June 19, 1934. M. FRÄNKL 1,963,841

COCURRENT EVAPORATOR WITH COUNTER CURRENT CONDENSATION FOR FRACTIONAL LIQUEFACTION

Filed Oct. 14, 1931

Fig. 1.

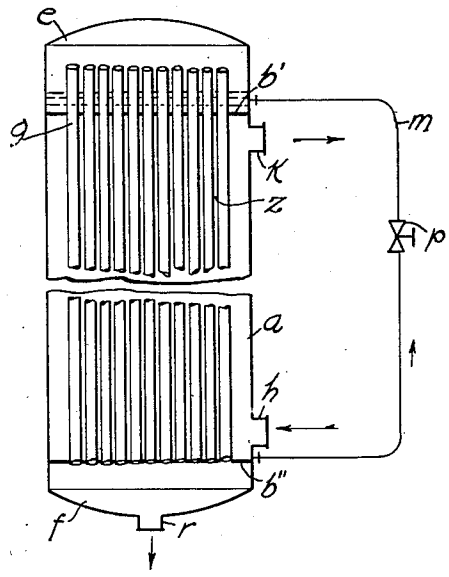


Fig. 2.

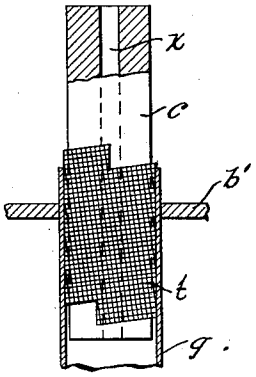


Fig. 3.

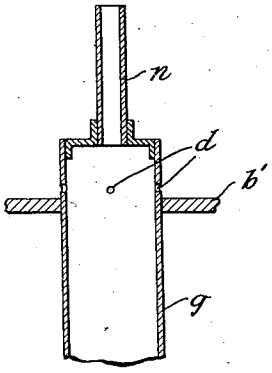


Fig. 6.

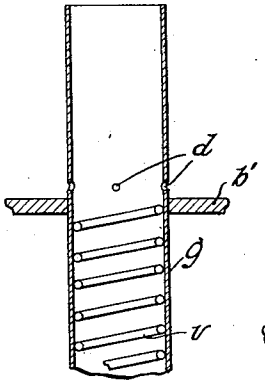


Fig. 5.

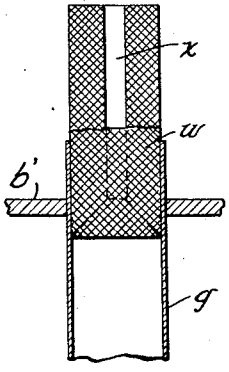
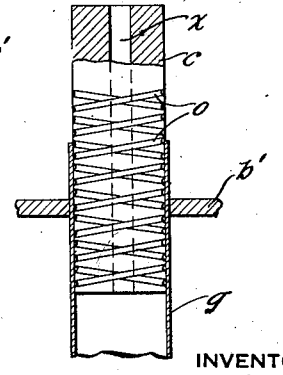


Fig. 4.



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COCURRENT EVAPORATOR WITH COUNTER-CURRENT CONDENSATION FOR FRACTIONAL LIQUEFACTION

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Application October 14, 1931, Serial No. 568,716
In Germany July 24, 1931

10 Claims. (Cl. 62—122)

The invention relates to an apparatus for the condensation of gaseous mixtures and the evaporation of a difficultly boiling component in a process for the resolution of gas mixtures, and more particularly for the resolution of air for the obtainment of nitrogen and oxygen therefrom.

If it is desired to separate the nitrogen only partially from air by fractional condensation by the Claude method, so that a mixture rich in oxygen—having an oxygen content of about 50 per cent—is recovered, then the vaporizer side of a condenser is filled with the produced liquid of 50 per cent oxygen content, and on the condenser side the air is passed up from below through the vertical pipes of an upright condenser. On its way through the pipes the oxygen is completely condensed out of the air and the nitrogen passes out at the top in gaseous form. The liquid produced on the pipe walls consists, in the upper part, of almost pure nitrogen, but in the lower part, of about half oxygen and half nitrogen.

The upper liquid, richer in nitrogen content, during its outflow, likewise becomes enriched with oxygen which it takes up from the air passed through the pipes, an equivalent amount of nitrogen vaporizing out of the liquid. That is, a fractionated condensation and a rectification occur simultaneously. The liquid crude oxygen produced, containing about 50 per cent O_2, is now led to the vaporizer side of the condenser and is there vaporized continuously in order to yield 50 per cent oxygen in a gaseous state. If, however, it is desired to recover a gas with a 50 per cent oxygen content, then the liquid must first be concentrated in the vaporizer to a 75 per cent O_2 content, because a liquid of approximately 75 per cent oxygen content is in equilibrium with 50 per cent oxygen gas. This enrichment proceeds in that, at first, only oxygen of 21 per cent strength vaporizes, then one of 25 per cent and so on, until the liquid has been concentrated to 75 per cent O_2.

On the vaporizer side of the condenser there is finally a liquid of 75 per cent strength to be vaporized and on the condenser side almost pure nitrogen is finally condensed. The liquid having a 75 per cent O_2 content possesses, at atmospheric pressure, a vaporizing temperature of −187.5° C., while the nitrogen liquefies only at −195.5° C., thus producing an 8° C. difference in temperature. In order to equalize this difference of 8° C., the air to be resolved must be compressed to 3 atm. absolute, in order to be able to liquefy it to its last trace of oxygen by means of a liquid with an oxygen content of 75 per cent.

In my co-pending application Serial No. 568,715 filed October 14, 1931 there is described a method for the resolution of gas mixtures in accordance with which a gas mixture is liquefied with accompanying fractionation and rectification, having counter-current flow of gas and condensed liquid, whereby a liquid enriched in the higher boiling point component is produced and vaporizing such liquid on the vaporizer side of a vaporizer-condenser with attending fractionation and rectification, but in contradistinction with prior practice, with co-current flow of gas and liquid. This application also describes an apparatus which includes a condenser-vaporizer suitable for carrying out the process and which is constructed of corrugated metal plates arranged in pairs and united by headers. This condenser-vaporizer effects a counter-current condensation with fractional rectification on the condenser side in combination with a direct or co-current rectification on the vaporizer side.

It is an object of this invention to provide an apparatus for use in the resolution of gas mixtures, of the general type described in the aforementioned co-pending application but in which the process may be more effectively and advantageously carried out with a decrease in the compression energy required.

It is a further object of the invention to provide a condenser-vaporizer having tubular members in which the condensation or liquefaction takes place on the outside of the tubular members and vaporization takes place on the inner side of said tubular members.

Further, it is an object of the invention to provide a condenser-vaporizer in which there shall be obtained a uniform distribution of liquid to all of the tubular members and in which the surface contact between the vapor and liquid will be increased.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements and arrangement of parts which will be exemplified in the construction hereinafter set forth and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawing, in which:

Fig. 1 illustrates a condenser-vaporizer assembly according to the invention; and

Figs. 2, 3, 4, 5, and 6 illustrate various modifications which may be applied to secure a distribution of the liquid over the inner surfaces of the tubular members.

According to the present invention the condenser-vaporizer is constructed in the form of a tubular vaporizer comprising a bundle of tubes *g* surrounded by a casing *a*. The tubes are positioned between an upper header *b'* and a lower header *b''*. Condensers of tubular form for low-boiling gas mixtures have been known for a long time, but with them the evaporation of the liquid always takes place on the outside, around the pipes, while the condensation of the gas mixture takes place in the pipes. The condenser-vaporizer of the invention operates in the reverse manner, namely, the liquefaction and fractionation take place on the outside of the tubes or pipes *g*, and vaporization is effected within the tubes. A further distinction is present in that the flow of liquid and vapors during vaporization is co-current.

The condenser-vaporizer of the invention comprises an outer or enveloping casing *a* which is provided at its lower part with a header *b''* and near its top with a header *b'*. Positioned between the headers and extending to a short distance above the upper header *b'* is a number of tubes *g*. There is thus provided a condensing space between the headers and about the tubes, and a vaporizing space within the tubes and at the ends of the casing. The vaporizing space therefore includes the top section *e* and the bottom section *f* of the casing. The condensation space between the headers is provided with a gas inlet *h* and an outlet *k*. A connection or conduit *m* leads from the top of the lower header to the top of the upper header for conducting liquid from the condenser to the vaporizer side of the apparatus, and is provided with an expansion valve *p*. The lower section *f* of the casing is provided with an outlet *r* for the vaporized product. In order to facilitate distribution of liquid over the inner surfaces of the tubes *g*, various means may be applied as shown in Figs. 2 to 6, and more definitely and specifically referred to hereinafter.

In operation the gaseous body, for example air, is introduced in cooled and compressed condition into the condenser chamber through the inlet *h*. On its way through the interspaces *z* the air will condense only to the extent of about half and thereby vaporize liquid flowing down the inner side of the tubes within the vaporizing chamber or zone. Accordingly, only gas is present at the bottom of the vaporizing tubes. This gas is led off through the outlet *r* and the cold content thereof may be used to forecool the air to substantially the point of liquefaction. On the outside of the tubes, or within the condensation zone, condensation proceeds in such a manner that in the first part of its course through the interspaces *z* a mixture having an oxygen content of about 50% is first condensed. As the air continues upwardly on its way, mixtures having 40, 30, 20 and 10% will condense until finally at the top all of the oxygen has been condensed out of the air and the gaseous or non-liquefied part consists wholly of nitrogen. The condensed liquid having an oxygen content of about 50% flows down along the walls of the tubes *g*, thereby constantly and intimately contacting with the ascending air, so that in addition to the fractional condensation a rectification simultaneously takes place whereby the entire condensed liquid is enriched on its way down to an oxygen content of about 50%. The oxygen containing liquid is formed on the condenser side of the tubes at a pressure of about 2 atm. absolute, and collects upon the top of the lower header *b''*. This liquid is then conducted through the conduit *m* to the top of the upper header *b'* into the vaporizer section or zone. The liquid during its conveyance from the condenser to the vaporizer zone passes through an expansion valve *p* whereby it is reduced to about atmospheric pressure.

On the vaporizer side the oxygen containing liquid flows into the tubes *g*, spreads out over the inner surface thereof, and is fully vaporized during its passage downward. The vaporized product is drawn off through the outlet *r*. If the vapor produced were drawn off from above as is the usual practice, the liquid flowing down would have to become enriched to almost 100% oxygen content. The vapor is therefore led down cocurrently with the vaporizing liquid, the liquid being thereby continuously cooled by the gas, and gives up oxygen to the latter. In this manner it is possible to carry out complete vaporization continuously so that even the last part of the vaporizing liquid cannot contain more than 75 to 80% oxygen. Hence, at the bottom on the condenser side, a liquid having an oxygen content of about 50% condenses out, while at the same point on the evaporator side a liquid mixture having an oxygen content of from 75 to 85% undergoes vaporization. At the top on the condenser side, however, a mixture separates with only 2 to 3% oxygen, whereas on the vaporizer side a liquid is undergoing vaporization having an oxygen content of about 50%.

The nitrogen separated on the condenser side passes out of the outlet-conduit *k*, and its content of cold may be used for cooling ingoing air. The vaporized oxygen is withdrawn from the vaporizer at a negative pressure of 0.6 to 0.3 atmospheres absolute, preferably 0.5 atmospheres absolute, in order to occasion the difference in pressure required for condensation of the air. Instead of withdrawing the crude oxygen at 0.5 atmospheres absolute, the air to be resolved might be compressed to 2 atmospheres absolute. However, since this amount is about twice as large as the amount of crude oxygen produced, this would involve a greater expenditure of energy inasmuch as the separated nitrogen would then pass out of the apparatus at about 2 atmospheres absolute. Higher pressure operation, therefore, may be effectively utilized only when the compression energy contained in the nitrogen is used by a detensioning thereof in an expansion engine or turbine whereby cold losses are covered.

In this form of the invention the liquid to be vaporized should be uniformly distributed to all the pipes *g* of the bundle. This is attained by a damming up or increase in the height of the liquid above the pipe-head *b'*, and may be effected by closing the pipes *g* at the top with stoppers *c* which are spirally wound with a metal fabric *t*, as shown in Fig. 2, or, as shown in Fig. 3, by lateral drillings *d* of one or more very small holes in the pipes *g*, closed above by a tubular member *n*, or as shown in Fig. 4, but cutting a simple, fine thread, or a cross thread *o* on the stoppers *c*, or by closing the pipes above with

stoppers *w* made of a porous stoneware material as in Fig. 5, the permeability of which is so slight, or whose resistance is so great that the outflow through the pipes can take place to a desired degree only after the establishment of a sufficient damming up of the liquid on the pipe head *b'*.

The surface contact of the liquid with the vapor therefrom should be at least as great as the metallic vaporizing surface, and it is desirable to occasion an increase of the surface contact beyond this amount. Further, a too rapid flow of the liquid down the vertical vaporizing surface must be prevented, and a turbulent flow of the vapor must be assured as well as a complete wetting of the vaporizer surface. For this purpose, wire coils *v* are inserted in pipes *g* as shown in Fig. 6.

On detensioning the liquid from the condenser pressure to the vaporizer pressure, a part (up to 10 per cent) of the liquid vaporizes, and this vapor is led internally through pipes *g*. To accomplish this, the pipes *g* are open above (Figs. 1 and 6) or the inserted stoppers which extend beyond the necessary damming up heights of the liquid are provided with an opening or channel *x* (Figs. 2, 4 and 5) passing therethrough, or a narrow tube *n* (Fig. 3), open at both ends, is set on each pipe or each stopper respectively.

Since certain changes may be made in the above construction and different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. An apparatus for condensation of a gaseous mixture and for vaporization of a difficultly boiling component in a process for the resolution of gas mixtures which comprises in combination an outer casing provided with an inlet connection for introducting a cooled gaseous mixture to be resolved and an outlet connection for withdrawal of a separated component, headers positioned near the bottom and near the top of said casing, a plurality of tubes extending between said headers and a conduit leading from the top of the lower header to the top of the upper header, whereby liquid condensed on the outer surfaces of the tubes and collected upon the lower header is conveyed to the upper header from which it passes to, flows down, and is vaporized upon the inner surfaces of said tubes.

2. An apparatus for condensation of a gaseous mixture and for vaporization of a difficultly boiling component in a process for the resolution of gas mixtures which comprises in combination an outer casing having an inlet connection for introducing a cooled and compressed gas mixture to be resolved and an outlet connection for withdrawal of a separated component, headers positioned near the bottom and near the top of said casing and a plurality of tubes positioned therein between said headers, a conduit leading from the top of the lower header to the top of the upper header whereby liquid condensed on the outer surfaces of the tubes and collected upon the lower header is conveyed to the top of the upper header, and each of said tubes being provided with means for effecting a distribution of the liquid to be vaporized over the inner surface of said tubes.

3. An apparatus for condensation of a gaseous mixture and for vaporization of a difficultly boiling component in a process for the resolution of gas mixtures which comprises in combination an outer casing having an inlet connection for introducing a cooled and compressed gas mixture to be resolved and an outlet connection for withdrawal of a separated component, headers positioned near the bottom and near the top of said casing and a plurality of tubes positioned therein between said headers, a conduit leading from the top of the lower header to the top of the upper header whereby liquid condensed on the outer surfaces of the tubes and collected upon the lower header is conveyed to the top of the upper header, and each of said tubes being provided with means for effecting a distribution of the liquid to be vaporized over the inner surface of said tubes and with means positioned upon the interior surface for increasing the surface of contact between liquid and vapor.

4. An apparatus for condensation of a gaseous mixture and for vaporization of a difficultly boiling component in a process for resolution of gas mixtures which comprises in combination an outer casing having an inlet connection for introducing a cooled and compressed gas mixture to be resolved and an outlet connection for withdrawal of a separated component, headers positioned near the bottom and near the top of said casing, a plurality of tubes positioned in said casing between said headers, a conduit leading from the top of the lower header to the top of the upper header whereby liquid condensed on the outer surfaces of the tubes and collected upon the lower header is conveyed to the top of the upper header and means for effecting a damming up of a liquid to be vaporized to such a height that uniform distribution of liquid upon the inner walls of the tube is effected.

5. An apparatus for condensation of a gaseous mixture and for vaporization of a difficultly boiling component in a process for the resolution of gas mixtures which comprises an outer casing provided with an inlet connection for introducing a cooled and compressed gas mixture to be resolved and an outlet connection for withdrawal of a separated component, headers positioned near the bottom and near the top of said casing, a plurality of tubes within said casing and positioned between said headers, a conduit leading from the top of the lower header to the top of the upper header, a stopper positioned in each of said tubes, and a metal fabric between said stopper and the tube in which it is positioned.

6. An apparatus for condensation of a gaseous mixture and for vaporization of a difficultly boiling component in a process for the resolution of gas mixtures which comprises an outer casing provided with an inlet connection for introducing a cooled and compressed gas mixture to be resolved and an outlet connection for withdrawal of a separated component, headers positioned near the bottom and near the top of said casing, a plurality of tubes within said casing and positioned between said headers, a conduit leading from the top of the lower header to the top of the upper header, a stopper having an opening therethrough positioned in each of said tubes,

and a metal fabric between said stopper and the tube in which it is positioned.

7. An apparatus for condensation of a gaseous mixture and for vaporization of a difficultly boiling component in a process for the resolution of gas mixtures which comprises an outer casing provided with an inlet connection for introducing a cooled and compressed gas mixture to be resolved, and an outlet connection for withdrawal of a separated component, headers positioned near the bottom and near the top of said casing, a plurality of tubes within said casing and positioned between said headers, a conduit leading from the top of the lower header to the top of the upper header, a stopper having an opening therethrough positioned in each of said tubes, and a spirally wound metal fabric between said stopper and the tube in which is is positioned.

8. An apparatus for condensation of a gaseous mixture and for vaporization of a difficultly boiling component in a process for the resolution of gas mixtures which comprises an outer casing provided with an inlet connection for introducing a cooled and compressed gas mixture to be resolved and an outlet connection for withdrawal of a separated component, headers positioned near the bottom and near the top of said casing, a plurality of tubes within said casing and positioned between said headers, a conduit leading from the top of the lower header to the top of the upper header, each of said tubes being provided upon its inner surface with means for increasing the surface of contact between a liquid and a vapor, and for preventing a too rapid outflow of liquid.

9. An apparatus for condensation of a gaseous mixture and for vaporization of a difficultly boiling component in a process for the resolution of gas mixtures which comprises an outer casing provided with an inlet connection for introducing a cooled and compressed gas mixture to be resolved and an outlet connection for withdrawal of a separated component, headers positioned near the bottom and near the top of said casing, a plurality of tubes within said casing and positioned between said headers, a conduit leading from the top of the lower header to the top of the upper header, each of said tubes being provided with a wire coil upon its inner surface for increasing the surface of contact and preventing too rapid outflow of liquid.

10. An apparatus for condensation of a gaseous mixture and for vaporization of a difficultly boiling component in a process for the resolution of gas mixtures, which comprises in combination an outer casing provided with an inlet connection for introducing a cooled gaseous mixture to be resolved and an outlet connection for withdrawal of a separated component, headers positioned near the bottom and near the top of said casing, means consisting of a plurality of vaporizing chambers extending between said headers and a conduit leading from the lower part of said outer casing to the upper header whereby liquid condensed on the outer surfaces of the vaporizing chambers and collected in the lower part of the outer casing is conveyed to the upper header from which it passes to, flows down, and is vaporized upon the surfaces of said vaporizing chambers.

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