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

(11) EP 0 709 632 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
**01.05.1996 Bulletin 1996/18**

(51) Int Cl.[6]: **F25J 3/04**

(21) Application number: **95307528.0**

(22) Date of filing: **24.10.1995**

(84) Designated Contracting States:
**BE DE FR GB IE IT NL SE**

(30) Priority: **25.10.1994 US 329035**
**19.01.1995 US 374060**
**31.05.1995 US 459946**

(71) Applicant: **The BOC Group plc**
**Windlesham Surrey GU20 6HJ (GB)**

(72) Inventor: **Mostello, Robert A.**
**Somerville, New Jersey 08876 (US)**

(74) Representative: **Wickham, Michael et al**
**c/o Patent and Trademark Department**
**The BOC Group plc**
**Chertsey Road**
**Windlesham Surrey GU20 6HJ (GB)**

# (54) Air separation method and apparatus for producing nitrogen

(57) Air is separated in a distillation column 30 into an oxygen-rich liquid bottom fraction and a nitrogen-rich head vapour fraction. A stream 50 of the oxygen-rich fraction is partially vaporised in a vaporiser 54 and subjected to phase separation in a phase separator 56. The resulting liquid phase 58 is reduced in pressure by passage through valve 60 and employed to cool head condenser 42 which condenses a part of the nitrogen rich head fraction to provide reflux for the column 30. A stream of vapour 62 flows from the phase separator 56 and is expanded by a turboexpander 64 with the performance of work. Nitrogen product is withdrawn from the top of the column 30 as stream 68. In an alternative embodiment (Figure 2) the stream 50 is divided, one part flowing to the valve 60 without being partially vaporised, and the other part being totally vaporised and sent to the turboexpander.

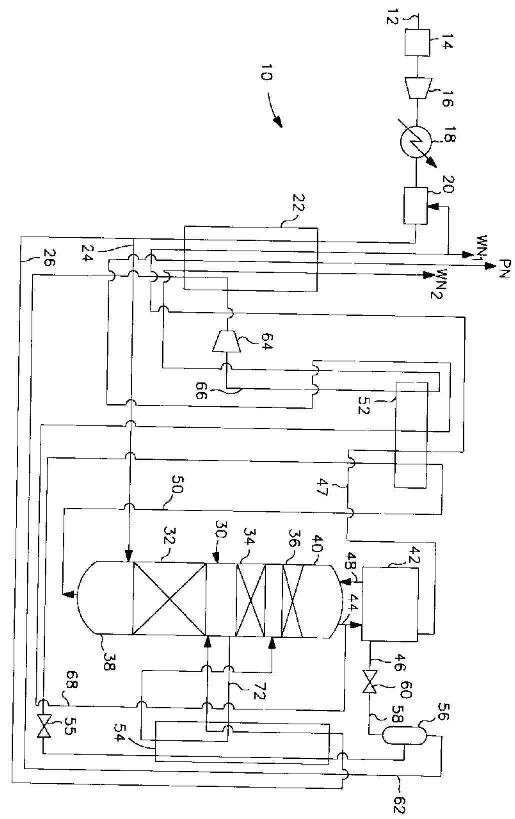


FIG. I

EP 0 709 632 A2

Printed by Jouve, 75001 PARIS (FR)

## Description

The present invention relates to a method and apparatus for separating air by low temperature rectification employing a distillation column so as to produce a nitrogen product.

Nitrogen is produced by low temperature rectification of air in an air separation plant. Often such plants employ a single distillation column and are known in the art as nitrogen generators. After air has been filtered, compressed and purified, the air is cooled to a temperature suitable for its rectification. This temperature is normally at or near the dew point of the air. Thereafter, the air is introduced into a distillation column having liquid-vapour contacting elements which may comprise trays and/or packings, either structured or random. In the distillation column an ascending vapour phase is contacted by a descending liquid phase. The result of such contact is that the liquid becomes evermore concentrated in oxygen to produce an oxygen enriched bottom liquid fraction and the vapour becomes evermore concentrated in nitrogen to produce a nitrogen rich head vapour fraction.

In order to provide reflux the column, a head condenser is provided in which the nitrogen vapour fraction is partially condensed. The condensate is returned to the distillation column as reflux. Typically, a stream of the oxygen-rich liquid is removed, is expanded to a low temperature, and is then used as the coolant for the head condenser. The nitrogen product is removed from the top region of the column as vapour.

There is continual heat leakage into the plant and enthalpy differences between the air feed and product streams at the warm end of the plant. Such heat leakage requires refrigeration to be supplied to the air separation plant. If the nitrogen product is to be maintained at column pressure, refrigeration is generally supplied from outside the column envelope. Work expansion obtained from the vaporised oxygen enriched liquid, all of which is vaporised in the head condenser, or by expanding air from a higher pressure down to column pressure are usual methods of supplying refrigeration. There are also "liquid assist plants" in which liquid nitrogen is added to the column from an external source in order to supply the requisite refrigeration.

As will be discussed, the present invention relates to an air separation method and apparatus in which refrigeration is generated in a manner that reduces the energy expenditure in producing a nitrogen product.

According to a first aspect of the present invention there is provided a method of separating air to produce a nitrogen product comprising:

separating the air by low temperature rectification in a distillation column to produce an oxygen rich bottom liquid fraction and a nitrogen rich head vapour fraction and condensing part of the nitrogen rich fraction in a head condenser to provide reflux for said distillation column;

partially vaporising a stream of the oxygen enriched liquid fraction;

separating said oxygen enriched liquid stream into liquid and vapour phases;

expanding a stream of the liquid phase to create a temperature difference between said liquid phase stream and the nitrogen rich vapour fraction and introducing the liquid phase stream as a coolant stream into the head condenser so that heat is transferred from said part of the nitrogen rich vapour to said coolant stream thereby causing condensation of the part of the nitrogen rich head vapour;

expanding a stream of the vapour phase with the performance of work to produce refrigeration for the method; and

extracting a product stream from a remaining part of said nitrogen rich vapour fraction to form said nitrogen product.

According to a second aspect of the present invention there is provided a method of separating air to produce a nitrogen product comprising:

separating the air by low temperature rectification in a distillation column to produce an oxygen rich bottom liquid fraction and a nitrogen rich head vapour fraction and condensing part of the nitrogen rich head vapour fraction in a head condenser to provide reflux for said distillation column;

dividing a stream of the oxygen rich liquid into first and second partial streams;

expanding said first partial stream to create a temperature difference between said first partial stream and said nitrogen rich vapour fraction and introducing said first partial stream as a coolant stream into the head condenser so that heat is transferred from said part of the nitrogen rich head vapour to said coolant stream thereby causing condensation of said part of the nitrogen rich head vapour;

vaporising the second partial stream;

expanding the vaporised second partial stream with the performance of work to produce refrigeration for the method; and

extracting a product stream from a remaining part of said nitrogen rich vapour to form said nitrogen product.

According to a third aspect of the present invention there is provided an apparatus for separating air to produce a nitrogen product, said apparatus comprising:

main heat exchange means for cooling air to a temperature suitable for its rectification;

a distillation column arranged to rectify the cooled air into an oxygen rich bottom liquid fraction and a nitrogen rich head vapour fraction;

a head condenser communicating with said distillation column for condensing part of the nitrogen head rich vapour fraction to provide reflux for said distillation column;

vaporisation means for partially vaporising a stream of the oxygen enriched liquid fraction;

a phase separator communicating with the vaporisation means for separating the partially vaporised oxygen enriched liquid stream into liquid and vapour phases;

the phase separator having an outlet for liquid communicating with the head condenser via a pressure reduction valve;

an expansion means for expanding a stream of the vapour phase with the performance of work, the expansion means communicating with an outlet for vapour from said phase separator; and

an outlet from the distillation column for a product stream of a remaining part of said nitrogen rich head vapour fraction;

According to a fourth aspect of the present invention there is provided an apparatus for separating air to produce a nitrogen product, said apparatus comprising:

main heat exchange means for cooling air to a temperature suitable for its rectification;

a distillation column arranged to rectify the air into an oxygen rich bottom liquid fraction and a nitrogen rich head vapour fraction;

a head condenser communicating with said distillation column for condensing part of the nitrogen rich head vapour to provide reflux for said distillation column;

an outlet from the distillation column for a stream of the oxygen rich bottom liquid fraction;

a pressure reduction valve communicating with the outlet for expanding a first part of the stream of oxygen-rich bottom liquid fraction, the pressure reduction valve having an outlet communicating with the head condenser;

vaporisation means for vaporising a second part of the stream of said oxygen rich bottom liquid;

expansion means for expanding said vaporised second part of the oxygen rich bottom liquid fraction with the performance of work to produce refrigeration;

an outlet from the distillation column for a product stream of a remaining part of the nitrogen rich head vapour fraction.

The present invention functions in all its aspects by taking advantage of the larger-than-necessary driving forces that are employed in the distillation of air to create the nitrogen product. In the present invention, the oxygen enriched liquid acts as a coolant for condensing reflux to the column and serves to supply at least part of the refrigeration needs of the plant, independent of aforementioned typical refrigeration processes.

Since not all of the oxygen enriched liquid is being utilised in a reflux condensation role, there is potentially an insufficient supply of reflux produced by the head condenser. In order to compensate for such reduced reflux production, intermediate reflux can be supplied, at the very least, by liquid air and preferably by both liquid air and another reflux stream of lesser oxygen content than air. Thus, in yet still another aspect, the present invention encompasses a method in which the oxygen enriched liquid stream or a part thereof is partially or wholly vaporised by indirectly exchanging heat with part of the air to be separated and, preferably, with another vapour stream withdrawn from the column of lesser oxygen content than air, thereby causing the part of the air to be separated and if present, the other vapour stream to liquefy. The part of the air to be separated and, preferably, the other liquefied vapour stream withdrawn from the column are then introduced into the distillation column as intermediate reflux streams to maintain production of the product stream at a level that would have been obtained had the entire oxygen rich liquid stream been utilised to condense the at least part of the nitrogen rich vapour tower overhead. Upstream of the partial vaporisation of the oxygen rich liquid stream or the complete vaporisation of part of the oxygen enrich liquid stream, the oxygen enriched liquid is preferably expanded to produce a temperature difference for the indirect heat exchange with the part of the air and preferably, if present, the vapour stream withdrawn from the column.

The present functions in all its aspects by taking advantage of the larger-than-necessary driving forces that are employed in the distillation of air.

Methods and apparatuses according to the invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a schematic flow diagram of a first air separation plant; and

Figure 2 is a schematic flow diagram of a second air separation plant.

Like components and streams in Figures 1 and 2 are indicated by the same reference numerals.

With reference to Figure 1, a single column nitrogen generator 10 is illustrated. An incoming air stream 12 is filtered by a filter 14 to remove dust particles and the like. Air stream 12, after having been filtered, is compressed by a compressor 16 and thereafter, the heat of compression is removed by a conventional after-cooler 18. Water, carbon dioxide and heavy trace components of the air such as hydrocarbons are removed by a conventional pre-purification unit 20 connected to or otherwise communicating with aftercooler 18. Pre-purification unit 20 can comprise several beds of adsorbent operating out of phase for regeneration purposes.

Air stream 12 having thus been filtered, compressed and purified is then introduced into a main heat exchanger 22 and is fully cooled by passage therethrough to a temperature suitable for its rectification. In this regard, the term "fully cooled" as used herein means cooled to a temperature at which the rectification is conducted. The term "fully warmed" as used herein means warmed to a warm end temperature of main heat exchanger 22. The term "partially warmed" means warmed in the heat exchanger 22 to a temperature above the rectification temperature but below the temperature of the warm end of main heat exchanger 22.

After having been fully cooled within main heat exchanger 22, air stream 12 is then divided into first and second subsidiary streams 24 and 26 respectively. First subsidiary stream 24 constitutes a major portion of the air to be separated and is introduced into a single distillation column 30 which is provided by liquid-vapour contacting elements 32, 34 and 36 which can be trays and/or structured packing, and/or random packing. Distillation column 30 rectifies the incoming air into an oxygen rich liquid fraction that collects within bottom region 38 of distillation column 30 and a nitrogen rich head vapour fraction which collects in a top region 40 of distillation column 30. A head condenser 42 is connected to or otherwise communicates with distillation column 30 to condense at least part of the nitrogen rich vapour fraction. To this end, part of a nitrogen vapour stream 44 flows out of the top region 40 of distillation column 30 and is introduced into head condenser 42. Nitrogen vapour stream 44 is in part condensed by a coolant stream 46, which in turn vaporises to produce a vaporised coolant stream 47. After condensation, nitrogen vapour stream 44 is returned as a reflux stream 48 to top region 40 of distillation column 30.

An oxygen enriched liquid stream 50 flows from bottom region 38 of distillation column 30. Oxygen enriched liquid stream 50 can then be preferably subcooled within a subcooler unit 52 to minimise vapour formation upon subsequent valve expansion. Thereafter, oxygen enriched liquid stream 50 is partially vaporised within a vaporiser 54 after having passed through a pressure reduction valve 55 and then introduced into a phase separator 56 to separate oxygen enriched liquid stream 50 into liquid and vapour phases.

A liquid phase stream 58 flows from phase separator 56 through a pressure reduction valve 60.

The resulting expansion sufficiently lowers the temperature of liquid phase stream 58 that it can serve as the coolant for head condenser 42. Thus, liquid phase stream 58 after passage through pressure reduction valve 60 forms the aforementioned coolant stream 46.

Phase separator 56 is also connected to or otherwise communicates with the main heat exchanger 22 so that a vapour phase stream 62 partially warms within main heat exchanger 22. Vapour phase stream 62 after having been partially warmed is expanded in a turboexpander 64 or other expansion machine connected to or otherwise communicating with main heat exchanger 22. The expansion of vapour phase stream 62 produces refrigeration in the form of a refrigerant stream 66.

The refrigerant stream 66 is warmed within subcooler unit 52, as is vaporised coolant stream 47 and a product stream 68, by countercurrent indirect heat exchange with the oxygen enriched liquid stream 50 which is thereby subcooled. The vaporised coolant stream 47, after subcooler unit 52, fully warms within main heat exchanger 22 to form a waste stream labelled $WN_1$ in Figure 1. Part of warm vaporised coolant stream 47 can be fed to pre-purification unit 20 for bed regeneration purposes. Main heat exchanger 22 is in communication with turboexpander 64 so that refrigerant stream 66 eventually fully warms within main heat exchanger 22 and is discharged as a waste stream, designated as $WN_2$ in Figure 1. A product stream 68 is taken from the nitrogen vapour head fraction collected in top region 40 of distillation column 30. After being warmed in subcooling unit 52, product stream 68 flows through main heat exchanger 22 and is discharged as a fully warmed product stream, labelled PN.

In single column nitrogen generator 10, oxygen enriched liquid stream 50 is partially vaporised in vaporiser 54 and thus only part of oxygen enriched liquid stream 50 is used as coolant for head condenser 42. As a result, there is less reflux contributed through condensation of nitrogen vapour in single column nitrogen generator 10 than in a nitrogen generator of the prior art in which the entire bottom fraction is used as coolant in the condenser 92. If no other reflux were added (an operation contemplated by the subject invention) a nitrogen generator of the present invention would have a lower production rate and/or produce nitrogen at a lower purity than a prior art generator but with a substantial power saving. However, preferably, compensation for such reduced reflux is effected by the provision of an intermediate reflux stream or streams introduced into lower portions of distillation column 30 where additional liquid reflux is particularly needed.

The intermediate reflux allows single column nitrogen generator 10 to achieve the same production rate and product purity as could be expected from a comparable prior art plant design. To form an intermediate reflux stream, second subsidiary air stream 26 is liquefied within vaporiser 54. In order for there to be a temperature difference between oxygen enriched liquid stream 50, after having been subcooled, and second subsidiary stream 26, pressure reduction valve 55 is provided to reduce the pressure and thereby the temperature of oxygen enriched liquid stream 50. This reduction in pressure of oxygen enriched liquid stream 50 is below the pressure of distillation column 30 and yet results in a sufficient pressure for oxygen enriched liquid stream 50 that vapour stream 62, derived therefrom, can serve in a refrigeration role. At lower distillation column pressures, for instance, below 8 bar(a), additional reflux to distillation column 30 is produced by liquefaction of a vapour stream 72 extracted from distillation column 30 at about the same point as second stream 26, after liquefaction, is introduced into distillation column 30. Vapour stream 72 is then liquefied within vaporiser 54 and introduced as additional reflux above the point of introduction of the liquefied second subsidiary stream 26. As is evident, pressure reduction valve 55 also serves to provide a temperature difference between oxygen enriched liquid stream 50 and vapour stream 72.

A possible variation to apparatus 10 involves operation of distillation column 30 at high pressure. In such case, an expansion machine might also be employed to expand to coolant stream 46. This would increase total plant refrigeration and therefore the amount of liquid produced. Additionally, such turboexpander could also be used to drive a recycle compressor to recycle part of the oxygen enriched liquid contained within coolant stream 46 back into distillation column 30 to increase production. As can also be appreciated, partial vaporisation of oxygen enriched liquid stream 50 may be effected in other ways than through liquefaction of a portion of the incoming air. For instance, in a low pressure column application, a stream from the column, not having the exact composition of liquid air, could be used in place of liquefied air.

With reference to Figure 2, an alternative embodiment of single column nitrogen generator 10 is illustrated. In this nitrogen generator 10, oxygen rich stream 50 after being subcooled within sub-cooler unit 52 is divided into first and second partial streams 50a and 50b. First partial stream 50a is expanded in first pressure reduction valve 60 to form coolant stream 46. Second partial stream 50b after having been expanded by pressure reduction valve 55 is then fully vaporised within vaporiser 54. The fully vaporised stream, designated by reference number 63, is then partially warmed within main heat exchanger 22 and expanded within turboexpander 64.

EXAMPLE 1

The following is a calculated example of a possible operation of single column nitrogen generator 10 (illustrated in Figure 1 ) in accordance with the present invention. In such example it is assumed that column 30 uses low pressure drop structured packing and has about 100 theoretical stages. Second partial stream 26 after having been liquefied is added to the distillation column at about six theoretical stages from the bottom. Stream 72 is withdrawn from the distillation column at a point of about six theoretical stages from the bottom and returned after condensing to a point about sixteen theoretical stages from the bottom of distillation column 30.

CHART FOR EXAMPLE 1

| Stream No | Flow $Nm^3/hr$ | Condition Liquid Vapour | Temperature K | Pressure bar (a) | $O_2$ Content % or parts per million |
|---|---|---|---|---|---|
| 12 | 13,400 | V | 305 | 1.01 | 20.96 |
| 24 | 11,739 | V | 93.0 | 3.17 | 20.96 |
| 26 | 1,454 | V | 93.0 | 3.17 | 20.96 |
| 47 | 3,901 | V | 87.6 | 1.21 | 53.32 |
| 50 | 6,670 | L | 92.6 | 3.17 | 41.92 |
| 58 | 3,901 | L | 90.1 | 2.27 | 53.32 |
| 62 | 2,768 | V | 90.1 | 2.27 | 25.85 |
| 66 | 2,768 | V | 83.0 | 1.09 | 25.85 |
| 68 | 6,670 | V | 88.3 | 3.10 | 2 ppm |
| 72 | 1,454 | V | 90.6 | 3.17 | 9.33 |

The letter "L" indicates the liquid state and the letter "V" the vapour state. Top product purity, nitrogen recovery as fraction of the air feed, and addition and withdrawal points depend on the values attributed to various physical properties by the data base employed in performing the calculations, and since different data bases do not always attribute the same value to the same physical property, will vary according to the data base. Losses inherent in operation of the pre-purification unit have been included in stream 12. As would be appreciated by those skilled in the art, subcooler 52 is at a low elevation with respect to the sump of distillation column 30.

In a comparable prior art design making a gaseous nitrogen product, identical in quantity, fractional recovery from air, purity and pressure, where a turboexpander makes refrigeration by expanding air into the distillation column, stream 12 would normally be compressed to about 3.94 bar(a). In Example 1, the air is compressed to about 3.45 bar(a). Accordingly, the method and apparatus according to respectively the first and third aspects of the invention make possible a substantial power saving.

EXAMPLE 2

The following is a calculated example of operation of the single column nitrogen generator 10 illustrated in Figure 2. In such example it is assumed that column 30 uses low pressure drop structured packing and has about 100 theoretical stages. Second partial stream 26 after having been liquefied is added to the distillation column at about six theoretical stages from the bottom. Stream 72 is withdrawn from the distillation column at a point of about six theoretical stages from the bottom and returned after condensing to a point about sixteen theoretical stages from the bottom of distillation column 30.

CHART FOR EXAMPLE 2

| Stream No | Flow $Nm^3/hr$ | Condition Liquid Vapour | Temperature K | Pressure bar (a) | $O_2$ Content % or parts per million |
|---|---|---|---|---|---|
| 12 | 13,400 | V | 305 | 1.01 | 20.96 |
| 24 | 11,259 | V | 92.6 | 3.10 | 20.96 |
| 26 | 2,080 | V | 92.6 | 3.10 | 20.96 |
| 47 | 3,889 | V | 86.3 | 1.21 | 41.92 |
| 50 | 6,669 | L | 92.4 | 3.10 | 41.92 |
| 50a | 3,889 | L | 87.0 | 3.03 | 41.92 |
| 63 | 2,780 | V | 92.1 | 2.18 | 41.92 |

Continuation of the Table on the next page

CHART FOR EXAMPLE 2 (continued)

| Stream No | Flow $Nm^3/hr$ | Condition Liquid Vapour | Temperature K | Pressure bar (a) | $O_2$ Content % or parts per million |
|---|---|---|---|---|---|
| 66 | 2,780 | V | 85.2 | 1.06 | 41.92 |
| 68 | 6,670 | V | 88.3 | 3.03 | 4.8 ppm |
| 72 | 1,008 | V | 90.3 | 3.09 | 9.06 |

In Example 2, the pressure of the stream 24 is 3.10 bar and is therefore even less than in Example 1.

**Claims**

**1.** A method of separating air to produce a nitrogen product comprising:

separating the air by low temperature rectification in a distillation column to produce an oxygen rich bottom liquid fraction and a nitrogen rich head vapour fraction and condensing part of the nitrogen rich fraction in a head condenser to provide reflux for said distillation column;

partially vaporising a stream of the oxygen enriched liquid fraction;

separating said oxygen enriched liquid stream into liquid and vapour phases;

expanding a stream of the liquid phase to create a temperature difference between said liquid phase stream and the nitrogen rich vapour fraction and introducing the liquid phase stream as a coolant stream into the head condenser so that heat is transferred from said part of the nitrogen rich vapour to said coolant stream thereby causing condensation of the part of the nitrogen rich head vapour;

expanding a stream of the vapour phase with the performance of work to produce refrigeration for the method; and

extracting a product stream from a remaining part of said nitrogen rich vapour fraction to form said nitrogen product.

**2.** A method as claimed in claim 1, wherein:

said oxygen enriched liquid stream is partially vaporised by indirectly exchanging heat with part of the air to be separated, thereby causing said part of the air to be separated to liquefy;

said part of the air to be separated is introduced into said distillation column as intermediate reflux; and

upstream of said partial vaporisation of said oxygen enriched liquid stream, said oxygen enriched liquid stream is expanded to produce a temperature difference for said indirect heat exchange between the part of said air and said oxygen enriched liquid stream.

**3.** A method of separating air to produce a nitrogen product comprising:

separating the air by low temperature rectification in a distillation column to produce an oxygen rich bottom liquid fraction and a nitrogen rich head vapour fraction and condensing part of the nitrogen rich head vapour fraction in a head condenser to provide reflux for said distillation column;

dividing a stream of the oxygen rich liquid into first and second partial streams;

expanding said first partial stream to create a temperature difference between said first partial stream and said nitrogen rich vapour fraction and introducing said first partial stream as a coolant stream into the head condenser so that heat is transferred from said part of the nitrogen rich head vapour to said coolant stream thereby causing condensation of said part of the nitrogen rich head vapour;

vaporising the second partial stream;

expanding the vaporised second partial stream with the performance of work to produce refrigeration for the method; and

extracting a product stream from a remaining part of said nitrogen rich vapour to form said nitrogen product.

**4.** A method as claimed in claim 3, wherein:

said second partial stream is vaporised by indirectly exchanging heat with part of the air to be separated, thereby causing said part of the air to liquefy;

said part of the air is introduced into said distillation column as intermediate reflux; and

upstream of said vaporisation of said second partial stream, said second partial stream is expanded to produce a temperature difference for the indirect heat exchange between said part of the air and the second partial stream.

**5.** A method as claimed in claim 2 or claim 4, further comprising:

removing a vapour stream from said distillation column;

condensing said vapour stream by indirectly exchanging heat between said vapour stream and said second partial stream; and

introducing said vapour stream back into said distillation column, above said intermediate reflux, as additional reflux.

**6.** A method as claimed in claim 5, wherein:

said oxygen enriched liquid stream is subcooled within a subcooling unit upstream of being partially vaporised;

said heat transfer to said coolant stream vaporises said coolant stream to form a vaporised coolant stream;

said air to be separated is divided into first and second subsidiary streams;

said first subsidiary stream is introduced into said distillation column; and

said second subsidiary stream forms that part of the air which is caused to liquefy;

**7.** A method as claimed in claim 1 or claim 3, additionally comprising introducing an intermediate reflux stream into the distillation column.

**8.** An apparatus for separating air to produce a nitrogen product, said apparatus comprising:

main heat exchange means for cooling air to a temperature suitable for its rectification;

a distillation column arranged to rectify the cooled air into an oxygen rich bottom liquid fraction and a nitrogen rich head vapour fraction;

a head condenser communicating with said distillation column for condensing part of the nitrogen head rich vapour fraction to provide reflux for said distillation column;

vaporisation means for partially vaporising a stream of the oxygen enriched liquid fraction;

a phase separator communicating with the vaporisation means for separating the partially vaporised oxygen enriched liquid stream into liquid and vapour phases;

the phase separator having an outlet for liquid communicating with the head condenser via a pressure reduction valve;

an expansion means for expanding a stream of the vapour phase with the performance of work, the expansion means communicating with an outlet for vapour from said phase separator;

an outlet from the distillation column for a product stream of a remaining part of said nitrogen rich head vapour fraction;

**9.** An apparatus for separating air to produce a nitrogen product, said apparatus comprising:

main heat exchange means for cooling the air to a temperature suitable for its rectification;

a distillation column arranged to rectify the air into an oxygen rich bottom liquid fraction and a nitrogen rich head vapour fraction;

a head condenser communicating with said distillation column for condensing part of the nitrogen rich head vapour to provide reflux for said distillation column;

an outlet from the distillation column for a stream of the oxygen rich bottom liquid fraction;

a pressure reduction valve communicating with the outlet for expanding a first part of the stream of oxygen-rich bottom liquid fraction, the pressure reduction valve having an outlet communicating with the head condenser;

vaporisation means for vaporising a second part of the stream of said oxygen rich bottom liquid;

expansion means for expanding said vaporised second part of the oxygen rich bottom liquid fraction with the performance of work to produce refrigeration;

an outlet from the distillation column for a product stream of a remaining part of the nitrogen rich head vapour fraction.

**10.** Apparatus as claimed in claim 8 or claim 9, further comprising a further heat exchanger for condensing a part of the air, the further head exchanger having an outlet for condensed air communicating with the distillation column.

**11.** Apparatus as claimed in claim 10, wherein the further heat exchanger has passages for condensing a stream of vapour from a first intermediate region of the distillation column, the passages communicating at their outlet ends with a second intermediate region of the distillation column above the first intermediate region.

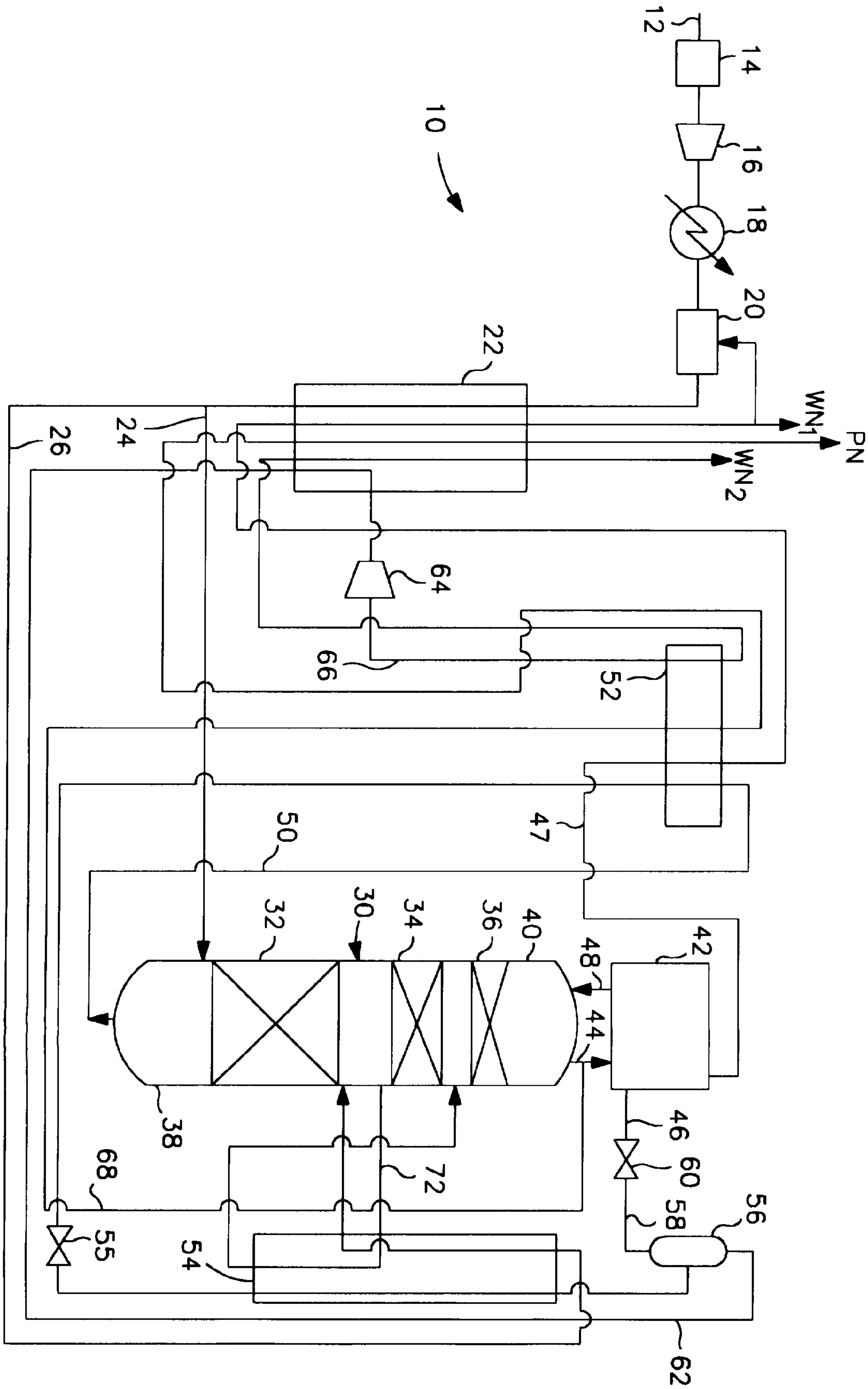
10
12
14
16
18
20
22
24
26
PN
$WN_1$
$WN_2$
30
32
34
36
38
40
42
44
46
47
48
50
52
54
55
56
58
60
62
64
66
68
72

FIG. 1

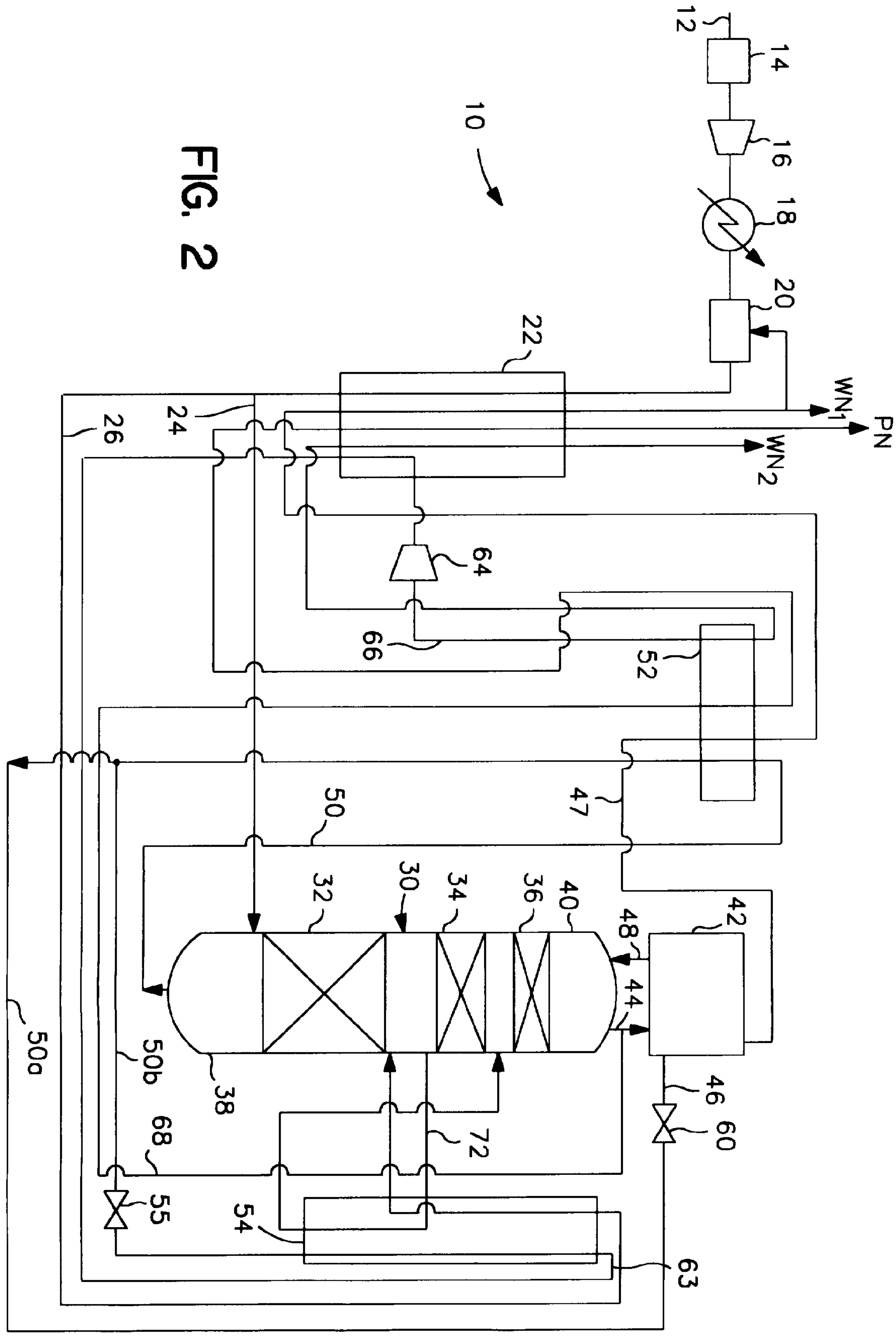
10
12
14
16
18
20
22
24
26
$WN_1$
PN
$WN_2$
64
66
52
47
50
30
32
34
36
40
42
48
44
46
60
38
50b
50a
68
72
55
54
63

FIG. 2

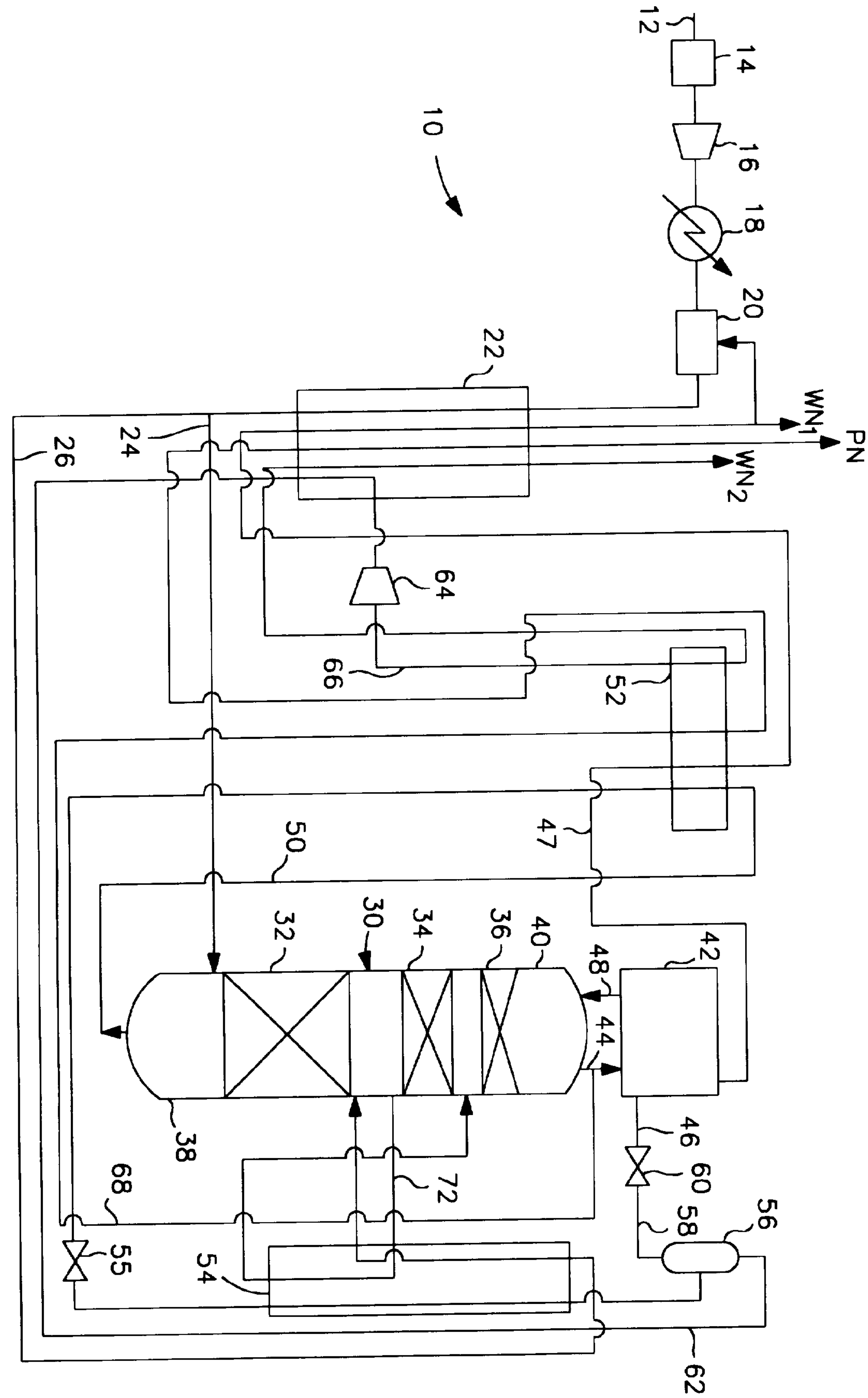
10
12
14
16
18
20
22
24
26
30
32
34
36
38
40
42
44
46
47
48
50
52
54
55
56
58
60
62
64
66
68
72
WN1
PN
WN2

FIG. I

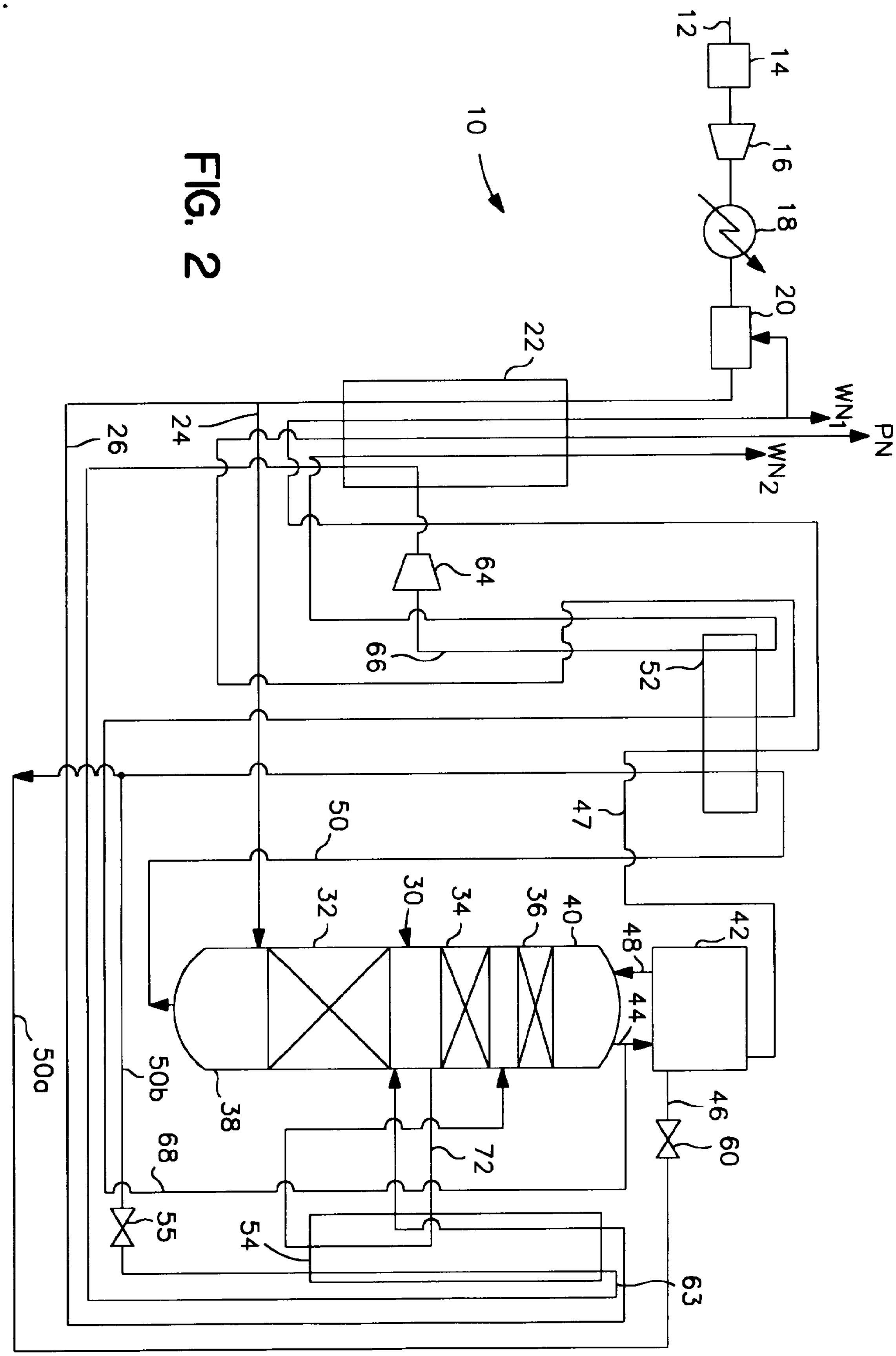
10
12
14
16
18
20
22
24
26
30
32
34
36
38
40
42
44
46
47
48
50
50a
50b
52
54
55
60
63
64
66
68
72
$WN_1$
PN
$WN_2$

FIG. 2