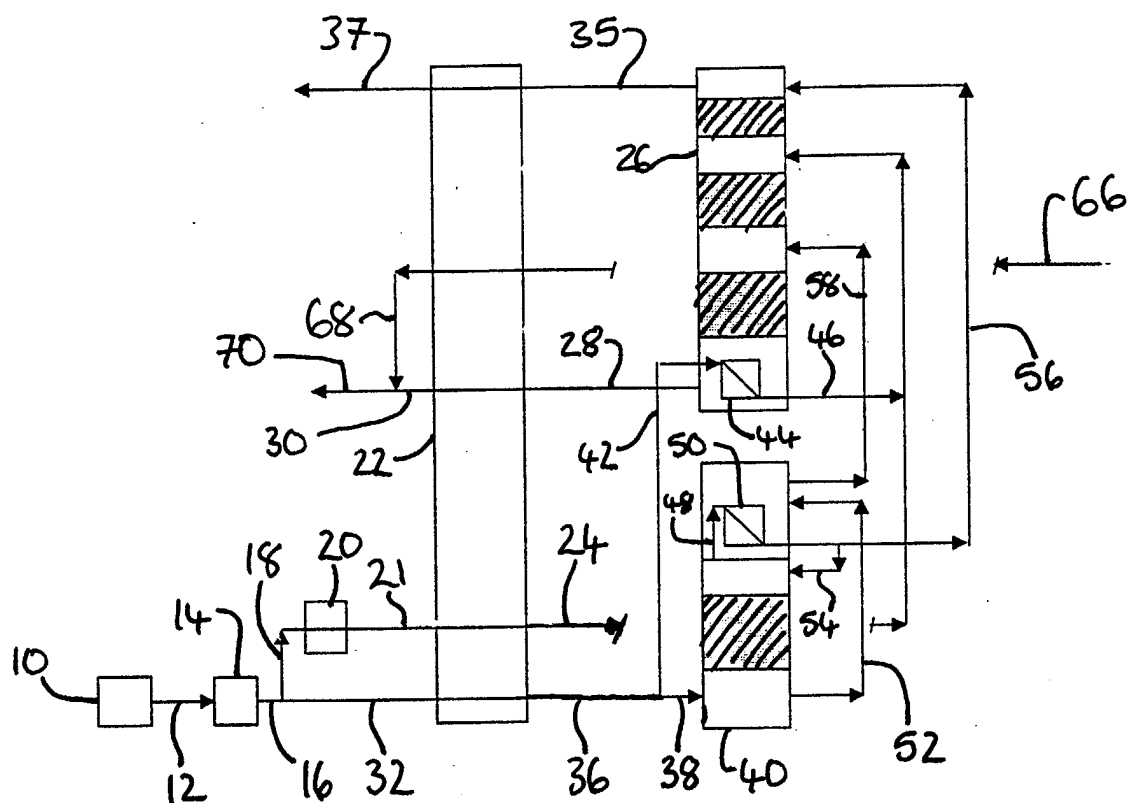


FIGURE 2

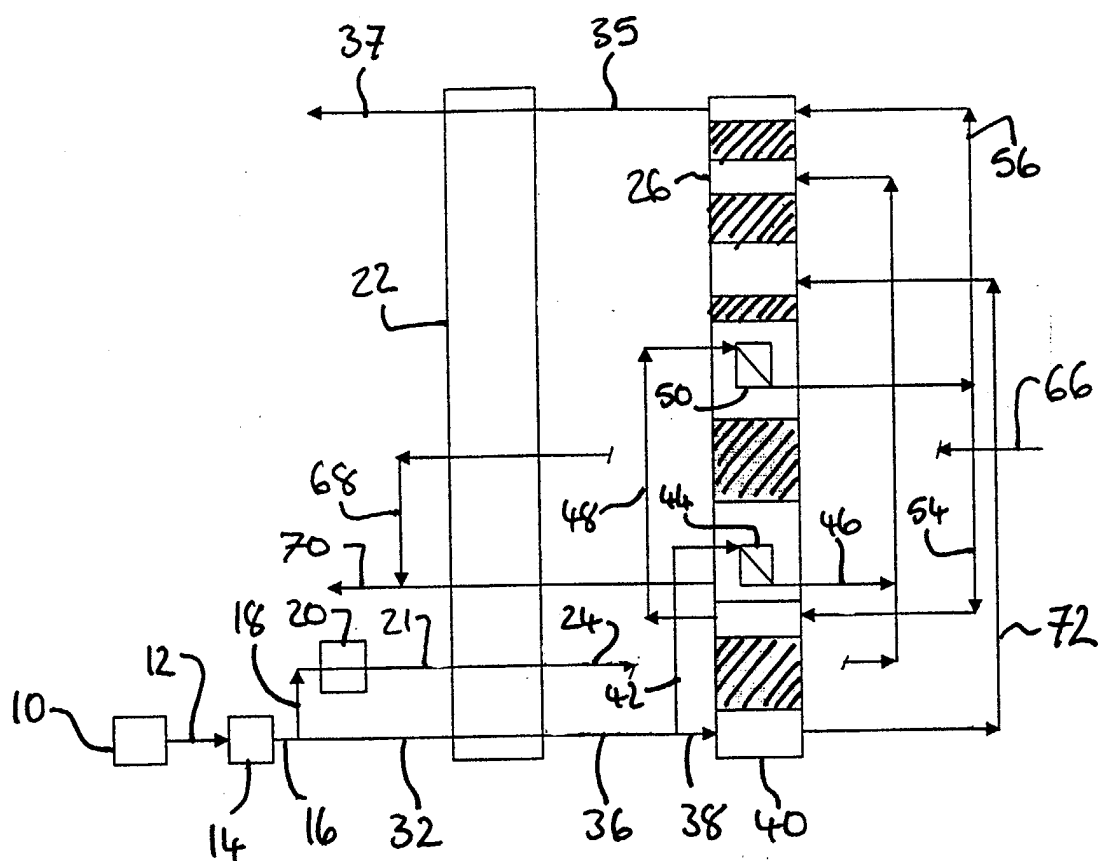


FIGURE 3

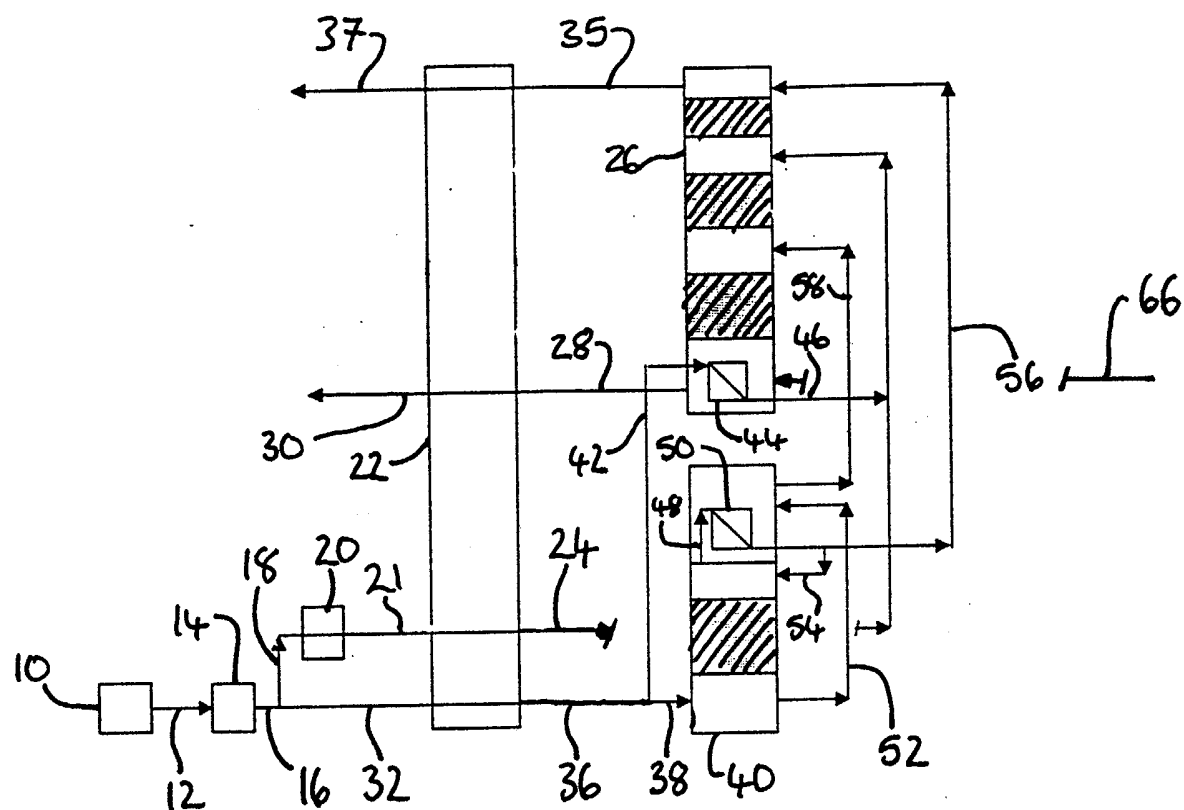


FIGURE 4

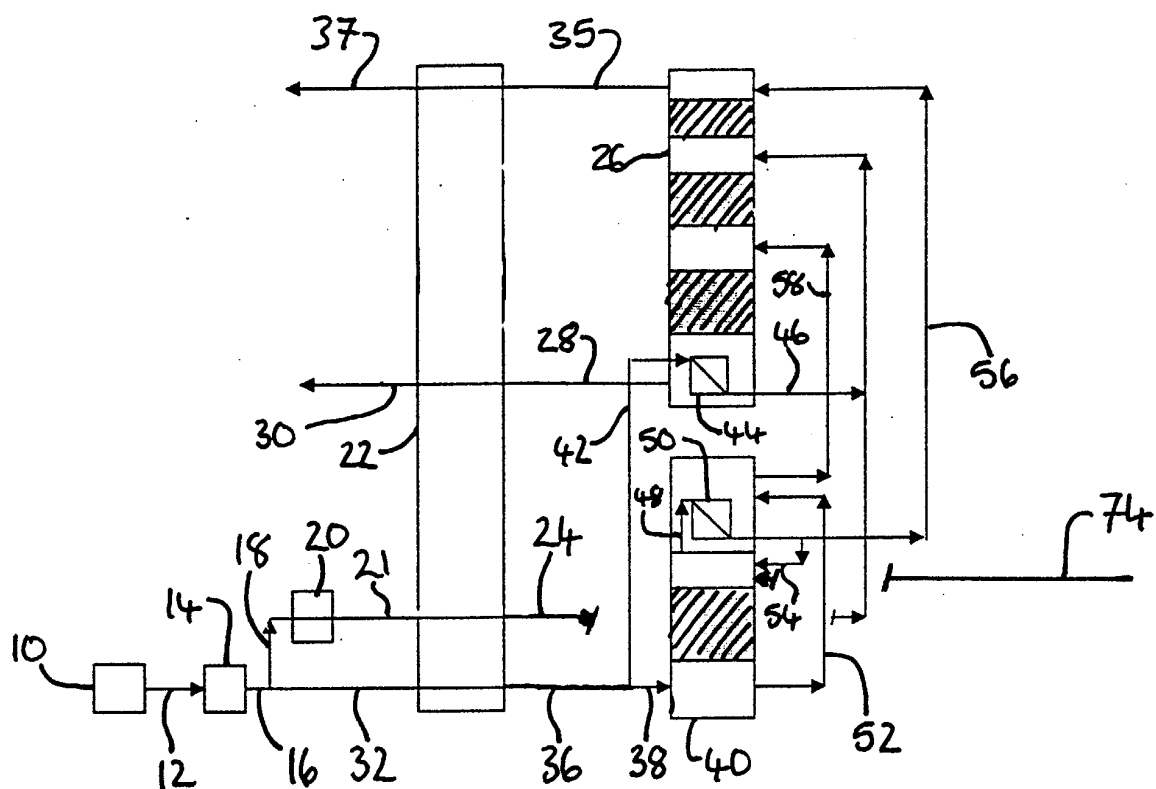


FIGURE 5

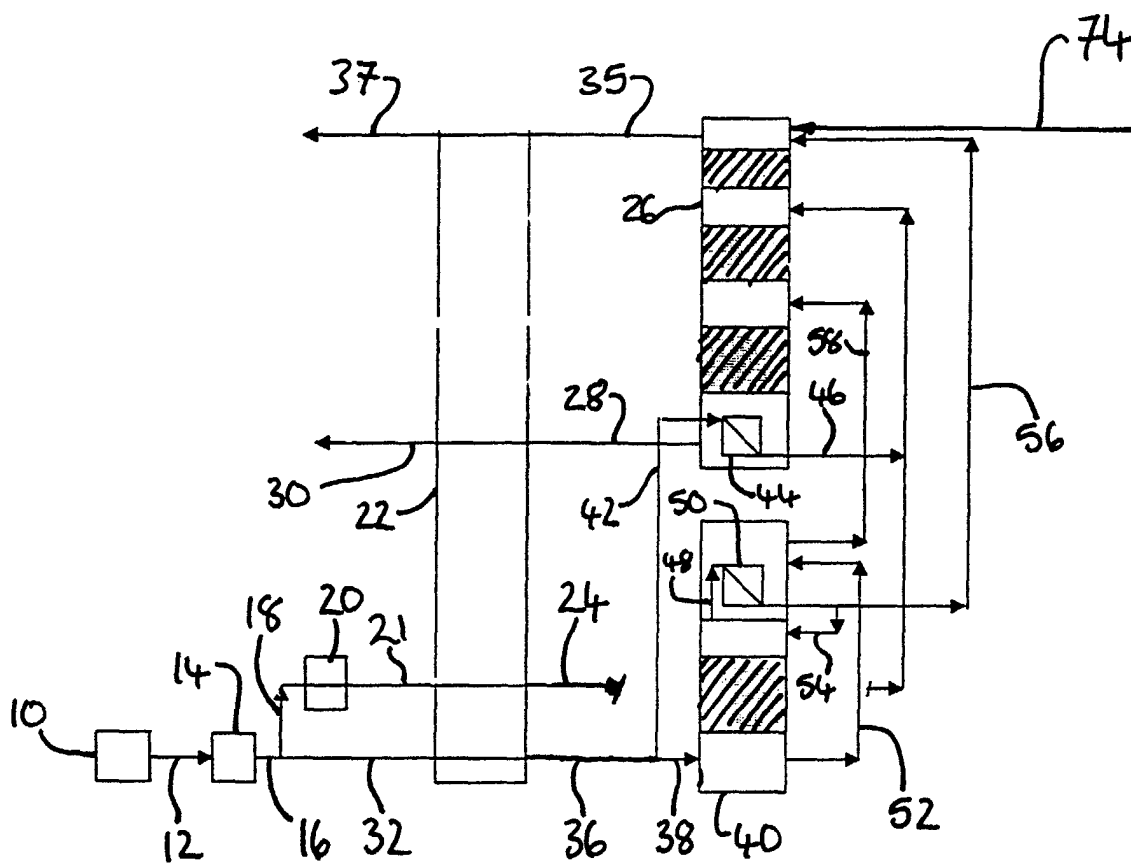


FIGURE 6



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 04 25 1844

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.7)
X	US 4 668 260 A (YOSHINO AKIRA) 26 May 1987 (1987-05-26) * paragraph [0037]; figure 3 * * column 8, line 19 - line 63; figure 8 * ---	1,2,7,8, 10,11, 14-18, 22,24, 25,29,30	F25J3/04
X	US 2003/110796 A1 (LAUTER MICHAEL ET AL) 19 June 2003 (2003-06-19) * paragraph [0037]; figure 3 * ---	1-4, 7-10, 14-19, 22-24, 28-30	
X	US 5 743 112 A (DEN RYO ET AL) 28 April 1998 (1998-04-28) * column 9, line 1 - line 32; figure 1 * ---	1,2,7,8, 10,11, 16-18, 22,24,25	
X	US 6 185 960 B1 (VOIT JUERGEN) 13 February 2001 (2001-02-13) * column 5, line 52 - column 7, line 36; figures 3,4 * -----	1-3,5,7, 8,10,11, 14-16, 18,20, 22,23, 25,28-30	TECHNICAL FIELDS SEARCHED (Int.Cl.7) F25J
The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 21 July 2004	Examiner Martínez Rico, C
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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**ANNEX TO THE EUROPEAN SEARCH REPORT
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21-07-2004

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