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(54) **PROCESS AND APPARATUS FOR
PRODUCING A PRESSURIZED PRODUCT
BY LOW-TEMPERATURE FRACTIONATION
OF AIR**

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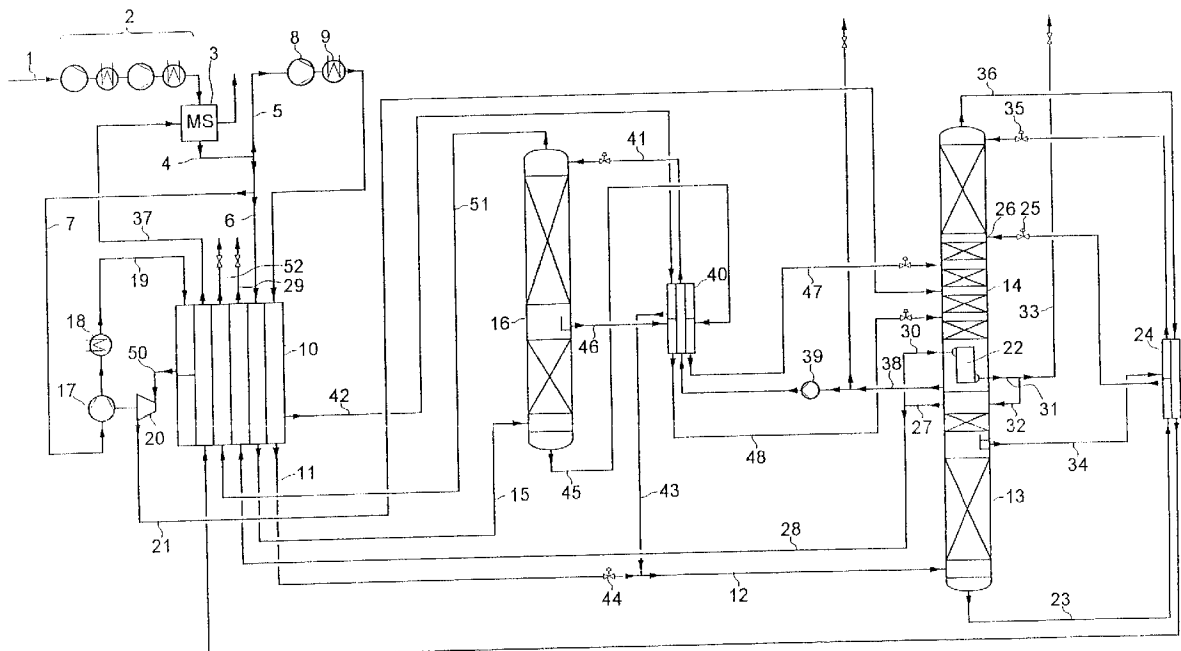
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(57) **ABSTRACT**

For producing a pressurized product by low-temperature fractionation of air in a rectification system which has a high-pressure column (13) and a low-pressure column (14), a first feed airstream (12) is introduced into the high-pressure column (13), and an oxygen-rich fraction (38) from the low-pressure column (14) is brought (39) to pressure in the liquid state and introduced (41) into a mixing column (16). A second feed airstream (6, 15) is introduced into the lower region of the mixing column (16) and brought into counter-current contact with the oxygen-rich fraction (41). The mixing column (16) is operated at a pressure (P_{MIS}) which is lower than the operating pressure (P_{HDS}) of the high-pressure column (13). A total airstream (1) which comprises the first and second feed airstreams is compressed (2) to a first pressure (p_1) which is lower than the operating pressure (P_{HDS}) of the high-pressure column (13) and is purified (3) at about this first pressure (p_2). The purified total airstream (4) is divided into the first (5) and the second (6) feed airstream. The first feed airstream (5) is further compressed (8) separately from the second feed airstream to a second pressure (P_2) which is at least equal to the operating pressure (P_{HDS}) of the high-pressure column (13).



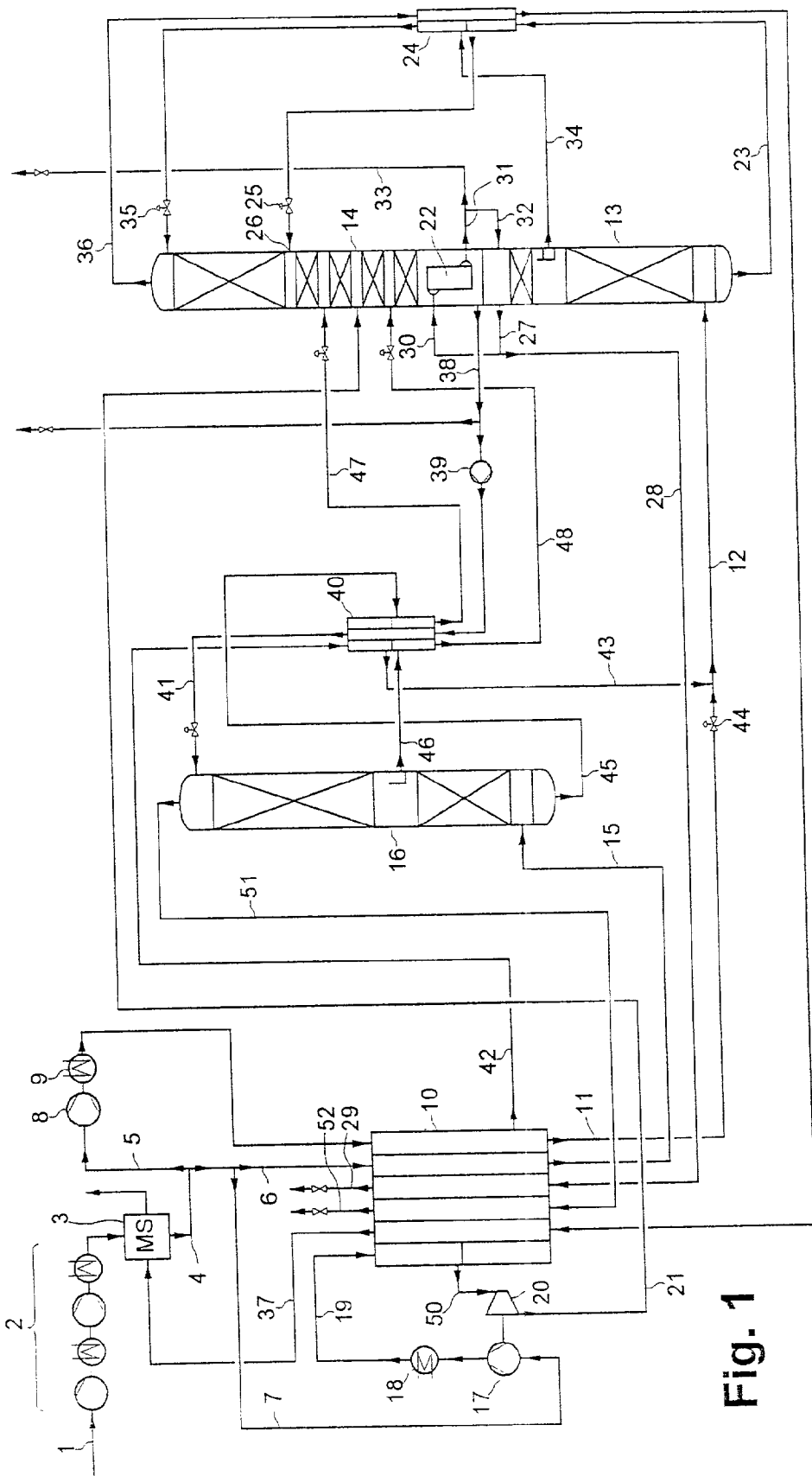


Fig. 1

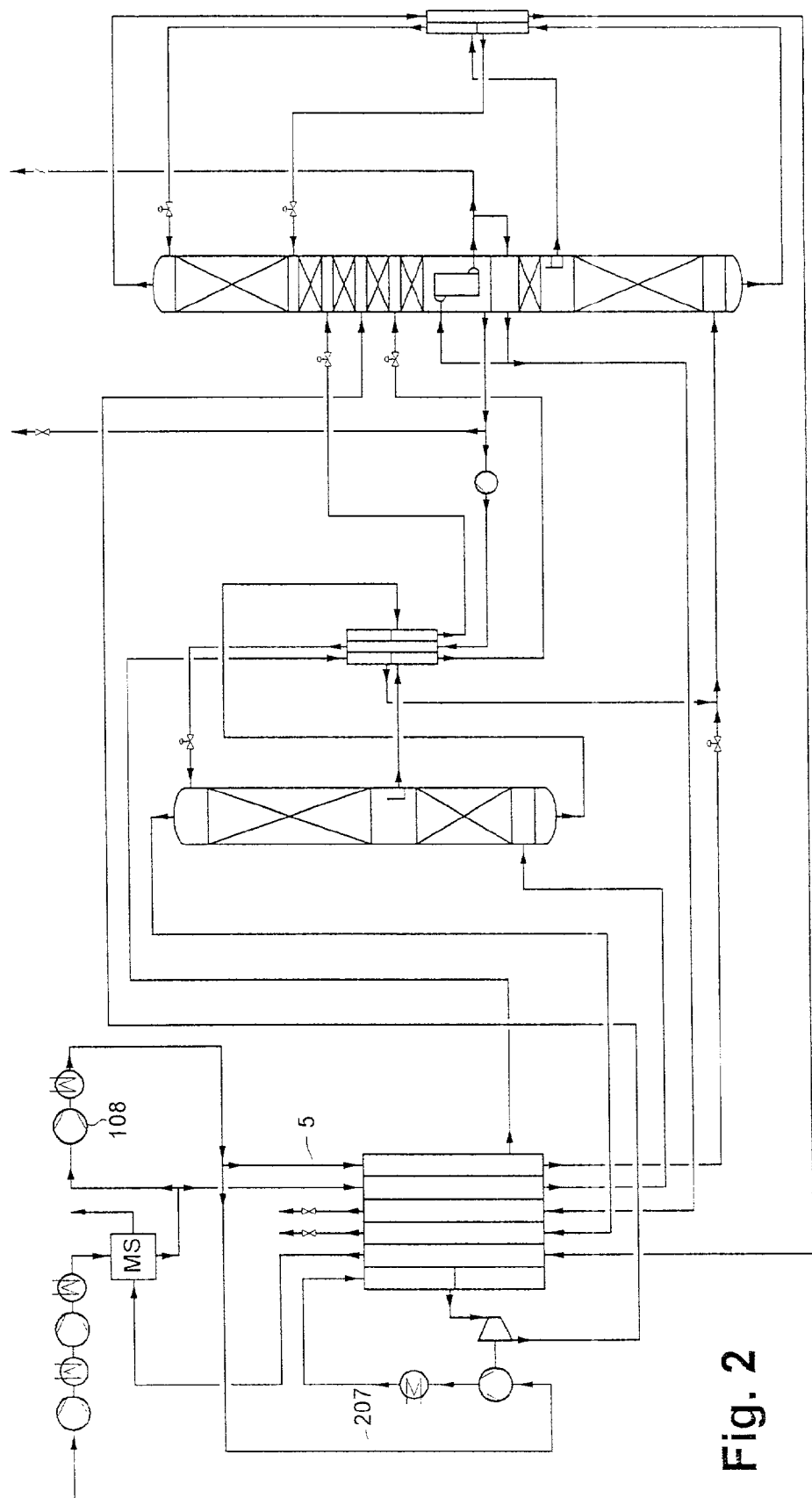
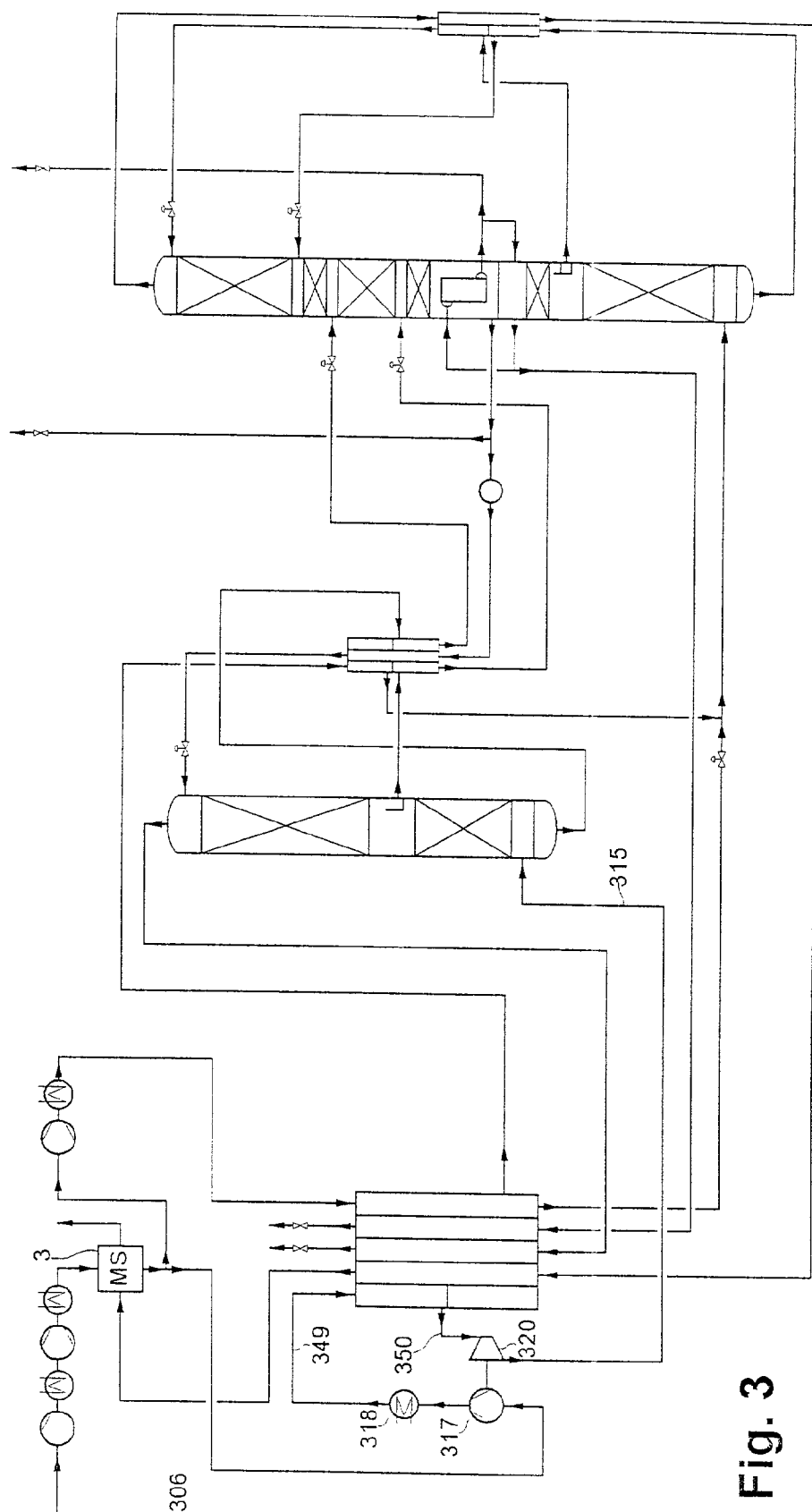


Fig. 2



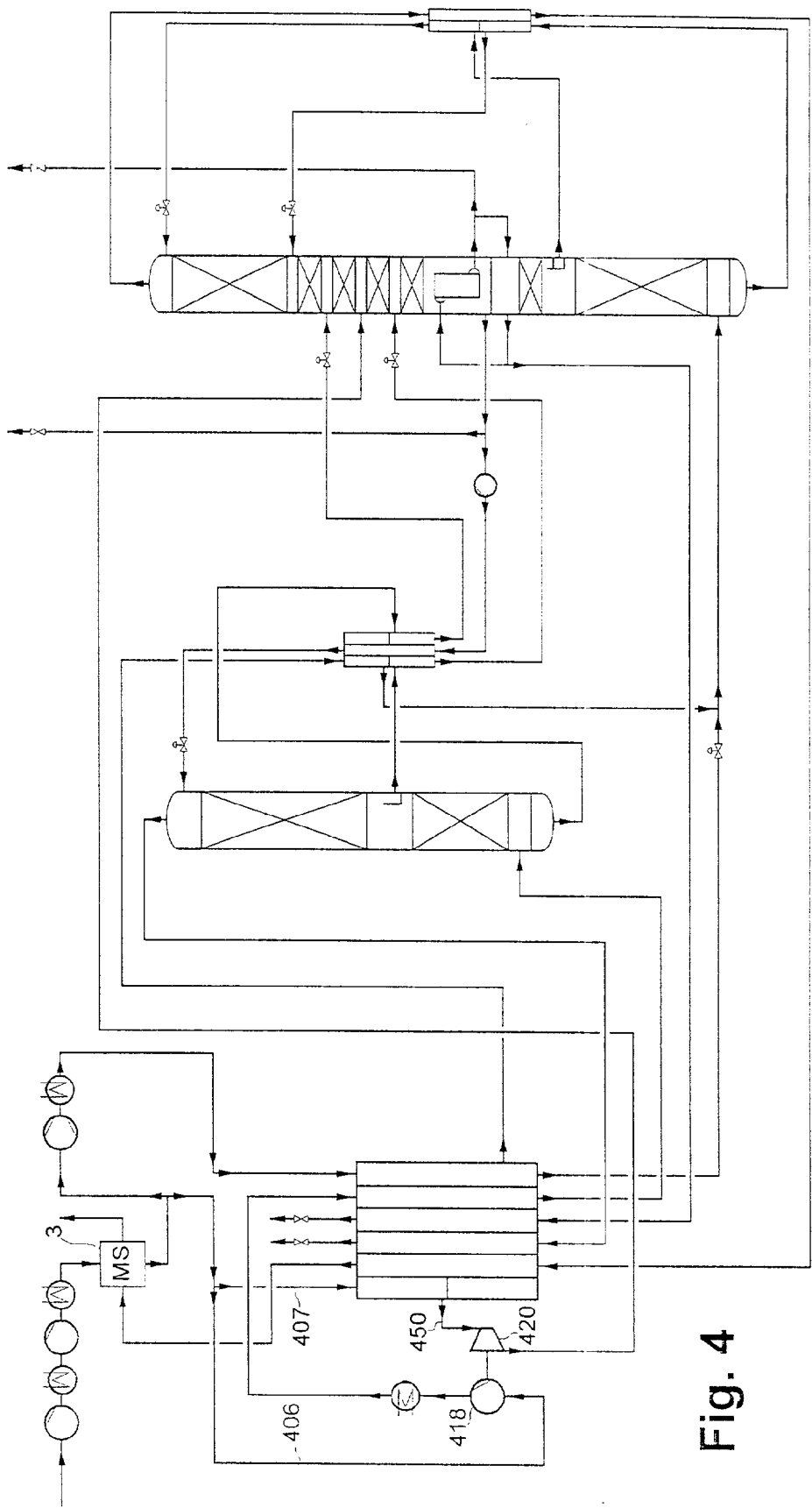


Fig. 4

PROCESS AND APPARATUS FOR PRODUCING A PRESSURIZED PRODUCT BY LOW-TEMPERATURE FRACTIONATION OF AIR

[0001] The invention relates to a process for producing a pressurized product by low-temperature fractionation of air with production of a gaseous pressurized product from a mixing column. In the invention, the mixing column is operated at a pressure which is lower than the operating pressure of the high-pressure column of the two-column system which serves for nitrogen-oxygen separation. separation.

[0002] The rectification system of the invention can be constructed as a two-column system, for example as a classic double-column system, or else as a three-column or multiple column system. It can, additionally to the columns for nitrogen-oxygen separation, have other apparatuses for producing other air components, in particular noble gases (for example krypton, xenon and/or argon).

[0003] The oxygen-rich fraction which is used as feed for the mixing column has an oxygen concentration which is higher than that of air and is, for example, 70 to 99.5 mol%, preferably 90 to 98 mol%. Mixing column is taken to mean a countercurrent contact column in which a more volatile gaseous fraction is charged in countercurrent to a less-volatile liquid.

[0004] The inventive process is suitable, in particular, for producing gaseous impure oxygen under pressure. Impure oxygen is here termed a mixture having an oxygen content of 99.5 mol% or less, in particular 70 to 99.5 mol%. The product pressures are, for example, 2.2 to 4.9 bar, preferably 2.5 to 4.5 bar. Obviously, the pressurized product, as required, can be further compressed in the gaseous state.

[0005] A process and an apparatus of the type mentioned at the outset are disclosed by EP 697576 A1. Here, the total air is compressed to about high-pressure column pressure and the mixing column air is then expanded to the operating pressure of the mixing column, with a part of the mixing column air being work-expanded. By this means, although the high pressure of this partial airstream can be used to produce cold, the known process is not energetically favourable in all cases.

[0006] The object underlying the invention is to specify a process of the type mentioned at the outset and a corresponding apparatus which have a particularly low energy consumption.

[0007] This object is achieved by means of the fact that a total airstream which comprises at least the first and second feed airstreams is compressed to a first pressure (p_1) which is lower than the operating pressure (p_{HDS}) of the high-pressure column and is advantageously purified at about this first pressure (p_1) that the purified total airstream is divided into the first and second feed airstreams and that the first feed airstream is further compressed separately from the second feed airstream to a second pressure (p_2) which is at least equal to the operating pressure (p_{HDS}) of the high-pressure column.

[0008] The total airstream is therefore not compressed to the highest pressure in the system, but to a lower value. The air fraction or air fractions which require a relatively high pressure, in particular the high-pressure-column air, are

specifically separately further compressed. As a result, the process can proceed with the lowest possible energy consumption in compression of the feed air.

[0009] The lowest equipment costs are achieved if the first pressure is about equal to the operating pressure of the mixing column. In this case the mixing column air (second feed airstream) can be introduced into the mixing column without further pressure-changing measures.

[0010] Alternatively thereto, the first pressure can be lower than the operating pressure (p_{MIS}) of the mixing column. In this case, the second feed airstream is further compressed separately from the first feed airstream to a third pressure (p_3) which is at least equal to the operating pressure (p_{MIS}) of the mixing column.

[0011] Preferably, the oxygen-rich fraction brought to pressure in the liquid state, before being introduced into the mixing column, is warmed in indirect heat exchange with a superheated airstream. The superheated airstream is formed, for example, by a portion of the feed air which is at high-pressure-column pressure. This is taken off at an intermediate temperature from the main heat exchanger in which feed air is cooled to about dewpoint, and brought to the indirect heat exchange with the oxygen-rich liquid without further temperature-changing measures. In this manner, the temperature of the liquid which is applied to the mixing column is optimally matched to the conditions in the countercurrent flow mass transfer within the mixing column.

[0012] Cold is produced in a favourable manner in the process by a third feed airstream being work-expanded and introduced into the low-pressure column. By this means the "natural" pressure drop between the first pressure or another process pressure can be utilized to compensate for insulation losses and, if appropriate, to liquefy a portion of the products.

[0013] Preferably, the third feed airstream, before the work expansion, is recompressed, in which case, in particular, mechanical energy produced during the work expansion is used to drive the recompression. In this case a turbine-booster combination can be used in which the expansion turbine and recompressor are mechanically coupled via a shared shaft.

[0014] The third feed airstream can be compressed to the first pressure and purified together with the first and second feed airstreams. Then it is either immediately fed to the recompression or recompressed still together with the first feed airstream.

[0015] Alternatively to injecting the third feed airstream into the low-pressure column, the second feed airstream, after its further compression, and before being fed into the mixing column, can be work-expanded. The further compression is then carried out to a second pressure which is markedly higher than the mixing column pressure.

[0016] The invention also relates to an apparatus for conducting the process.

[0017] The invention and further details of the invention are described in more detail below with reference to exemplary embodiments shown in the drawings. In this case:

[0018] FIG. 1 shows a process and an apparatus having work expansion of a portion of the air compressed to the first pressure,

[0019] FIG. 2 shows a modified process having work expansion of a portion of the air compressed to the second pressure,

[0020] FIG. 3 shows a process having work expansion of the mixed-column air and

[0021] FIG. 4 shows another variant of FIG. 1 without recompression of the turbine air.

[0022] In the case of the process shown in FIG. 1, feed air 1 is brought in a two-stage air compressor 2 with after-cooling to a first pressure p_1 of, for example, 2.7 to 3.7 bar, preferably about 3.2 bar and, at preferably this pressure, enters into a purification device 3, which is preferably formed by a pair of conventional molecular-sieve adsorbers. The purified total air 4 divided into three partial streams 5, 6, 7.

[0023] The first feed airstream 5 is further compressed in a first recompressor 8 to a second pressure p_2 of, for example, 4.4 to 7.0 bar, preferably about 5.7 bar, and, after after-cooling 9 flows into a main heat exchanger 10. The first feed airstream leaves the main heat exchanger 10 via line 11 at about dewpoint temperature and is fed via line 12 into a high-pressure column 13. The operating pressure P_{DS} of the high-pressure column 13 is, for example, 4.3 to 6.9 bar, preferably about 5.6 bar. The rectification system in addition has a low-pressure column 14 which is operated at, for example, 1.3 to 1.7 bar, preferably about 1.5 bar.

[0024] The second feed airstream C is also passed through the main heat exchanger 10 at about the first pressure p_1 (minus pipe losses and pressure drops in the cleaning device) and finally flows via line 15 to the mixing column 16. The feed point is directly above the bottom of the mixing column 16.

[0025] The third partial stream 7 is recompressed from about the first pressure P_1 to a third pressure p_3 of, for example, 3.8 to 5.6 bar, preferably about 4.7 bar, in a second recompressor 17 and, after after-cooling 18 is fed via line 19 to the warm end of the main heat exchanger. However, it is only cooled to an intermediate temperature and is taken off again from the main heat exchanger 10 before the cold end via line 50 and work-expanded in a turbine 20. The expanded air 21 is injected into the low-pressure column 14. Recompressor 17 and turbine 20 are directly mechanically coupled.

[0026] The rectification system is designed in the exemplary embodiments as a classic Linde double-column apparatus having a condenser-evaporator 22 as main condenser. However, the invention can also be used in rectification systems having other condenser and/or column configurations.

[0027] Oxygen-enriched liquid 23 from the bottom of the high-pressure column 13 is cooled in a first sub-cooling countercurrent heat exchanger 24 and fed, after throttling 25, to the low-pressure column 14, at an intermediate point 26. Gaseous nitrogen 27 from the top of the high-pressure column 13 can in part 22 be warmed in the main heat exchanger 10 and produced as pressurized nitrogen product 29. The remainder 30 is essentially completely condensed in the main condenser 22. The liquid nitrogen 31 produced here is at least in part 32 introduced as reflux into the high-pressure column 13. If required, another portion 33 can be

taken off as liquid product. An intermediate liquid (impure nitrogen) of the high-pressure column 34 serves, after sub-cooling 24 and throttling 35, as reflux for the low-pressure column. Gaseous impure nitrogen 36 from the top of the low-pressure column is warmed in the heat exchangers 24 and 10 and finally taken off via line 37. It can be used, as shown, as regeneration gas for the purification device 3.

[0028] Liquid oxygen 38 is taken off from the bottom of the low-pressure column brought to a pressure of, for example, 5.7 to 6.5 bar, preferably about 6.1 bar, in a pump 39, warmed in a second sub-cooling countercurrent heat exchanger 40 and finally introduced (41) into the top of the mixing column 16. In the second sub-cooling countercurrent heat exchanger 40, in particular, a superheated airstream 42 is cooled which is branched off from the first feed airstream upstream of the cold end of the main heat exchanger, more precisely at an intermediate temperature which is lower than the inlet temperature of the turbine 20. This airstream, after its cooling, is recombined via line 43 with the first feed airstream 11. Via the valve 44, the amount of the airstream flowing through the second sub-cooling countercurrent heat exchanger is set.

[0029] From the top of the mixing column 16, gaseous impure pressurized oxygen 51 is taken off, warmed in the main heat exchanger 10 and produced as product 52. Bottoms liquid 45 and an intermediate liquid 46 are taken off from the mixing column and fed via the lines 47 and 48, respectively, to the low-pressure column 14 at a suitable point.

[0030] FIG. 2 differs from Figure only in that the third feed airstream 207 is further compressed together with the second feed airstream in the first recompressor 108. As a result, a higher inlet pressure is reached at the turbine 20 and correspondingly more cold is produced.

[0031] In the variant of FIG. 3, the purification device is operated at a first pressure P_1 which is higher than the operating pressure P_{M1S} of the mixing column. The first pressure p_1' is here, for example, 2.7 to 3.7 bar, preferably about 3.2 bar. Here the second feed airstream 306 is expanded upstream of its feed into the mixing column. A third feed airstream which is injected into the low-pressure column does not exist. The second feed airstream 306 is further compressed downstream of its branching off from the purified total air in the second recompressor 317, which is driven by the turbine 320. The second feed airstream 349 which is further compressed, for example, to 3.8 to 5.6 bar, preferably about 4.7 bar, is fed via line 350 to the turbine 320 and is work-expanded there to about mixed-column-pressure P_{M1S} .

[0032] Similarly to the case in FIG. 3, in the process of FIG. 4, the purification 3 is operated at a particularly low first pressure p_1'' of, for example, 2.7 to 3.7 bar, preferably about 3.2 bar. The turbine 420 is, as in FIG. 1, subjected to a third feed airstream 407, 450 which here, however, is not recompressed, but is directly work-expanded from about the first pressure p_1 to about low-pressure-column pressure. The recompressor 418 driven by the turbine is here used for further compression of the second feed airstream to the second pressure p_2 , which is about equal to the operating pressure P_{M1S} of the mixing column.

[0033] In all exemplary embodiments, the air compressor and the recompressor 8, 108 are preferably jointly con-

structed as a three-stage machine. In other words, the further compression of the first feed airstream is carried out in the third stage of a machine whose first and second stages serve for air compression upstream of the purification 3. Alternatively thereto, this machine can also be constructed in four stages, with in this case the first three stages being arranged before the purification device 3.

[0034] Referring back to the process, whereas it is advantageous for the compressed total air stream to be purified at the compression pressure, it is also possible that purification can be conducted upstream or downstream for individual feed streams and/or at different pressures.

[0035] The preceding examples can be repeated with similar success by substituting the generically or specifically described reactants and/or operating conditions of this invention for those used in the preceding examples. Also, the preceding specific embodiments are to be construed as merely illustrative, and not limitative of the remainder of the disclosure in any way whatsoever.

[0036] The entire disclosure of all applications, patents and publications, cited above and below, and of corresponding German application 10015602.9, are hereby incorporated by reference.

[0037] From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention, and without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions.

1. A process for producing a pressurized product by low-temperature fractionation of air in a rectification system which has a high-pressure column (13) and a low-pressure column (14), in which

a first feed airstream (12) is introduced into the high-pressure column (13),

an oxygen-rich fraction (38) from the low-pressure column (14) is brought (39) to pressure in the liquid state and introduced (41) into a mixing column (16),

a second feed airstream (6, 15, 306, 406) is introduced into the lower region of the mixing column (16) and brought into countercurrent contact with the oxygen-rich fraction (41),

with the mixing column (16) being operated at a pressure (p_{MIS}) which is lower than the operating pressure (p_{HDS}) of the high-pressure column (13), and in which

a gaseous top product (51) is taken off from the upper region of the mixing column (16) and produced as pressurized product (52),

characterized in that

a total airstream (1) which comprises the first and second feed airstreams is compressed (2) to a first pressure (p_1) which is lower than the operating pressure (p_{HDS}) of the high-pressure column (13),

the total airstream (4) is divided into the first (5) and the second (6, 306, 406) feed airstreams and in that

the first feed airstream (5) is further compressed (8, 108) separately from the second feed airstream to a second

pressure (p_2) which is at least equal to the operating pressure (p_{HDS}) of the high-pressure column (13).

2. Process according to claim 1, characterized in that the first pressure (p_1) is about equal to the operating pressure (p_{MIS}) of the mixing column (16).

3. Process according to claim 1, characterized in that the first pressure is lower than the operating pressure (p_{MIS}) of the mixing column (16) and in that the second feed airstream (306, 406) is further compressed (317, 417) separately from the first feed airstream to a third pressure (p_3) which is at least equal to the operating pressure (p_{MIS}) of the mixing column (16).

4. Process according to one of claims 1 to 3, characterized in that the oxygen-rich fraction brought to pressure in the liquid state, before the introduction (41) into the mixing column (16), is warmed in indirect heat exchange (40) with a superheated airstream (42).

5. Process according to one of claims 1 to 4, characterized in that a third feed airstream (7, 50, 207, 407, 450) is work-expanded (20, 420) and introduced (21) into the low-pressure column (14).

6. Process according to one of claims 1 to 5, characterized in that the third feed airstream (7), before the work expansion (20), is recompressed (17) with, in particular, mechanical energy produced during the work expansion (20) being used for the recompression (17).

7. Process according to one of claims 1 to 6, characterized in that the third feed airstream is formed downstream of the purification (3) by a portion of the total airstream (4) and is fed (7, 207) directly, or after joint recompression (108) with the first feed airstream, to the recompression (17).

8. Process according to one of claims 1 to 4, characterized in that the second feed airstream (306, 349, 350) is work-expanded (320) before its introduction into the mixing column.

9. Apparatus for producing a pressurized product by low-temperature fractionation of air by a rectification system which has a high-pressure column (13) and a low-pressure column (14) and having

a first feed air line (5, 11, 12) which leads into the high-pressure column (13),

a liquid line (38, 41) for taking off an oxygen-rich fraction from the low-pressure column (14), which comprises means (39) for pressure elevation and leads to a mixing column (16),

a second feed air line (6, 15) which leads to the lower region of the mixing column (16), and having

an oxygen product line which is connected to the upper region of the mixing column (16),

characterized by

a total air line which leads via an air compressor (2) and a purification device (3) and is connected downstream to the first and second feed air lines and by

a recompressor (8, 108) which is disposed in the first feed air line (5, 11, 12).

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