The invention relates to a transportable package for a low-temperature air separation plant which has a main heat exchanger (2a, 2b, 2c) for cooling feed air (1) and a double column (5) for separating the cooled feed air, wherein the double column (5) has a high-pressure column and a low-pressure column that are arranged above one another. The transportable package has a cold box (20, 400), in the interior of which accessories of the double column (5), in particular pipelines (7, 11, 12) and valves, are arranged, but not the double column and not the main heat exchanger, wherein the transportable package has connections for joining the pipelines to the double column and to the main heat exchanger. Moreover, the invention relates to a low-temperature air separation plant and to a method for producing a low-temperature air separation plant using this transportable package.
TRANSPORTABLE PACKAGE HAVING A COLD BOX, LOW-TEMPERATURE AIR SEPARATION PLANT AND METHOD FOR PRODUCING A LOW-TEMPERATURE AIR SEPARATION PLANT

[0001] The invention relates to a transportable package for a low-temperature air separation plant as classified in the preamble of claim 1.

[0002] Modular transportable units of this type, from which an air separation plant is constructed, are generally referred to as “packaged units” (PUs) and are described in US 2007199344 A1 or U.S. Pat. No. 5,461,871 for example.


[0004] The distillation column system in the invention comprises a two-column system for nitrogen-oxygen separation featuring a high-pressure column and a low-pressure column, which are arranged one on top of the other (to make a so-called double column). Between the two columns there is generally arranged a main condenser which is constructed as a condenser-vaporizer and via which the high-pressure column and the low-pressure column are in heat-exchanging communication. The distillation column system, in addition to the nitrogen-oxygen separation columns, may additionally comprise further apparatus for obtaining high-purity products and/or other air components, in particular noble gases, for example an argon production apparatus comprising a crude argon column and optionally a pure argon column and/or a krypton-xenon production apparatus.

[0005] The term “condenser-vaporizer” refers to a heat exchanger in which a first condensing stream of fluid enters into an indirect exchange of heat with a second vaporizing stream of fluid. Every condenser-vaporizer comprises a liquefaction space and a vaporization space, which consist of liquefaction passages and vaporization passages, respectively. The liquefaction space is where the condensation (liquefaction) of a first steam of fluid is practiced, while the vaporization space is where the vaporization of a second stream of fluid is practiced.

[0006] The vaporization and liquefaction spaces are formed by groups of passages which are in a heat-exchanging inter-relationship.

[0007] A “main heat exchanger” serves to cool feed air by indirect heat exchange with return streams from the distillation column system. It may be formed of one or more heat exchanger portions in parallel and/or serial inter-connection, for example of one or more plate-type heat exchanger blocks.

[0008] A “cold box” herein is to be understood as meaning an insulating enclosure which completely encompasses a thermally insulated interior in outer walls; plant components to be insulated, for example one or more separation columns and/or heat exchangers, are arranged in the interior. The insulating effect may be brought about through appropriate engineering of the outer walls and/or by filling the interspace between the plant components and the outer walls with insulating material. The latter version preferably employs a penetrable material such as, for example, perlite. Not only the distillation column system for nitrogen-oxygen separation in a low-temperature air separation plant but also the main heat exchanger and further cold plant components have to be enclosed by one or more cold boxes. The external dimensions of the cold box usually determine the in-transit dimensions of the package in the case of prefabricated plants. The “height” of a cold box is to be understood as meaning the dimension in the vertical direction based on the orientation of the cold box in plant operation; the “cross section” is the area perpendicular thereto (the horizontal). In transit, the height of the cold box determines the in-transit length and the cross section determines the in-transit height and width.

[0009] PUs are fabricated in a factory which is generally remote from the installation site of the air separation plant. This allows some substantial prefabrication and hence some minimization of the construction requirements at the installation site, where conditions are frequently very much more difficult. The prefabricated package or packages are transported from the factory to the installation site, the cold-box package with one or more separation columns in a horizontal arrangement. Package length and width are subject to restrictions for this kind of transportation. This technology has hitherto only been used for medium-sized air separation plants when the columns are at least partly packed with structured packings, since packed columns generally require a greater installed height than plate columns. Comparatively large plants with packed columns are made with a comparatively low degree of prefabrication; more particularly, the cold box is not constructed until at the installation site. Alternatively, conventional rectification plates are used exclusively; this does provide a relatively large capacity per unit column installed height, but results in noticeably increased energy requirements over packed columns.

[0010] The invention has for its object to engineer a transportable package of the type referred to at the beginning such that it is employable for low-temperature air separation plants of a capacity for which prefabrication of the column cold box in its entirety was hitherto impossible.

[0011] This object is achieved by the characterizing features of claim 1.

[0012] The present invention utilizes a specific conduit box which is prefabricated separately from the double column box and the main heat exchanger box. Removing some, preferably all, conduits and valves which are typically accommodated in the double column box makes it possible to render the column box correspondingly narrower. This means that even a relatively high capacity double column plant which hitherto had to be fabricated on site can be prefabricated as PU.

[0013] The conduit cold box of the transportable package as claimed in claim 1 contains at least one, preferably two or more or else all of the components listed hereinbelow:

[0014] The crude oxygen line from the high-pressure column into the low-pressure column

[0015] The LIN line from the high-pressure column/main condenser to the low-pressure column

[0016] The liquid air line to the high-pressure and/or low-pressure columns

[0017] The GAN line from the top of the low-pressure column to the countercurrent subcooler and/or to the main heat exchanger

[0018] The impure nitrogen line from an intermediate location on the low-pressure column to the countercurrent subcooler and/or to the main heat exchanger

[0019] The valve for decompressing crude LOX from the high-pressure column into the low-pressure column

[0020] The LIN line from the high-pressure column, or the liquefaction space of the main condenser, to the low-pressure column
0021. The product line(s) from the double column to a counter-current subcooler and/or to the main heat exchanger.

0022. Every other line that traverses the counter-current subcooler.

0023. Every line that leads from the argon box to the double column box, and vice versa, for example the argon transition line(s) between the low-pressure column and the crude argon column, the lines to and from the overhead condenser of the crude argon column and optionally to and from the overhead condenser of the pure argon column.

0024. The valve(s) for each and every one of the rectied lines, where applicable.

0025. For example, the cold box of the transportable package (the conduit box) does not contain a separation column, i.e., no crude argon column, no mixing column and so on.

0026. Alternatively, the cold box of the transportable package does contain at least one argon column, i.e., a crude argon column or a pure argon column, a mixing column, a krypton-xenon column or a pure oxygen column. For example, the cold box could contain the pure argon column as sole separation column; since it is extremely slender and requires less space than the conduits, it would still be called a conduit box (albeit with a pure argon column).

0027. The cold box of the transportable package (the conduit box) of the invention may contain a counter-current subcooler.

0028. A “counter-current subcooler” is a unit which is separate from the main heat exchanger and which serves to subcool or warm one or more liquids from one of the columns of the distillation column system for nitrogen-oxygen separation or else from a mixing column countercurrently to one or more cold gaseous return streams. These return streams come from a column of the distillation column system (generally from the low-pressure column in the case of systems comprising two or more columns). For example, liquid streams depressurized at boiling temperature from a column of higher pressure (from the high-pressure column of a two-column system, for example) into a column of lower pressure (into the low-pressure column, for example) are cooled down in a countercurrent subcooler to very close to the boiling temperature that corresponds to the lower level of pressure. This in effect minimizes the flash produced on expanding from the higher to the lower pressure. When liquid oxygen is led from a low-pressure column through the countercurrent subcooler before being injected into a mixing column, it is conversely warmed in order to become very close to the boiling point under the—generally higher—pressure of the mixing column. In the opposite direction, the cold return streams coming from the columns at the dewpoint temperature are warmed at the lower pressure. Since these streams pass into the main heat exchanger, the process air into the high-pressure column likewise becomes warmer; that is, it is closer to the dewpoint temperature. The proportion of prefiltered air is minimized.

0029. But the cold box of the transportable package (the conduit box) of the present invention, aside from the counter-current subcooler, preferably contains no further heat exchanger for exchanging sensible heat, particularly not the main heat exchanger. But the conduit box may contain one or more heat exchangers for exchanging latent heat, for example a condenser-vaporizer as used for cooling or heating a separation column. Alternatively, the box does not contain any heat exchanger other than the counter-current subcooler.

0030. In one specific embodiment of the invention, the cold box of the transportable package contains a crude argon column which has an overhead condenser which is constructed as a condenser-vaporizer. The cold box could in this case be referred to as a combined conduit and argon box.

0031. The construction of the crude argon column may be in one piece, as shown in EP 377117 B2—U.S. Pat. No. 5,019, 145, or two or more pieces, for example two pieces, as shown in EP 628777 B1—U.S. Pat. No. 5,426,946. When the construction is in two or more pieces, it is preferable for all the pieces to be accommodated in the cold box. The combined conduit and argon box may additionally accommodate a pure argon column.

0032. The present invention also provides a low-temperature air separation plant with a first transportable plant component accommodating a double column, wherein the double column comprises a high-pressure column and a low-pressure column, which are arranged one on top of the other, and a second cold box which is part of a package as claimed in any of claims 1 to 5, wherein the conduits of the second cold box are connected to the double column and to the argon system, if present.

0033. The first transportable plant component in a first version encompasses a first cold box in which the double column is accommodated.

0034. In a second version, the first plant component encompasses the double column without cold box, i.e., without insulating enclosure. In this case, the double column completely prefabricated in the interior is transported to the building site as an essentially cylindrical component part lying on its side and is endowed with the insulating enclosure (cold box) on the building site.

0035. The cold box of the second plant component will hereinafter be referred to as “second cold box”.

0036. The plant preferably further includes a main heat exchanger box, a further cold box where the main heat exchanger is accommodated. The main heat exchanger box is fabricated, and transported to the installation site, separately from the first and second cold boxes.

0037. When argon is to be produced and the second cold box is not constructed as an argon box, the low-temperature air separation plant may further include a third cold box which contains a crude argon column which has an overhead condenser which is constructed as a condenser-vaporizer. The third cold box is also called the argon box and is separate from the first and second cold boxes and from the main heat exchanger box.

0038. The construction of the crude argon column may be in one piece, as shown in EP 377117 B2—U.S. Pat. No. 5,019, 145, or two or more pieces, for example two pieces, as shown in EP 628777 B1—U.S. Pat. No. 5,426,946. When the construction is in two or more pieces, all the pieces are accommodated in the third cold box. The third cold box may additionally accommodate a pure argon column.

0039. The vaporization space of the overhead condenser of the crude argon column is preferably connected to the low-pressure column via a two-phase conduit constructed such that not only gas but also liquid flow back from the vaporization space of the overhead condenser into the low-pressure column during the operation of the low-temperature air separation plant. The conduit in question may pass through the second cold box.
This may be used to save the installed height otherwise required for distributors and collectors in the low-pressure column. To minimize on installed height with packed columns, the gas and liquid from the argon system are injected at the same location. Compared with separate injection at different locations, one distributor is saved, amounting to about one meter in installed height. This version may offer advantages when in-transit length is particularly critical, although it is less favorable in process-engineering terms.

The invention also provides a method for producing a low-temperature air separation plant as defined in claims 9 and/or 10, wherein the transportable package described above is used. The purification unit is constructed as a molecular sieve adsorber for example. Alternatively, the air may also be purified in a reversible heat exchanger (revex or regenerator); in this case, the purification unit and the main heat exchanger are formed by the same apparatus.

The invention is preferably useful for air separation plants designed to recover more than 2000, preferably more than 9000 standard m³/h of oxygen product and less than 35000 standard m³/h, preferably less than 29000 standard m³/h of oxygen product. More particularly, argon may be recovered as further product.

The invention and also further details of the invention will now be more particularly elucidated with reference to two working examples diagrammatically illustrated in the drawing, where

**FIG. 1** shows a first working example of the invention as a purely conduit box, and

**FIG. 2** shows a second working example as a combined conduit and argon box.

What is not shown in the drawing is that atmospheric air is compressed in an air compressor and purified in a purifying means in **FIG. 1**. The purified feed air is cooled down to about dewpoint in a main heat exchanger against product streams. The main heat exchanger in the example consists of three parallel-connected plate-type heat exchanger blocks 2a, 2b, 2b, which are accommodated in a conjoint cold box, the main heat exchanger box 10.

In general, the main heat exchanger may also consist of one block or alternatively of one, two, three or more blocks. These may be connected in parallel or else subdivided according to their functions, for example into a high-pressure exchanger and a low-pressure exchanger.

A connecting conduit 3 feeds the cooled air into a cold box 20, which will hereinafter be referred to as a conduit box. Within said conduit box 20, the air is forwarded in conduits and optionally via valves and finally directed via a line into a double column 5. Alternatively, the air flows directly from the main heat exchanger box 10 into the column box 30; in that case, the conduit box 12 does not contain a line for gaseous feed air.

The double column 5 is accommodated in a further cold box 30, the column box. Final and intermediate products of the double column are directed via a multiplicity of connecting lines 6 (merely indicated in the drawing) into the conduit box 20 and fed from there to further conduits and/or plant components of the kind which are customary in low-temperature air separation plants, such as valves or a countercurrent subcooler, which are accommodated in the conduit box. In this working example, the conduit box contains particularly the following component parts:

- Liquid air line 7
- Countercurrent subcooler 8
- Turboseparator 9, where liquid is separated off upstream of an expansion turbine
- GAN line 11 for gaseous nitrogen from the low-pressure column
- Impure nitrogen line 12 for gaseous impure nitrogen from the low-pressure column

(Said impure nitrogen line 12 and GAN line 11 pass directly from the conduit box 20 into the main heat exchanger box 10 (as is not shown in the drawing).

What is also not directly shown in the drawing are the lines which lead from the argon box to the column box, all or essentially all of which are likewise accommodated in the conduit box. This includes the lines for the fluids that flow in liquid form to the vaporization space of the overhead condensers of the pure, and crude argon columns, and those for the gaseous and possibly liquid return streams from there, and also the argon transfer lines, i.e., the feed line for the crude argon column and the return line from the crude argon column into the low-pressure column.

The conduit box further contains all the lines which are assigned to the column box and which, in conventional plants, would be accommodated in the column box.

A multiplicity of connecting lines 13 and, respectively, 14 (merely indicated in the drawing) direct the return streams of the plant (product streams and/or residue streams) from the conduit box 20 into the main heat exchanger box 10 and, after they have been warmed in the main heat exchanger 2a, 2b, 2c, withdraw them warm out of the main heat exchanger 10.

The working example additionally recovers argon by directing an argon-containing stream from the double column 5 via the conduit box and line 15 into a further cold box 40, which has been constructed as an argon box. Said argon box 40 contains a one-piece crude argon column 41 for argon-oxygen separation with overhead condenser (not depicted) and a pure argon column 42 for argon-nitrogen separation.

The argon product and the residual fractions of the argon recovery process are directed via connecting lines 16 (merely indicated in the drawing) back into the conduit box 20 and then further flow as return streams 15 to the main heat exchanger box.

Alternatively, the argon box may also be omitted.

The conduit box may be prefabricated in full; that is, a prototyping shelter with consoles is built, which does not constrain transportability. All drives for the valves may be left fitted during shipment. This and any instrumentation including transmitters may be fitted, similarly data lines from the transmitter to the input/output card of the digital process control system. The prefabricated conduit box includes a central bus terminal at which the box is connected centrally to the process control system at the installation site. All instrumented air lines and control lines, cables, etc may already be wired up/connected in the factory.

The fully prefabricated conduit box may be pretested while still in the factory. The operating platform may be rescaled for shipment.

The boxes 10, 20, 30, 40 may each have its own structural engineering. Connections between the boxes (such as, for example, insulators surrounding conduits leading from one box to the next) may be made flexible or rigid. In addition to each individual box’s own structural engineering, the steel construction of the boxes may be deliberately connected together in order that the structural engineering may be fur-
ther improved by static coupling, for example by dedicated supports which may also be used as a walkable deck.

**FIG. 2** shows a second embodiment of the invention in a combined conduit and argon box 400. In addition to the component elements of conduit box 20 from FIG. 1, this combined box 400 contains the crude argon column 41, without a pure argon column in the concrete example. Alternatively, a pure argon column could additionally be accommodated in the combined conduit and argon box 400. In other respects, the construction of the plant corresponds to that described in connection with FIG. 1.

11. A transportable package for a low-temperature air separation plant comprising a main heat exchanger (2a, 2b, 2c) for cooling down feed air (1), a double column (5) for separating the cooled feed air and a crude argon column (41) which has an overhead condenser which is constructed as a condenser-vaporizer, wherein the double column (5) comprises a high-pressure column and a low-pressure column, which are arranged one above the other in a first transportable plant component (30) and the crude argon column and the overhead condenser are arranged in a third cold box, wherein the transportable package comprises a cold box (20), the interior of which accommodates accessories to the double column (5), including at least the lines to and from the overhead condenser of the crude argon column, but not the main heat exchanger, wherein the cold box (20) does not contain a separation column and wherein the transportable package comprises terminals for connecting the conduits to the double column, to the crude argon column and to the main heat exchanger.

12. The package as claimed in claim 11, characterized in that the cold box (20) contains a countercurrent subcooler (8).

13. The package as claimed in claim 12, characterized in that the cold box (20) aside from the countercurrent subcooler (8) contains no further heat exchanger for exchanging sensible heat.

14. A low-temperature air separation plant with a first transportable plant component (30) accommodating a double column (5), wherein the double column (5) comprises a high-pressure column and a low-pressure column, which are arranged one on top of the other, a second transportable plant component (20) which is constructed as a package as claimed in claim 11, and a third cold box (40) which contains a crude argon column (41) which has an overhead condenser which is constructed as a condenser-vaporizer, wherein the conduits (7, 11, 12) of the second plant component (20) are connected to the double column (5).

15. The low-temperature air separation plant as claimed in claim 14, wherein the vaporization space of the overhead condenser is connected to the low-pressure column via a two-phase conduit constructed such that not only gas but also liquid flow back from the vaporization space of the overhead condenser into the low-pressure column during the operation of the low-temperature air separation plant.

16. A method for producing a low-temperature air separation plant as claimed in claim 14, which comprises the steps of producing the first transportable plant component (30) as a transportable package and transporting it to the installation site, producing the second transportable plant component (20) as a transportable package as claimed in claim 14 and transporting it to the installation site, connecting the conduits of the second transportable plant component (20) at the installation site to the double column (5) of the first transportable plant component (30), and connecting the double column (5) at the installation site to an air compressor for compressing feed air, to a purification unit for compressed feed air and to a main heat exchanger (2a, 2ab, 2c) for cooling purified feed air (1), and further comprises the steps of producing a third cold box (40) as transportable package and transporting it to the installation site, wherein the third cold box (40) contains conduit terminals and a crude argon column (41) which has an overhead condenser which is structured as a condenser-vaporizer, and connecting at least some of the conduit terminals of the third cold box (40) at the installation site to conduits of the second cold box (20).

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