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(54) **METHOD AND APPARATUS FOR SEPARATING AIR BY CRYOGENIC DISTILLATION**

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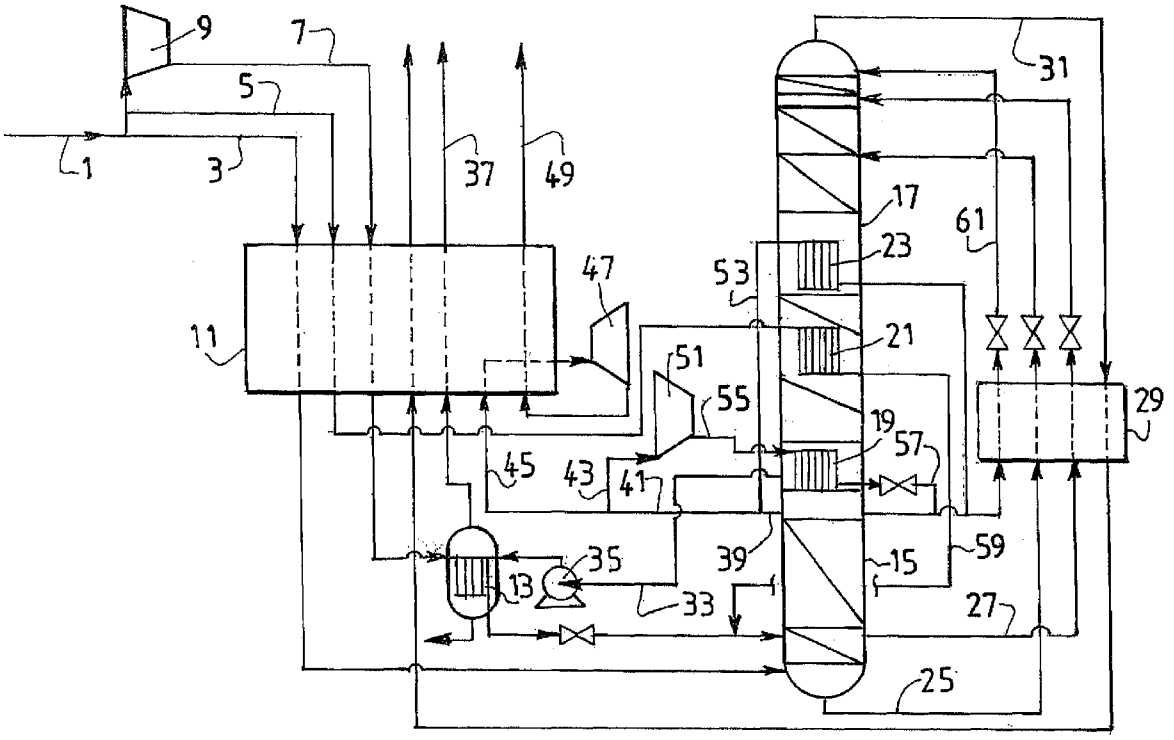
(57) **ABSTRACT**

A method and to an apparatus for producing oxygen by separating air using cryogenic distillation is presented.



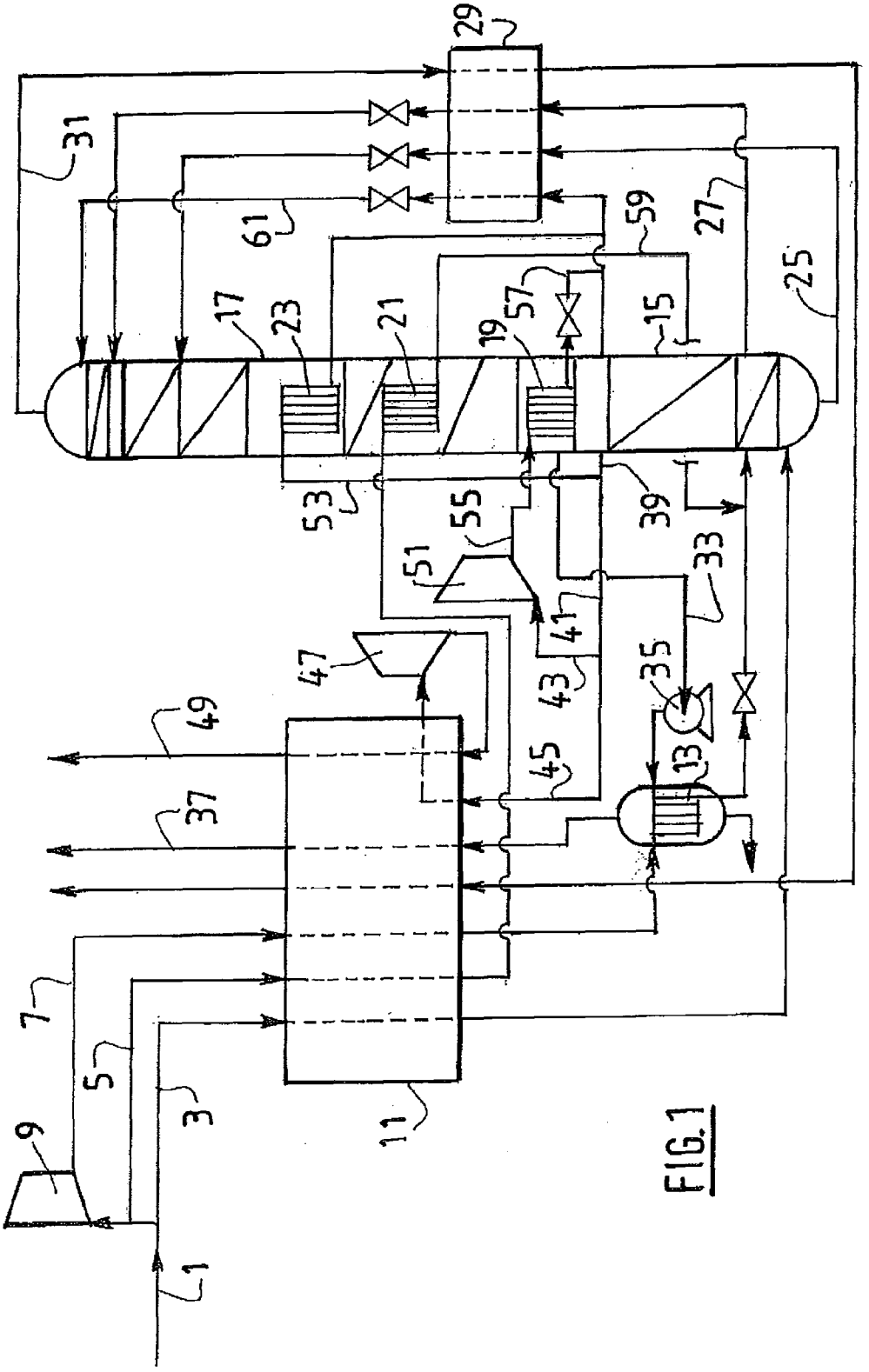

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FIG.1

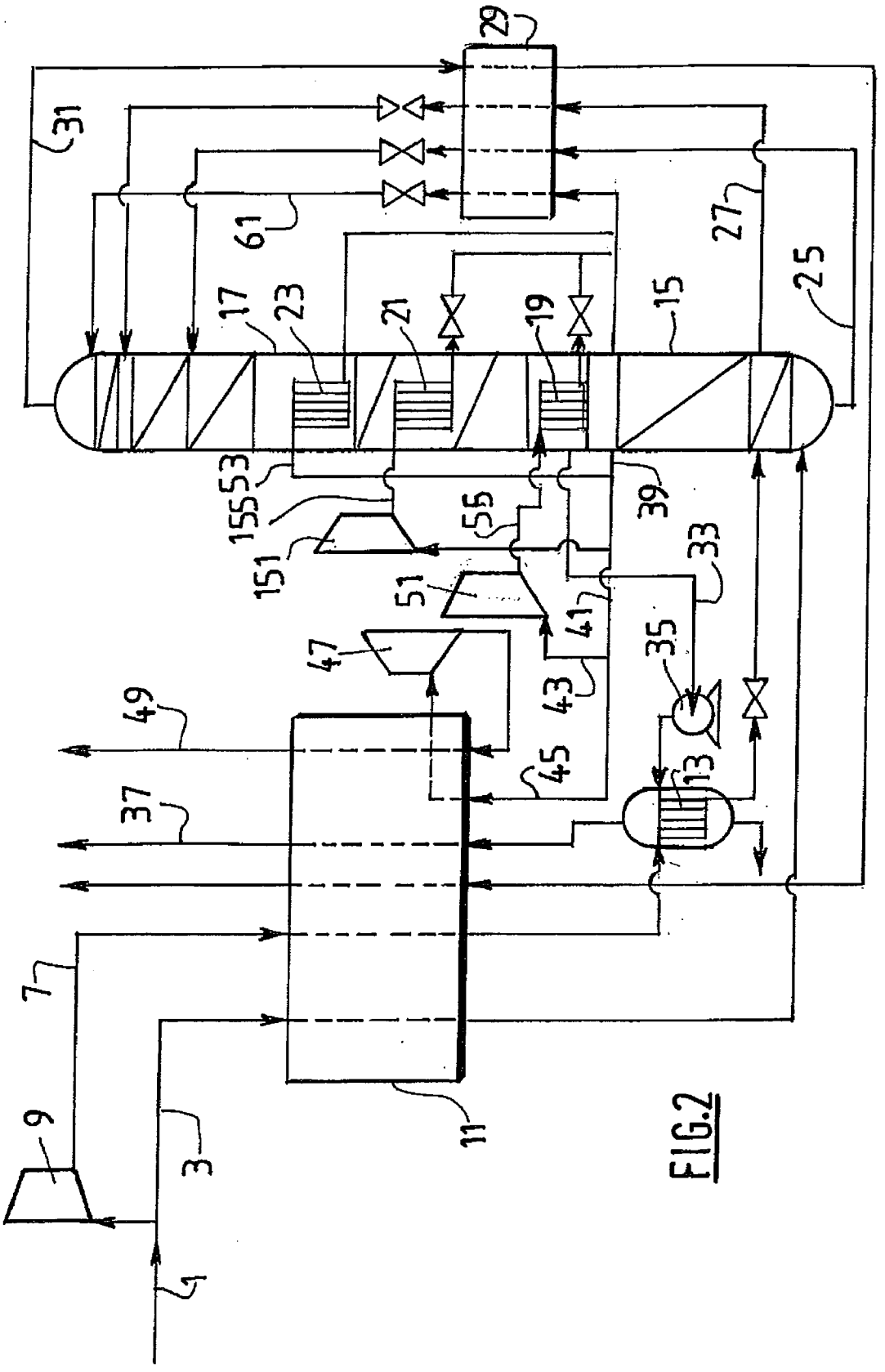
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FIG.2

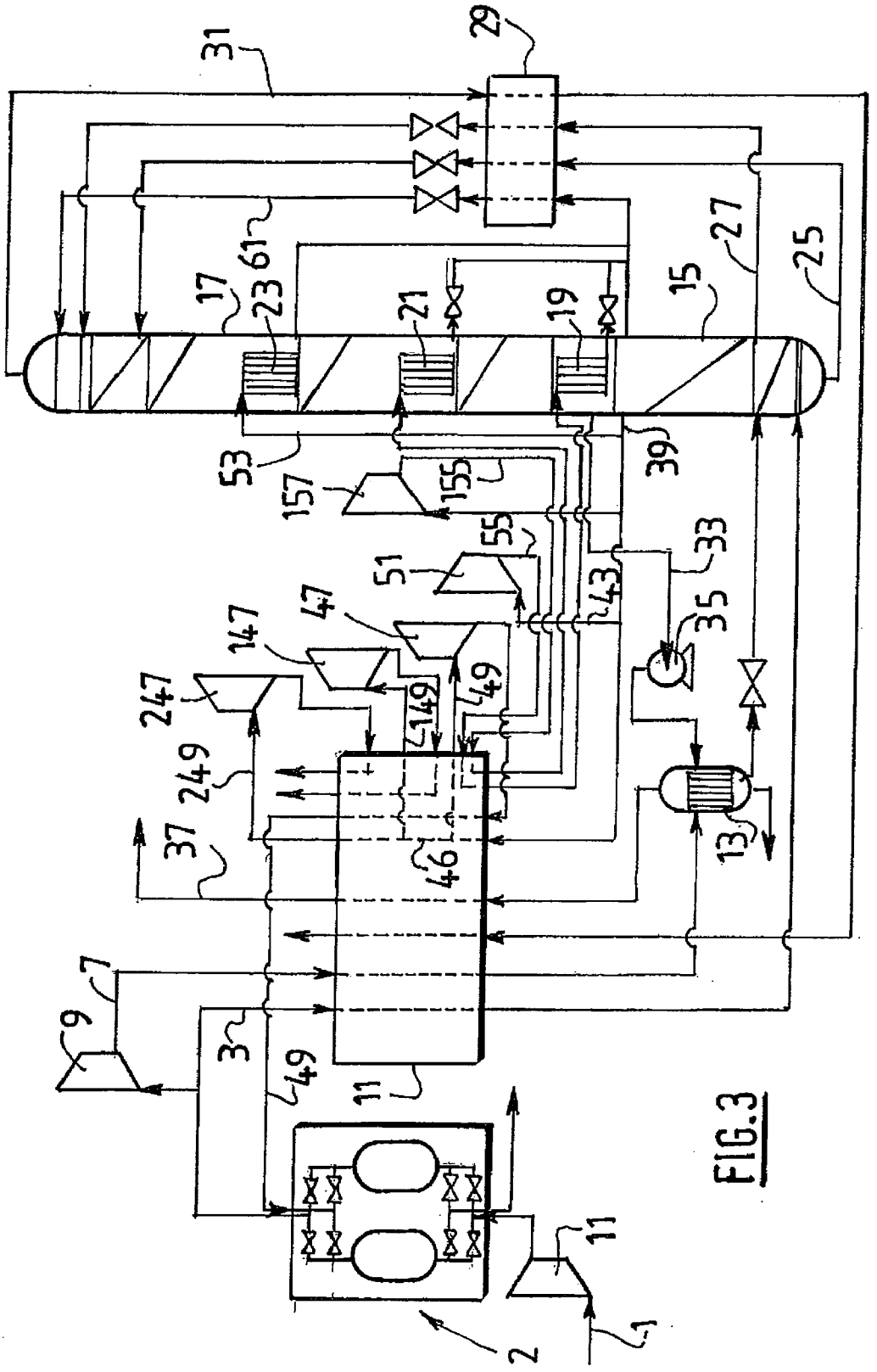
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FIG.3

METHOD AND APPARATUS FOR SEPARATING AIR BY CRYOGENIC DISTILLATION

[0001] The present invention relates to a method and to an apparatus for producing oxygen by separating air using cryogenic distillation.

[0002] One object of the invention is to reduce the specific energy of separation of low-pressure low-purity oxygen, particularly in schemes where the pressurized nitrogen is not realized as an asset in its own right by the end-customer.

[0003] The object of the invention is achieved via the use of a scheme employing three vaporizers in the low-pressure column, in which:

[0004] the bottom vaporizer operates on cold compressed medium-pressure nitrogen

[0005] the upper intermediate vaporizer operates on medium-pressure nitrogen

[0006] the lower intermediate vaporizer operates either on medium-pressure air or on medium-pressure nitrogen which is cold compressed.

[0007] Depending on variables, the specific energy saving represents between 0.5% and 7%.

[0008] U.S. Pat. No. 5,006,139 describes a method for producing nitrogen using a low-pressure column the bottom vaporizer of which is heated by a flow of medium-pressure nitrogen compressed in a cold compressor. According to the invention, there is also a proposal to use several turbines in order better to optimize the exchange line.

[0009] The method of the present invention produces gaseous oxygen and preferably does not produce nitrogen from the medium-pressure column.

[0010] One subject of the invention provides a method for producing oxygen by separating air using cryogenic distillation in an installation comprising a double column comprising a medium-pressure and a low-pressure column, the low-pressure column containing a bottom vaporizer, an intermediate vaporizer and an upper vaporizer, in which method:

[0011] a) compressed air is purified in a purification unit, cooled in an exchange line and fed to the medium-pressure column of the double column

[0012] b) an oxygen-rich fluid is withdrawn from the low-pressure column, heated up and sent to the customer

[0013] c) nitrogen tapped off from the medium-pressure column is split into at least three parts

[0014] d) a first part of the nitrogen is expanded in a first turbine

[0015] e) a second part of the nitrogen has its pressure raised in a cold compressor and is sent to the bottom vaporizer, the nitrogen thus condensed being sent to at least one column of the double column

[0016] f) a third part of the nitrogen is sent to the upper vaporizer, with no pressure-modifying step downstream of the column from which it is tapped off and upstream of the upper vaporizer, the nitrogen thus condensed being sent to at least one column of the double column

[0017] g) a gaseous flow is sent to the intermediate vaporizer, this flow consisting of purified and cooled compressed air or of the nitrogen tapped off from the medium-pressure column and compressed in a cold compressor.

[0018] According to other optional aspects:

[0019] the gaseous flow sent to the intermediate vaporizer, is nitrogen from the medium-pressure column

[0020] the gaseous flow sent to the intermediate vaporizer is purified and cooled compressed air

[0021] the first part of the nitrogen expanded in the first turbine is used for regenerating the purification unit

[0022] the first turbine drives the cold compressor in which the pressure of the second part of the fluid is raised and provides substantially all the cold energy for the method

[0023] the low-pressure column has no top condenser

[0024] all the gaseous nitrogen from the top of the medium-pressure column is split into just the three parts

[0025] all the gaseous nitrogen from the top of the medium-pressure column is split into just four parts, the fourth part being sent to the intermediate vaporizer

[0026] substantially all the cold energy is produced by expanding nitrogen from the medium-pressure column in at least one turbine

[0027] a liquid oxygen flow from the low-pressure column is vaporized, possibly after pressurizing it, to produce the fluid sent to the customer.

[0028] Another aspect of the invention provides an apparatus for producing oxygen by separation of air using cryogenic distillation comprising a double column comprising a medium-pressure column and a low-pressure column, the low-pressure column containing a bottom vaporizer, an intermediate vaporizer and an upper vaporizer, a purification unit, an exchange line, at least one first turbine, at least one cold compressor, means for sending compressed air, purified in the purification unit and cooled in the exchange line, to the medium-pressure column of the double column, means for withdrawing an oxygen-rich fluid from the low-pressure column, means for possibly heating it up, said means consisting at least in part of the exchange line and means for sending the heated-up oxygen-rich fluid sent to the customer, means for splitting the nitrogen tapped off from the medium-pressure column into at least three parts, means for sending a first part of the nitrogen to a first turbine, means for sending a second part of the nitrogen to a cold compressor where its pressure can be raised, means for sending the raised-pressure second part to the bottom vaporizer, means for sending the nitrogen thus condensed to at least one column of the double column, means for sending a third part of the nitrogen to the upper vaporizer, without a pressure modifying means downstream of the column from which it was tapped off and upstream of the upper vaporizer, means for sending the nitrogen thus condensed being sent to at least one column of the double column, means for sending a gaseous flow to the intermediate vaporizer, this flow consisting of purified and cooled compressed air or of nitrogen tapped off from the medium-pressure column and compressed in the second cold compressor.

[0029] The apparatus may possibly comprise:

[0030] means for connecting the intermediate vaporizer to the top of the medium-pressure column

[0031] means for connecting the outlet of the first turbine to the purification unit

[0032] the first turbine is coupled to the cold compressor in which the pressure of the second part of the fluid is raised and constitutes the only turbine in the apparatus

[0033] the low-pressure column has no top condenser

[0034] means for vaporizing liquid oxygen, possibly in the exchange line, and possibly means for pressurizing liquid oxygen upstream of the means for vaporizing the liquid oxygen.

[0035] The invention will be described in greater detail with reference to FIGS. **1**, **2** and **3** which are schematic diagrams of air separation apparatuses according to the invention.

[0036] FIG. **1** shows an air separation apparatus in which a pressurized and purified air flow **1** is split into three flows **3**, **5**, **7**. The flow **3** is cooled as it passes from one end of the exchange line **11** to the other and is sent to the medium-pressure column **15** of a double column. The flow **5** is cooled as it passes from one end of the exchange line **11** to the other and is sent to an intermediate vaporizer **21** of the low-pressure column **17** of the double column **15**, **17**. The other air flow **7** has its pressure raised in a hot pressurizer **9**, is cooled by passing from one end of the exchange line **11** to the other and is sent to a vaporizer **13** where it condenses at least partially by exchanging heat with pressurized liquid oxygen. The condensed air is either sent in its entirety to the medium-pressure column or split between the medium-pressure column and the low-pressure column **17**.

[0037] Rich liquid **25**, lean liquid **61** and possibly a liquid **27** somewhat like liquid air are sent from the medium-pressure column **15** to the low-pressure column **17** as reflux flows after supercooling in the exchanger **29**.

[0038] A flow of liquid oxygen **33** is tapped off from the low-pressure column, pressurized by the pump **35** and vaporized in the vaporizer **13** upstream of the exchange line **11**. The fluid **33** may also be compressed by the effect of a hydrostatic head, without the pump **35**.

[0039] Low-pressure nitrogen **31** is tapped off from the top of the low-pressure column **17** and is heated up in the exchangers **29**, **11**.

[0040] A medium-pressure gaseous flow of nitrogen **39** is tapped off from the top of the medium-pressure column **15** and split into two. One part **53** is sent to an upper vaporizer **23** of the low-pressure column **17** where it condenses before being returned to the medium-pressure column by way of reflux. The remainder of the nitrogen **41** is split into two, one portion **43** being sent to a cold compressor **51** to form a flow **55**, and this flow **55** is sent to the bottom vaporizer **19** of the low-pressure column **17**. In this vaporizer **19** it condenses and then acts as reflux for at least one of the columns.

[0041] The remainder **45** of the nitrogen is sent to the exchange line, is heated up to an intermediate level, and is sent to a turbine **47**. The nitrogen expanded in the turbine **47** is sent to the cold end of the exchange line and heats up, becoming the flow **49**.

[0042] This yields a potential energy saving of 0.5% over the scheme disclosed in WO-A-2007/129152.

[0043] FIG. **2** shows an air separation apparatus in which a pressurized and purified air flow **1** is split into two flows **3**,**7**. The flow **3** is cooled as it passes from one end of the exchange line **11** to the other and is sent to the medium-pressure column **15** of a double column. The other air flow **7** has its pressure raised in a hot pressurizer **9**, is cooled as it passes from one end of the exchange line **11** to the other and is sent to a vaporizer **13** where it condenses at least in part by exchange of heat with pressurized liquid oxygen. The condensed air is either sent in its entirety to the medium-pressure column or split between the medium-pressure column and the low-pressure column **17**.

[0044] Rich liquid **25**, lean liquid **61** and possibly a liquid **27** somewhat like liquid air are sent from the medium-pressure column **15** to the low-pressure column **17** as reflux flows after supercooling in the exchanger **29**.

[0045] A flow of liquid oxygen **33** is tapped off from the low-pressure column, pressurized by the pump **35** and vaporized in the vaporizer **13** upstream of the exchange line **11**. The fluid **33** may also be compressed using a hydrostatic head, without the pump **35**.

[0046] Low-pressure nitrogen **31** is tapped off from the top of the low-pressure column **17** and heats up in the exchangers **29**, **11**.

[0047] A medium-pressure gaseous flow of nitrogen **39** is tapped off from the top of the medium-pressure column **15** and split into two. One part **53** is sent to an upper vaporizer **23** of the low-pressure column **17** where it condenses before being returned to the medium-pressure column by way of reflux. The remainder of the air is once again split into two. One fraction is sent to the cold compressor **151** to become the flow **155** which heats the intermediate vaporizer **21** before being sent to the columns by way of reflux. The remainder of the nitrogen **41** is split into two, one portion **43** being sent to a cold compressor **51** to form a flow **55**, and this flow **55** is sent to the bottom vaporizer **19** of the low-pressure column **17**. In this vaporizer **19** it condenses and then serves as reflux for at least one of the columns.

[0048] The remainder **45** of the nitrogen is sent to the exchange line, is heated up to an intermediate level and is sent to a turbine **47**. The nitrogen expanded in the turbine **47** is sent to the cold end of the exchange line and heats up, becoming the flow **49**. Having the two cold compressors **51**, **151** on the medium-pressure nitrogen line allows the distribution of power across the compressors to be adjusted to best suit the low-pressure column reboiling requirement.

[0049] An energy saving of 1.7% over the scheme of WO-A-2007/129152 can be achieved.

[0050] FIG. **3** shows an air separation apparatus in which an air flow **1**, pressurized by a compressor M and purified in a purification unit **2** is split into two flows **3**, **7**. The flow **3** is cooled as it passes from one end of the exchange line **11** to the other and is sent to the medium-pressure column **15** of a double column. The other **7** has its pressure raised in a hot pressurizer **9**, is cooled by passing from one end of the exchange line **11** to the other and is sent to a vaporizer **13** where it condenses at least in part by exchange of heat with pressurized liquid oxygen. The condensed air is either sent in its entirety to the medium-pressure column or split between the medium-pressure column and the low-pressure column **17**.

[0051] Rich liquid **25**, lean liquid **61**, and possibly a liquid **27** somewhat like liquid air are sent from the medium-pressure column **15** to the low-pressure column **17** by way of reflux flows following supercooling in the exchanger **29**.

[0052] A flow of liquid oxygen **33** is tapped off from the low-pressure column, pressurized by the pump **35** and vaporized in the vaporizer **13** upstream of the exchange line **11**. The fluid **33** may also be compressed using a hydrostatic head, without the pump **35**.

[0053] Low-pressure nitrogen **31** is tapped off from the top of the low-pressure column **17** and is heated up in the exchangers **29**, **11**.

[0054] A medium-pressure gaseous flow of nitrogen **39** is tapped off from the top of the medium-pressure column **15** and split into two. One part **53** is sent to an upper vaporizer **23**

of the low-pressure column **17** where it condenses before being returned to the medium-pressure column by way of reflux. The remainder of the air is once again split into two. One fraction is sent to the cold compressor **151** where it becomes the flow **155**, the flow **155** being cooled in the exchange line **11** before being used to heat the intermediate vaporizer **21** before being sent to the columns by way of reflux. The remainder of the nitrogen **41** is split into two, one portion **43** being sent to a cold compressor **51** to form a flow **55**, and this flow **55** is sent to the bottom vaporizer **19** of the low-pressure column **17** after having been cooled in the exchange line **11**. In this vaporizer **19** it condenses and then serves as reflux for at least one of the columns.

[0055] The remainder **45** of the nitrogen is sent to the exchange line, heats up to an intermediate level and is split into two. One part **49** of the nitrogen **45** is sent to a turbine **47**. The nitrogen expanded in the turbine **47** is sent to the cold end of the exchange line and is heated up before being used periodically to regenerate the purification unit **2**. The remainder of the nitrogen **46** continues to be heated up in the exchange line **11** and is split into two, one part **149** being sent to a turbine **147** at a higher inlet temperature than the turbine **47**. This part of the nitrogen is expanded, heated up and discharged into the atmosphere. The remainder **249** of the nitrogen is sent to a turbine **247** at a higher inlet temperature than the turbines **47**, **147**. This part **249** of the nitrogen is expanded, heated up and discharged into the atmosphere.

[0056] An energy saving of 7% over the scheme of WO-A-2007/129152 can be achieved.

1-15. (canceled)

16. A method for producing oxygen by separating air using cryogenic distillation in an installation comprising a double column comprising a medium-pressure column and a low-pressure column, the low-pressure column containing the bottom vaporizer, an intermediate vaporizer and an upper vaporizer, said method comprising:

a) purifying compressed air in a purification unit, cooling said purified compressed air in an exchange line, and feeding the cooled compressed air to the medium-pressure column of the double column;

b) withdrawing an oxygen-rich fluid from the low-pressure column, heating the oxygen-rich fluid and sending the heated oxygen-rich fluid to a customer

c) withdrawing a nitrogen stream from the medium-pressure column, and splitting said nitrogen stream into at least three parts

d) expanding a first part of the nitrogen in a first turbine,

e) increasing the pressure of a second part of the nitrogen in a cold compressor and sending said pressurized nitrogen to the bottom vaporizer, sending the nitrogen thus condensed to at least one column of the double column;

f) condensing a third part of the nitrogen in the upper vaporizer, with no pressure-modifying step downstream of the column from which it is tapped off and upstream of the upper vaporizer, sending the nitrogen thus condensed to at least one column of the double column;

g) sending a gaseous flow to the intermediate vaporizer, this flow consisting of the nitrogen withdrawn from the medium-pressure column and compressed in a cold compressor.

17. The method of claim **16**, in which the first part of the nitrogen expanded in the first turbine is used for regenerating the purification unit.

18. The method of claim **16**, wherein the first turbine drives the cold compressor in which the pressure of the second part of the nitrogen is raised and provides substantially all cold energy required for the method.

19. The method of claim **16**, wherein the low-pressure column has no top condenser.

20. The method of claim **16**, wherein all the gaseous nitrogen from the top of the medium-pressure column is split into just the three parts.

21. The method of claim **16**, wherein all the gaseous nitrogen from the top of the medium-pressure column is split into just four parts, the fourth part being sent to the intermediate vaporizer.

22. The method of claim **16**, wherein substantially all cold energy required for the method is produced by expanding nitrogen from the medium-pressure column in at least one turbine.

23. The method of claim **16**, wherein a liquid oxygen flow from the low-pressure column is vaporized to produce the fluid sent to the customer.

24. The method of claim **23**, wherein said liquid oxygen is pressurized after removal from the low-pressure column and prior to vaporization.

25. An apparatus for producing oxygen by separation of air using cryogenic distillation comprising a double column comprising;

a) a medium-pressure column and a low-pressure column, the low-pressure column containing a bottom vaporizer, an intermediate vaporizer and an upper vaporizer,

b) a purification unit, a

c) n exchange line,

d) at least one first turbine,

e) at least one cold compressor,

f) means for sending compressed air, purified in the purification unit and cooled in the exchange line, to the medium-pressure column of the double column,

g) means for withdrawing an oxygen-rich fluid from the low-pressure column,

h) said means consisting at least in part of the exchange line means for sending the oxygen-rich fluid sent to the customer,

i) means for splitting the nitrogen withdrawn from the medium-pressure column into at least three parts,

j) means for sending a first part of the nitrogen to the first turbine,

k) means for sending a second part of the nitrogen to the cold compressor where its pressure is raised,

l) means for sending the raised-pressure second part to the bottom vaporizer,

m) means for sending the nitrogen thus condensed to at least one column of the double column,

n) means for sending a third part of the nitrogen to the upper vaporizer, without a pressure modifying means downstream of the column from which it was withdrawn from and upstream of the upper vaporizer,

o) means for sending the nitrogen thus condensed being sent to at least one column of the double column,

p) means for sending a gaseous flow to the intermediate vaporizer, this flow consisting of purified and cooled compressed air or of nitrogen

tapped off from the medium-pressure column and compressed in the second cold compressor,

also comprising means for connecting the intermediate vaporizer to the top of the medium-pressure column so that the nitrogen tapped off from the top of this column is sent to the intermediate vaporizer.

26. The apparatus of claim **25**, further comprising g') means for heating said oxygen-rich fluid from step g).

27. The apparatus of claim **25**, further comprising means for connecting the outlet of the first turbine to the purification unit.

28. The apparatus of claim **25**, wherein the first turbine is coupled to the cold compressor in which the pressure of the second part of the fluid is raised and constitutes the only turbine in the apparatus.

29. The apparatus of claim **25**, wherein the low-pressure column has no top condenser.

* * * * *