HELCALLY DISTRIBUTED HEAT EXCHANGE FRACTIONATING COLUMN

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Filed Sept. 28, 1967, Ser. No. 671,378
Int. Cl. F25j 3/02; B91d 3/24

U.S. Cl. 62—42

12 Claims

ABSTRACT OF THE DISCLOSURE

A plate type fractionating column for cryogenic service having a helical tube bundle and a helical arrangement of plates interwound therewith to provide distributed heat exchange throughout a substantial portion of the column.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to a fractionating column for cryogenic service having a distributed heat exchange means extending throughout a substantial portion of the column.

Description of the prior art

Fractionating columns for low temperature rectification or gas-separation often include internal boilers and condensers. Such columns may consist of a single duty column, or may comprise both exhausting and enriching sections in a compound fractionating column, or may comprise a double fractionating column. The term compound fractionating column, as used herein, shall be understood to mean a fractionating column having both an exhausting or stripping section, and an enriching or rectification section. As used herein, a double column is one in which the condenser for one column serves as a boiler for the other. Such columns are well known in the art and are illustrated, for example, in FIGURES 12—34 and 12—35, respectively of Perry's Chemical Engineers' Handbook, Fourth edition, McGraw-Hill Book Co., Inc., New York, 1963.

In a compound column, when applied to air-separation, for example, cooling in the condenser may be accomplished by evaporating a liquid refrigerant while heating in the boiler may be accomplished by condensing a vapor. The use of latent heat, rather than sensible heat, of heat exchange media permits an approach to reversible heat transfer which is limited only by the temperature drop due to the heat exchanger wall and the boundary films. In a conventional compound tower, all of the cooling required in the top part of the column takes place in a condenser at the top of the column which is at the lowest temperature existing in the column, while all the heating required in the bottom part of the column takes place in a boiler at the bottom of the column which is at the highest temperature existing in the column. These facts contribute substantially to the thermodynamic losses of the compound tower and prevent even an idealized compound tower from being reversible in a thermodynamic sense.

Although the fractionating column of this invention will be described in terms of an air rectification column, it will be understood that it is equally applicable to use with other fluids which may be separated in a fractionating column.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a plate type fractionating column particularly suitable for cryogenic service and capable of providing inherently higher efficiencies than are presently obtainable in conventional compound columns. This object is accomplished by a novel application of the principle of distributed heat exchange in one or more of the column sections to more nearly meet the requirements of an idealized fractionating column with thermodynamic reversibility.

Another object of the present invention is to provide a plate type fractionating column for cryogenic service wherein column service heat exchange takes place principally through a helical tube bundle.

This invention provides a distributed heat exchange column comprising bubble plates, weirs, and suitable supports, and having a helical tube bundle with extended heat transfer surface interwound with the bubble plates over relatively large sections of the column.

BRIEF DESCRIPTION OF THE DRAWING

The invention will be further understood by reference to the accompanying drawing in which:

FIGURE 1 is an elevation of a preferred embodiment of a fractionating column illustrating a column constructed in accordance with the present invention;

FIGURE 2 is an irregular vertical cross-sectional view of the fractionating column of FIGURE 1; and

FIGURE 3 is a fragmentary view in larger scale of the incircled portion of FIGURE 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIGURES 1 and 2, column 51 is shown supported upon its foundation by legs 52 joined to the base assembly 53 which is a simple cup-like structure. The base assembly is joined to a cylindrical body shell 54, preferably by means of a suitable flange joint 55. A cover or top assembly 56 is likewise joined to the cylindrical body by flange joint 57. Lifting eyes 58 are provided on cover 56 and cylindrical body shell 54, for erection and disassembly. In the illustrated embodiment, a feed inlet connection 59 is located on the cylindrical body 54, a heavier product tap 60 extends from base assembly 53, and a lighter product tap 61 extends through cover 56.

As illustrated in FIGURE 2, located along the axis of column 51 is a spine 63. In the illustrated embodiment, spine 63 is in two sections comprising an upper section 68 and a lower section 69 constructed from hollow conduits and joined end to end by flanges 72 which may be bolted or welded together. The illustration of FIGURE 2 is shown for pictorial clarity in four differing portions viz. A, B, C and D wherein different parts of the assembly are shown and others left out. However, it should be noted that although portions A, B and C depict different components, every component shown belongs in every portion. This will be further clarified in the description following. Four distributors 73, 74, 75 and 76 are provided at the ends.
of the upper and lower spine sections. The distributors 73, 74, 75 and 76 are boxed in at their interior ends by non-permeable diaphragms 77, 78, 79 and 80 respectively which are secured to the inner periphery of the spine section by welding or other suitable means. The exterior distributor 74 and distributor 77, 78, 79 and 80 contain the refrigerating medium. The parallel flow of exchange fluid, adjacent flanges 72 in the upper and lower sections are boxed in respectively by the upper face and the lower face of a non-permeable separator plate 81 which is sandwiched between upper spine section 68 and lower spine section 69 at joint 72. The exterior ends of the distributors 76 on the upper and lower sections 68 and 69 respectively opposite flange 72 are boxed in by end plates 82 and 83 respectively. At the lower end of the column, a lower fluid entrance connection 84 communicates with its associated distributor 76 at the lower end of spine section 69 through an opening provided in end plate 83 where it is joined thereto. Connection 84 extends through base assembly 53 and through a slip-over bellows sleeve 85 in such manner that the sleeve 85 is fastened over flange 88 secured to the end of the entrance connection 84 to provide a tight seal while maintaining flexibility and allowing for expansion.

At the upper end of the column, a upper fluid entrance connection 89 similarly communicates with its associated distributor 73 through an opening provided in end plate 82 where it is joined thereto. The upper entrance connection 89 extends through the cover 86 and through a slip-over bellows sleeve 90 in such manner that the sleeve 90 is fastened over a connection flange 92 secured to the end of the upper helium entrance connection.

A fluid return connection 93 extends from the upper distributor portion of the lower spine section 69 through the cylinder's center section wall of column 51. Likewise a fluid return connection 95 extends from the lower distributor portion of upper spine section 68 through the outer wall of column 51. A lower helical tube bundle 98 is positioned in the lower portion of the column 51. A similar upper helical tube bundle 99 is positioned in the upper part of the column 51. The bottom or inlet ends of the tubes in the lower tube bundle 98 are secured to and communicate with the distributor 76 in the lower spine section 69 adjacent end plate 83. The lower helical tube bundle 98 winds about the lower spine section 69 and is preferably supported thereto. The exit ends of the tubes in the lower helical tube bundle 98 terminate at the distributor 75 in the upper end of lower spine section 69. Similarly, the upper helical tube bundle 99 is wound about and preferably supported from the upper spine section 68. Inlet ends of the individual tubes of the upper helical tube bundle 99 in communication with distributor 73 at the upper end of the column and the exit ends of the tube communicating with the distributor 74 at the lower end of spine section 68.

In operation, a heat exchange medium, e.g., helium, introduced through entrance connection 84 passes via distributor 76 in the lower spine section 69 through tubes in the lower heat exchanger tube bundle 98 and is discharged therefrom into return connection 93 via distributor 75 at the top of the lower spine section. Likewise, refrigerating medium, e.g., water, entering the distributor 73 at the top of the upper spine section 68 from entrance connection 89 passes down through the tubes of the helical tube bundle 99 to discharge into distributor 74 at the lower part of the upper spine section 68 and is discharged through return connection 95. The tubes in each row of the tube bundles enter spine section 69 at a vertical angle from essentially a radial direction, with each succeeding row being preferably angularly displaced about 18° and vertically displaced to match the helix angle. In the particular embodiment illustrated there are 20 rows of vertically spaced tubes, and 4 tubes in each row. The upper section of the column contains a single upper helical sieve plate 100 which is mounted on the upper spine section 68 and interwoven between successive terms of the upper tube bundle 99. The lower section of the column contains a similar helical sieve plate 101 mounted on the lower spine 69 and interwoven between successive terms of the lower tube bundle 98.

Although not shown throughout their length in FIGURE 2, the helical sieve plates 93, 94, 95 and 96 as well as the respective helical sieve plates 101 and 100 extend between distributors 73 and 74 and distributors 75 and 76 as shown for example in section A of FIGURE 2. Other components which would only interfere with the pictorial clarity of section A have been left out of section A but shown in section B, C or D. The helical sieve plates 100 and 101 can be preferably manufactured by cutting sectors from flat sieve material having inner and outer diameters approximately ¾ inch larger than the intended helix inner and outer diameters of the sieve plate. The sectors are warped to form the intended helix pitch, which approximates that of the tube bundle with which it is associated, seam welded to the spine 63, and joined to each other along mating radial lines. In a preferred embodiment in a 30 feet high column, 5 feet in internal diameter, the spine would have a 9 inch outer diameter.

Radial weirs 105 are attached by welding or other means to the spine 63 and the sieve plates 100 and 101. A spacing of 30° between radial weirs is preferred. The radial weirs are attached over the entire length of both upper and lower helical sieve plates but for clarity are shown only in section C, with the sieve plate 100. Baffle plates or web supports 106 (see sections B and D of FIGURE 2 and also FIGURE 3) are mounted vertically and radially at regular intervals, preferably 90°, on top both helical plates 100 and 101, for example replacing each third radial weir 105. The web supports 106 are preferably seam welded to the spine 63 and tack welded to the plates. An exemplary manufacturing method for the web supports 106 is shown in FIGURE 3 wherein vertical strips having a width slightly smaller than the center to center distance of two adjoining tubes being supported in the tube bundle and having along the strip length, semi-circular cut-out portions corresponding to the vertical tube spacing of the tube bundle for mating thereto are welded together along their length when fitted over the adjacent row of tubes. Each support contains openings 108 for liquid flow. The web support 106 whether or not constructed by the above suggested method using vertical strips forms an integral support plate with tube openings therein. The upper and lower helical tube bundles 99 and 88 respectively have a base course of tubes wound in the form of a helix which pierce the assembled web support 106.

The web support 106 performs three functions, structural support to the assembly, including stiffening of the spine 63 or other support means, tube spacing, and gas channelling. By the latter is meant, the web support 106 and elements force the upward flowing vapor to travel parallel to the axis of column 51 and successively through sieve plates 101 and 100 and plate liquid as required for rectification. This prevents the presence of a helical path of low resistance for the vapor in the column, thereby greatly increasing gas-liquid contact. The helical path of the downflowing liquid however is advantageous since there is always a liquid compositional variation existing between successive sieve plate piercing by the upflowing vapor.

In operation for air rectification, a refrigerant, for example helium, enters the top of the upper tube bundle 99 sufficiently colder than the nitrogen leaving the column allowing heat to be absorbed from the column contents, thereby condensing nitrogen on the outside tube surface of the upper tube bundle 99. Condensation of gas from the column contents on the outside surfaces of the tubes continues along the height of the upper tube bundle 99. At the same time, liquid on the upper plate 100 of the column 51 is also cooled by the refrigerant by heat transfer through the walls of the tubes through the web-sup-
ports 106 which are joined to the plate 100. This, in turn, also effects condensation of gas bubbling through liquid on the plate 100 adding to the efficiency of the desired heat exchange. The temperature of the condensate increases as it moves downward along the plate 100 in the column with the composition of the condensate becoming increasingly richer in oxygen content. Helium inside the tubes meanwhile is warmed by its acceptance of the heat released by condensation of air components outside the tubes.

The heat exchange medium, e.g. helium entering the lower entrance connection 84 at the bottom of the column, is at a temperature such that the bottom product, e.g. oxygen, cools the heat exchange medium which thus furnishes heat to the column contents and vaporizes some of the liquid at the bottom of the column. As the helium flows upward through the lower helical tube bundle 98, it continues to give heat to the column contents, causing additional vaporization of liquid of ever poorer oxygen content. The creation of an upwardly flowing vapor stream in the lower part of the column is, in effect, a staged stripping operation, necessary for the production of high purity oxygen product. As in the case of the upper helical tube bundle 99, condensation of heat from the metal sieve plate 101 through the web supports 106 to the tubes of the lower bundle 98 facilitates rapid and efficient heat transfer.

The air to be rectified, previously chilled to approximately saturation temperature, enters the column through feed inlet connection 59, joins upwardly flowing vapor from the bottom section of the column and passes upwardly through openings in the sieve plate 100 above the feed inlet. As the vapor passes up through the sieve plate 100, it comes into intimate contact with the liquid on the plate and is thereby cooled and rectified. In its passage between successive portions of the helical sieve plate 100, it is also further cooled by contact with tubes comprising the upper tube bundle 99. These actions result in partial condensation and staged rectification until the lighter product or vapor rising from the top tray is practically pure oxygen.

The liquid so generated collects along the helical plate 100, overflowing the radial weirs 105 to flow downward. In this example, liquid oxygen is removed through heavier product tap 60 in the base and gaseous nitrogen is removed through lighter product tap 61 in the cover 56 as products of the separation.

The following is a specific example of a column in accordance with the present invention in which the column effects separation of air to produce 150 tons per day of liquid oxygen of 98 percent purity at −294° F. and 565 tons per day of gaseous nitrogen of 97 percent purity at −315° F., in which helium is the heat transfer fluid in both the upper and lower tube bundles. In this example, 715 tons per day of air at −308° F. and 1 percent wet is fed to the column operated at 20.7 p.s.i.g. The upper tube bundle is supplied with 858 tons per day of gaseous helium at −357° F. and 182.5 p.s.i.g.; while the lower tube is supplied a like amount at 527.5 p.s.i.g. and −281° F.

The upper and lower tube bundles are made up of 80 tubes each having a mean interior diameter of 1¾” internal diameter. The diameter of the tubes is grades such that smaller tubes are used for the smaller diameter helices. These smaller diameter tubes act to compensate for the shorter path in the inside or tighter helices of tubes and the resultant distribution of flow between tubes. The overall column dimensions are approximately 5 feet in diameter by 30 feet in height.

The advantages of distributed heat exchange in fractionating columns are not limited to the separation of air into two component streams. Distributed heat exchange can be applied to other separation, including those having several feeds and several take-offs. Obviously, the advantages accrue in columns of large, moderate, or small size. The invention, therefore, is not restricted to the particular separation in the above examples, namely, separation of air into liquid oxygen and gaseous nitrogen, nor to the specific choice of helium as the heat exchange medium. The specific examples, however, illustrate a practical construction of a distributed heat exchange column which can be applied to various separation problems by those skilled in the art.

Further, the present invention includes a fractionating column not using distributed heat transfer (i.e., the helical tube bundle) but rather incorporating the helical plate, weirs attached thereto and web supports as well as the support means such as the central spine.

I claim:
1. A plate type fractionating column for cryogenic serv
2. A plate type fractionating column according to claim 1, wherein said helical sieve plate has weirs attached thereto over its length.
3. A plate type fractionating column for cryogenic service according to claim 1 wherein there are a plurality of helical tube bundles, and a plurality of associated feed inlet means, heat exchange medium intake means, heat exchange medium exhaust means, helical sieve plates and product withdrawal means.
4. A plate type fractionating column for cryogenic service according to claim 1, wherein said helical tube bundle and helical sieve plate are supported from a single axially disposed cylindrical spine member.
5. A plate type fractionating column for cryogenic service according to claim 4 wherein said single axially disposed cylindrical spine member has integral therewith separate distributors along portions of its length which form in part said upper and lower intake means and said upper and lower exhaust means.
6. A plate type fractionating column according to claim 2, wherein baffle plates are mounted vertically and radially between successive spirals of said helical sieve plate and are provided with openings therein adjacent the upper side of said sieve plate for liquid flow.
7. A plate type fractionating column according to claim 4 wherein said sieve plate comprises sectors of flat sieve material warped to form the intended helix pitch and welded to said support and to each other along mating radial lines.
8. A plate type fractionating column according to claim 4 wherein radial weirs are joined to said support and to said helical sieve plates along substantially the entire length of said helical plate.
9. A plate type fractionating column according to claim 8, wherein said radial weirs are spaced 30° apart.
10. A plate type fractioning column according to claim 8, wherein vertical baffle plates are mounted on said helical sieve plate and attached to said support and extend radially from said support.
11. A plate type fractionating column according to claim 10, wherein said vertical baffle plates are spaced 90° apart.
12. A plate type fractionating column according to claim 10, wherein said baffle plates have channels formed therein adjacent the upper surface of said sieve plate.

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