July 7, 1970 R. BECKER 3,518,839

LOW TEMPERATURE FRACTIONATION OF GASEOUS MIXTURES WITH PRELIMINARY AND SPLIT STREAM HEAT EXCHANGE

Filed March 31, 1967 2 Sheets-Sheet 1

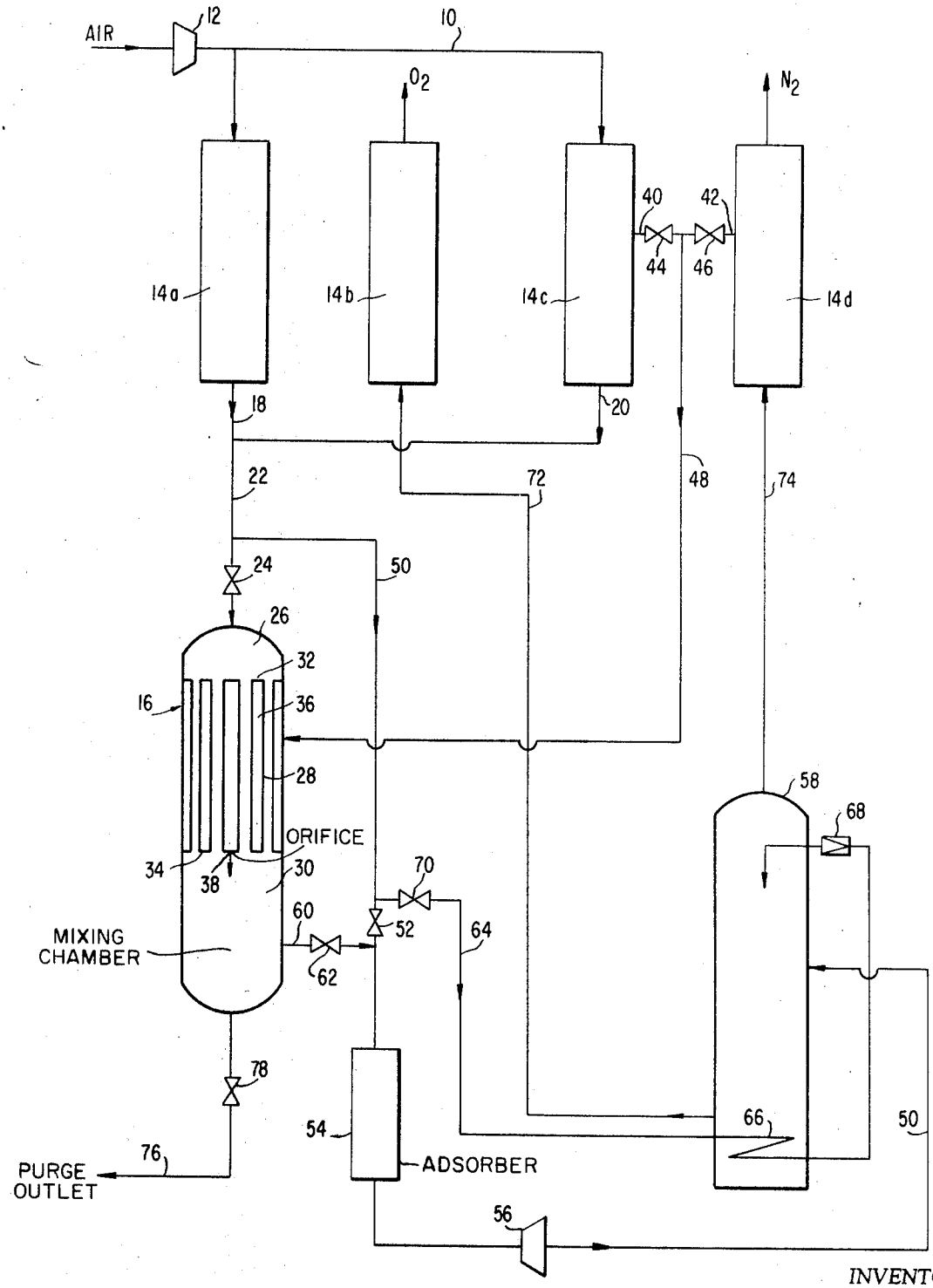


FIG. 1

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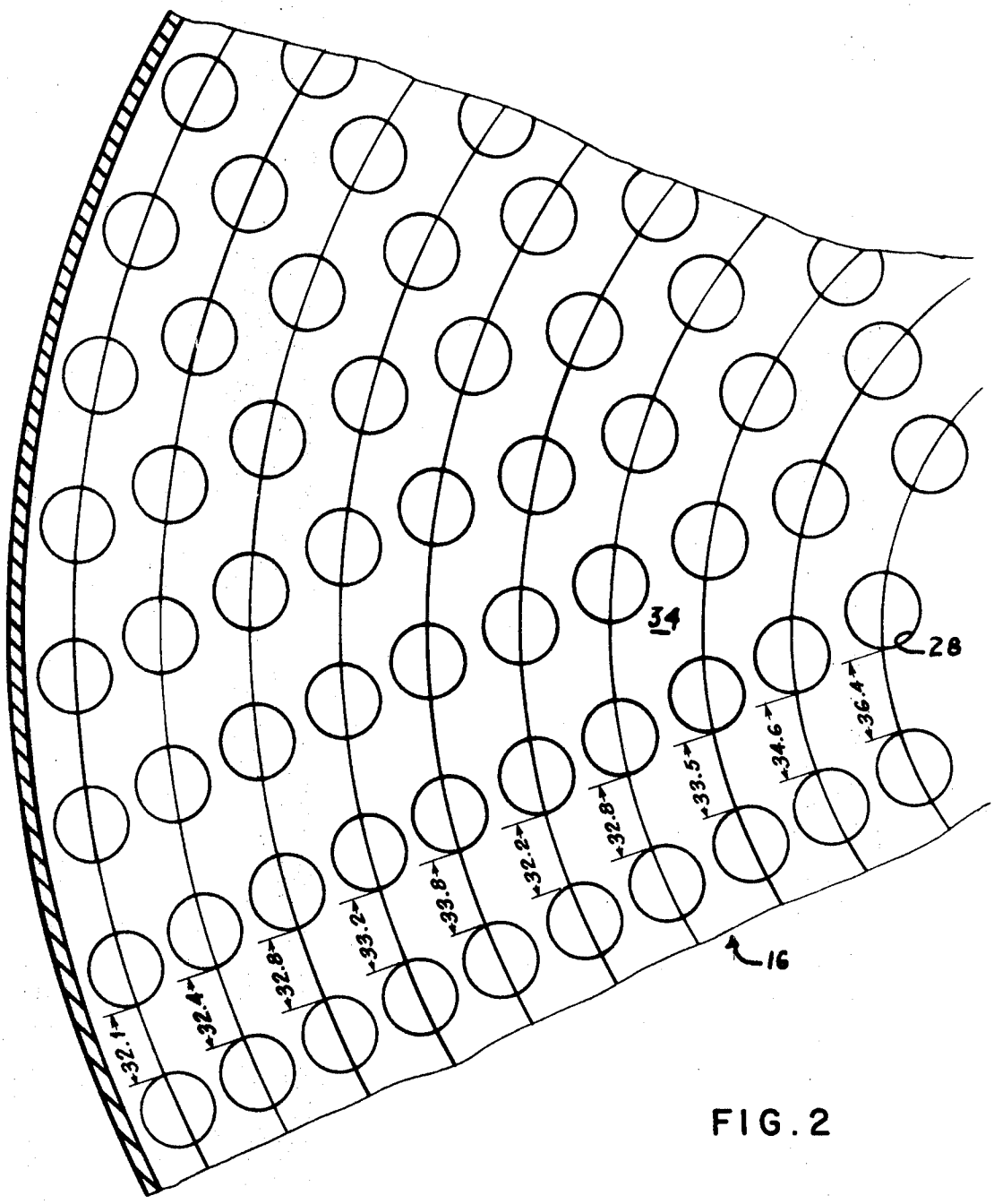


FIG. 2

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LOW TEMPERATURE FRACTIONATION OF GASEOUS MIXTURES WITH PRELIMINARY AND SPLIT STREAM HEAT EXCHANGE

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Int. Cl. F25j 5/00
U.S. Cl. 62—13 15 Claims

ABSTRACT OF THE DISCLOSURE

In the low temperature separation of gases utilizing reversible heat exchangers for the cooling and cleaning of incoming gases, wherein a branch of partially cooled and cleansed air is withdrawn from the middle portion of the reversible heat exchangers, the improvement of completing the cooling and cleaning of said withdrawn gases in a single countercurrent heat exchanger without interrupting the separation process, thereby avoiding the use of a parallel countercurrent heat exchanger for cleaning purposes.

BACKGROUND OF THE INVENTION

This invention relates generally to a process and apparatus for cleaning and fractionating gaseous mixtures at low temperatures, and in particular to the separation of air into enriched streams of oxygen and nitrogen.

In the prior art, gaseous mixtures have been cleaned by cooling same in heat exchangers which cool and clean the mixture and congeal the impurities contained therein. In one such prior art process, the gaseous mixture is first cooled in a set of interchangeable, reversible or regenerative heat exchangers. To achieve very small temperature differences at the outlet, and to facilitate the vaporization of condensed impurities in the next cycle, a minor portion of the gaseous mixture in a partially cleaned, partially cooled state is withdrawn at a point intermediate the inlet and outlet of the heat exchangers. This partially cleaned withdrawn portion is then passed into a sheet and tube heat exchanger, or the like, in indirect countercurrent heat exchange relationship with the fully cooled and cleaned gas whereby the remaining impurities in the partially cleaned gas are congealed. The primary problem involved in the aforedescribed process is that deposits build up in the countercurrent heat exchanger, so it must be periodically shut down for cleaning. Consequently, it has been standard practice, heretofore, to provide at least two countercurrent heat exchangers in parallel, so that, as the cleaning of one becomes necessary, the other may be switched into line to take over the function of the former. The requirement for two countercurrent heat exchangers of the prior art is a particular disadvantage in that such a unit is very expensive.

SUMMARY OF THE INVENTION

This invention provides a process and apparatus whereby a single countercurrent (crosscurrent) heat exchanger can be utilized in lieu of two of such heat exchangers in parallel as required in the prior art, by providing means to periodically bypass relatively cold, fully purified gaseous mixture normally flowing through the crosscurrent heat exchanger to be cleaned, while maintaining the flow of the partially cleaned gaseous mixture therethrough to sublime and remove the congealed impurities.

It is therefore an object of this invention to provide a novel continuous process and apparatus utilizing a crosscurrent heat exchanger for performing low temperature fractionation of gaseous mixtures in a more economical

and compact manner than heretofore possible by providing means to clean the crosscurrent heat exchanger of impurities deposited therein in a fast and efficient manner, thereby obviating the necessity for two parallel countercurrent heat exchangers.

It is another object of this invention to provide a novel crosscurrent heat exchanger for low temperature separation of gaseous mixtures which is operable at a higher degree of efficiency for a longer period of time than prior art heat exchangers by furnishing a novel distribution of heat exchange tubes throughout the cross-sectional area thereof.

It is still another object of this invention to provide a process for separating gaseous mixtures at low temperatures utilizing a crosscurrent heat exchanger wherein the heat exchanger is purged more quickly and less expensively than heretofore by furnishing means to periodically shut down the flow of refrigerant to the heat exchanger while maintaining the flow of warmer gaseous mixture to be cleaned therethrough to thereby vaporize and purge impurities deposited in the heat exchanger.

These and other objects of the invention will become more apparent to those skilled in the art by reference to the following detailed description when viewed in light of the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of one cycle of a separating system incorporating the features of this invention; and

FIG. 2 is cross-sectional plan view of a heat exchanger in accordance with the invention, in the scale approximately 1:2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, a gas inlet line **10** communicates with a turbocompressor **12** and, through a suitable switching arrangement, with pairs of reversible or regenerative heat exchangers **14***a*, **14***b*, **14***c* and **14***d*. The latter are also called regenerators or heat accumulators. Gas line **10** is provided with means to switch communication thereof between reversible heat exchangers **14***a* and **14***c*, as shown in the drawings, to the reversible heat exchangers **14***b* and **14***d*. Such switching and the apparatus for accomplishing the switching is well known to those skilled in the art.

The heat exchangers **14***a* and **14***c* communicate with a crosscurrent heat exchanger, shown generally at **16**, through switchable conduits **18** and **20** manifolded into a countercurrent heat exchanger inlet conduit **22**. The aforedescribed switching apparatus is adapted to switch these conduits to the heat exchangers **14***b* and **14***d* concurrently with the switching of the gas line **10**. Communication to the countercurrent heat exchanger **16** is controlled by a valve **24** in the conduit **22**. The crosscurrent heat exchanger **16** is provided with an inlet chamber **26** which communicates, through a plurality of heat exchanger tubes **28**, with a mixing chamber **30**. Plates **32** and **34**, disposed at the upper and lower ends of the tubes **28** respectively, enclose the area surrounding the tubes **28** and define therewith a zone **36** surrounding the tubes which communicates with the mixing chamber **30** through an orifice **38** in the lower plate **34**. The mixing chamber preferably has such a volume that the speed of the gas leaving orifice **38** is reduced from approximately 0.4–2 m./sec. to 0.2–1 m./sec.

Referring again to the reversible heat exchangers **14***c* and **14***d*, conduits **40** and **42**, controlled by valves **44** and **46** respectively, communicate with the heat exchangers intermediate the warm and cold ends thereof. These conduits are communicative with a transfer conduit **48** which,

in turn, communicates with the zone **36** in the crosscurrent heat exchanger **16**.

A bypass conduit **50** communicates with the conduit **22** upstream of the valve **24** and, through a valve **52**, temperature equalizing means **54** and turbine **56**, with a fractionating column **58**. The temperature equalizing means must have a large heat transfer area, preferably in the form of regenerator packing or adsorbents such as silica gel. The mixing chamber **30** of the crosscurrent heat exchanger **16** communicates with the conduit **50** through a discharge conduit **60**, controlled by a valve **62**, which, in turn, is connected to the conduit **50** downstream of the valve **52**. A branch conduit **64** communicates with the conduit **50** upstream of the valve **52** and with a coil **66** in the fractionating column, and ultimately terminates through an expansion valve **68** in the upper portion of the column **58**. Flow through the conduit **64** is controlled by a valve **70**.

The lower portion of the fractionating column **58** communicates with the reversible heat exchanger **14*b*** through a product discharge conduit **72** while the upper portion of the fractionating column is similarly communicative with the reversible heat exchanger **14*d*** through a discharge conduit **74**. With respect to conduits **72** and **74**, as well as conduits **18** and **20**, there are provided conventional switching means for alternate pairing of the reversible heat exchangers to either the input or discharge side of the circuit.

An impurity discharge conduit **76** is communicative with the sump of the heat exchanger **16** and flow therethrough is controlled by a valve **78**.

Turning now to FIG. 2 of the drawings, the crosscurrent heat exchanger **16** is shown in crosssectional detail in the scale approximately 1:2. This illustrates a preferred arrangement of the tubes wherein the tubes are spaced more closely at the periphery of the heat exchanger than at the center. By decreasing the tube spacing toward the periphery of the heat exchanger in such a manner, premature clogging of certain sections of the heat exchanger because of a non-uniform load upon the tube surfaces is prevented. In detail, the distribution of the tubes becomes apparent from the attached table. The free spaces between the tubes of the innermost circle is approximately 1.13 times greater than in the outermost circle. The values in the table and the dimension in FIG. 2 relate to a crosscurrent heat exchanger of 3.5 m. weight, having tubes with 30 mm. diameter therein.

In operation, with the reversible heat exchangers **15*a*** and **14*c*** precooled either by discharge from the apparatus or external sources, air, compressed in the compressor **12**, is passed through the heat exchanger **14*a*** and **14*c*** for cooling and cleaning thereof. Fully cleaned and cooled air, exiting at a temperature, for example, from 85 to 110° K., is then directed through the conduits **18** and **20** and the conduit **22** to the inlet chamber **26** of the heat exchanger **16**. The valve **44** in the conduit **40** is maintained open in the switching cycle illustrated to withdraw partially cleaned, partially cooled air from the heat exchanger **14*c*** intermediate the warmed and cooled ends thereof. As an example, 2 to 8% of the incoming gas is withdrawn from the heat exchanger **14*c*** through the conduit **40** at a temperature of between 150 and 230° K.

The partially cooled air is transmitted through the conduit **48** to the zone **36** in the heat exchanger **16** for final cleaning thereof. It is found perferable to direct the partially cleaned air into the heat exchanger **16** through the zone **36** rather than through the tubes **28** since impurities frozen out of the gas being cleaned are more easily removed from the exterior of the tube surfaces than from the interior thereof. The partially cleaned gas then passes in indirect heat exchange relationship with the fully cleaned gas passing through valve **24** to congeal further impurities.

The almost completely cleaned gas from the zone **36** then exists through the orifice **38** into the mixing chamber **30**, where it is mixed directly with warmed, fully cleaned gas which has passed through tubes **28**. Because the loss of kinetic energy incurred by passing into the mixing chamber and since a lower temperature of the mixed gas is obtained as compared to the gas leaving through orifice **38**, additional impurities are congealed from the gas to be cleaned, thus obtaining a higher degree of purity of the final product.

Preferably, only a portion of the fully cleaned gas from the heat exchangers **14*a*** and **14*c*** is diverted for cooling in the countercurrent heat exchanger. The remaining portion, preferably about 60 to 90%, is bypassed through the conduit **50** and mixed with gas leaving the heat exchanger **16** through the conduit **60**. The mixture of gases from conduit **50** and conduit **60** is then fed into the temperature equalizing device **54** which preferably contains a regenerative mass of such character that carbon dioxide and hydrocarbons can be adsorbed therein. The mixed gas from the temperature equalizing device **54** then is expanded through the turbine **56** and discharged into the fractioning column **58**.

A portion, preferably at least 50%, of the total input air of the gas flowing through the bypass conduit **50** is withdrawn through the conduit **64** to provide heat in the coil **66** for the sump of the fractioning column **58** prior to being passed through pressure reduction valve **68** and discharged as reflux liquid into the upper portion of the column.

Fractionation products withdrawn from the column **58** at the bottom thereof through the conduit **72**, and from the head thereof through the conduit **74**, are discharged through the reversible heat exchangers **14*b*** and **14*d*** for cooling same. When air is cleaned as in the described embodiment, the products of the fractioning column would typically be oxygen through the heat exchanger **14*b*** and nitrogen through the heat exchanger **14*d***.

After the heat exchanger **16** has been operated for about one month, the load of congealed impurities, such, for example, as CO_2 in the zone **36**, is such that the heat exchanger must be cleaned. At that point, the flow of cold, purified air from the conduit **22** is interruputed by closing the vale **24**; however, the warm, partially cleaned air from the conduit **48** is allowed to continue to enter the zone **36**. Simultaneously the valve **78** in the conduit **76** is opened and the valve **62** in the conduit **60** is closed so that the warm air passing through the zone **36** vaporizes the deposited impurities and discharges through the conduit **76**.

After a relatively short time, for example, approximately 10–12 hours, the tube surfaces of the heat exchanger **16** are free from congealed components, and the valves **24** and **62** can be reopened with the valve **78** simultaneously being closed to recommence the heat exchange operation in exchanger **16**. As compared to total operating time, the cleaning time required by the process of this invention is so short that the temporary loss of 2–8% of the air to be fractionated does not unbalance the system to any significant extent

The substances passing into the gaseous phase during the cleaning of the heat exchanger **16** may be discharged to the outside together with the partially cleaned gaseous mixture used to achieve the vaporization. This is particularly suitable when the congealed components, for example, CO_2, are of little value, and do not provide an air pollution problem. Alternatively, the gas produced during the cleaning period of the heat exchanger **16** may be warmed, for example, in coils provided in the reversible heat exchangers **14*a*** through **14*d***, in order to make use of the cold inherent in this gas, and employed as instrument air, or for other purposes, as desired.

Although air is specifically referred to in the specifically described process and apparatus, it should be obvious that any gaseous mixture may be treated thereby.

The preceding examples can be repeated with similar success by substituting the generically and specifically

described reactants and operating conditions of this invention for those used in the preceding examples.

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. Consequently, such changes and modifications are properly, equitably, and intended to be, within the full range of equivalence of the following claims.

TABLE

Diameters of tube circles (mm.)									
275	350	425	500	575	650	725	800	875	950
Number of tubes									
13	17	21	25	29	32	36	40	44	
Free spaces between tubes (mm.)									
36.4	34.6	33.5	32.8	33.8	33.2	32.8	33.2	32.4	32.1
Free cross-sectional areas within the tube circles ($m.^2$)									
1.66	2.06	2.46	2.87	3.30	3.78	4.18	4.79	4.99	5.38

What is claimed is:

1. An apparatus for low temperature separation of gaseous mixtures comprising:

a single crosscurrent heat exchanger having an elongated housing with a first inlet and outlet in opposite ends thereof, a plurality of spaced parallel heat exchange tubes disposed in said housing in concentric rings about the longitudinal centerline thereof and communicating with said first inlet and outlets to form a first heat exchange zone therein, means isolating the space between said tubes to form a second heat exchange zone therein, a second inlet in the periphery of said housing proximate said first inlet communicating with said second zone, a second outlet through said isolating means communicating said second zone with said first zone proximate said first outlet;

conduiting means including a source of low temperature gas communicating with said first zone through said first inlet;

conduiting means including a source of relatively warmer impurity containing gas communicating simultaneously with said second zone through said second inlet for cooling and congealing of the impurities therein by heat exchange with said low temperature gas; and means including a valve disposed between said source of low temperature gas and said first zone and a valve in said first outlet to interrupt the flow of low temperature gas to said first zone and to divert flow of gas from said second zone to exhaust vaporized and purged impurities deposited in said second zone.

2. An apparatus in accordance with claim **1**, further comprising at least one reversible heat exchanger for cooling and cleaning gas passed therethrough, said reversible heat exchanger having an inlet and outlet thereto, the outlet of said reversible heat exchanger comprising said source of low temperature gas, said source of warmer impurity containing gas comprising tap means disposed intermediate the outlet and inlet of said reversible heat exchanger to draw gas therefrom in a partially cleaned and partially cooled condition.

3. An apparatus in accordance with claim **2**, further comprising a rectification column, a bypass means including a bypass conduit communicating a portion of the gas from said reversible heat exchanger directly to said rectification column, and means communicating said first outlet of said crosscurrent heat exchanger with said bypass conduit.

4. An apparatus in accordance with claim **3** wherein said bypass means further includes temperature equalization means and an expansion turbine communicative with said bypass conduit downstream of the point of communication thereof with said first outlet of said crosscurrent heat exchanger.

5. An apparatus in accordance with claim **1** wherein the first zone of said heat exchanger comprises an inlet chamber communicating with said plurality of heat exchange tubes and wherein the second zone comprises the zone surrounding said tubes, said second zone terminating together with the ends of said tubes in a mixing chamber, at least one outlet conduit means including a valve communicating with said mixing chamber.

6. An apparatus in accordance with claim **5** wherein the relative spacing between said tubes is increased toward the center thereof in such a manner that the free through-flow cross section outside the tubes increases slowly from the center to the periphery of the heat exchanger.

7. In a process for low temperature separation of gaseous mixtures wherein a gaseous mixture is cooled and cleaned from impurities contained therein in two separate parallel streams, the one stream being cooled to a lower temperature and being cleaned totally, the other stream being cooled to an intermediate temperature and being cleaned partially and wherein at least a first portion of said one stream and said other stream are brought into simultaneous indirect heat exchange with each other in a heat exchange zone in order to freeze out remaining impurities in said other stream the improvement comprising the steps of periodically interrupting the flow of the relatively cold gaseous mixture and continuing the flow of the relatively warm, partially cleaned gaseous mixture to vaporize the frozen congealed impurities, and removing the vaporized impurities and the partially cleaned mixture from said heat exchange zone.

8. A process in accordance with claim **7** wherein the initial gaseous mixture is cooled and cleaned in at least one reversible heat exchanger prior to heat exchange of said one stream with said other stream and wherein said other stream is withdrawn from an intermediate point of at least one of said reversible heat exchangers.

9. A process in accordance with claim **7** wherein said one stream and said other stream after said indirect heat exchange therebetween, are mixed in a mixing zone to congeal additional impurities from said other stream said mixing zone being so dimensioned as to reduce the velocity and kinetic energy of said other stream as compared to the velocity and kinetic energy of same during said indirect heat exchange.

10. A process in accordance with claim **9** wherein said mixed streams are rectified after heat exchange therebetween.

11. A process in accordance with claim **10** wherein a second portion of said first stream is diverted upstream of said heat exchange zone and mixed directly with said mixed streams prior to rectification thereof.

12. In a process for the low temperature separation of gaseous mixtures wherein a gaseous mixture is cooled and cleaned from impurities contained therein in two separate parallel streams, the one stream (**22**) being cooled to a low temperature and being cleaned totally, the other stream (**48**) being cooled to an intermediate temperature and being cleaned partially, and wherein said streams are brought into simultaneous indirect heat exchange relationship with each other in a heat exchange (**16**) in order to freeze out remaining impurities in said other stream (**48**) and the thus cleaned mixture is separated in a rectifier (**58**), the improvement comprising the steps of bypassing a major portion of said one stream (**50**) directly to the rectifier (**58**) so that the output thereof is substantially unaffected by periodic shutdown of the heat exchanger (**16**) for cleaning thereof, and during said shutdown bypassing remaining minor portion of said one stream (**24**) to said rectifier (**58**), employing said minor portion, during normal operation of said heat exchanger (**16**), to cool said other stream (**48**).

13. An apparatus in accordance with claim **1**, further comprising at least one reversible heat exchanger for cooling and cleaning gas passed therethrough, said reversible heat exchanger having an inlet and outlet thereto, the outlet of said reversible heat exchanger comprising said source of low temperature gas, said source of warmer impurity-containing gas comprising tap means disposed intermediate

the outlet and inlet of said reversible heat exchanger to draw gas therefrom in a partially cleaned and partially cooled condition, and a rectification column, bypass means including a bypass conduit communicating a portion of the gas from the cold end of said reversible heat exchanger directly to said rectification column, and means communicating the outlet of said crosscurrent heat exchanger with said bypass conduit.

14. A heat exchanger for low temperature separation of gaseous mixtures comprising:

an elongated housing having at its frontal area an inlet communicating with a source of low temperature gas and an outlet thereto;

a plurality of heat exchange tubes disposed in said housing in longitudinal spaced relationship to one another and to the inlet and outlet of said housing and arranged in concentric rings about the longitudinal centerline thereof to form an inlet zone communicating through said tubes with a mixing zone proximate said outlet, means isolating the space between said tubes to form a separation zone therearound, said separation zone having an inlet communicating simultaneously with a source of relatively warmer impurity containing gas through the periphery of said housing and an outlet communicating with said mixing zone at a point proximate the longitudinal centerline of said housing, means directing said relatively warmer gas normal to said heat exchange tubes.

15. An apparatus in accordance with claim 14 wherein the free spacing between the tubes in the rings proximate the center of said housing being greater than the free space of the tubes proximate the periphery thereof.

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WILBUR L. BASCOMB, Primary Examiner

U.S. Cl. X.R.

62—25, 38; 165—110

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,518,839 Dated July 7, 1970

Inventor(s) RUDOLF BECKER

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, Line 14, under "Number of Tubes" after "44" add

---48---

Column 5, Line 16, change "33.8,33.2, 32.8, 33.2"to

---32.2, 33.8, 33.2, 32.8---

SIGNED AND
SEALED
OCT 13 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents

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