Dec. 15, 1953 H. F. BUSCHOW 2,662,749

ANNULAR FLOW HEAT EXCHANGER

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Fig. 1

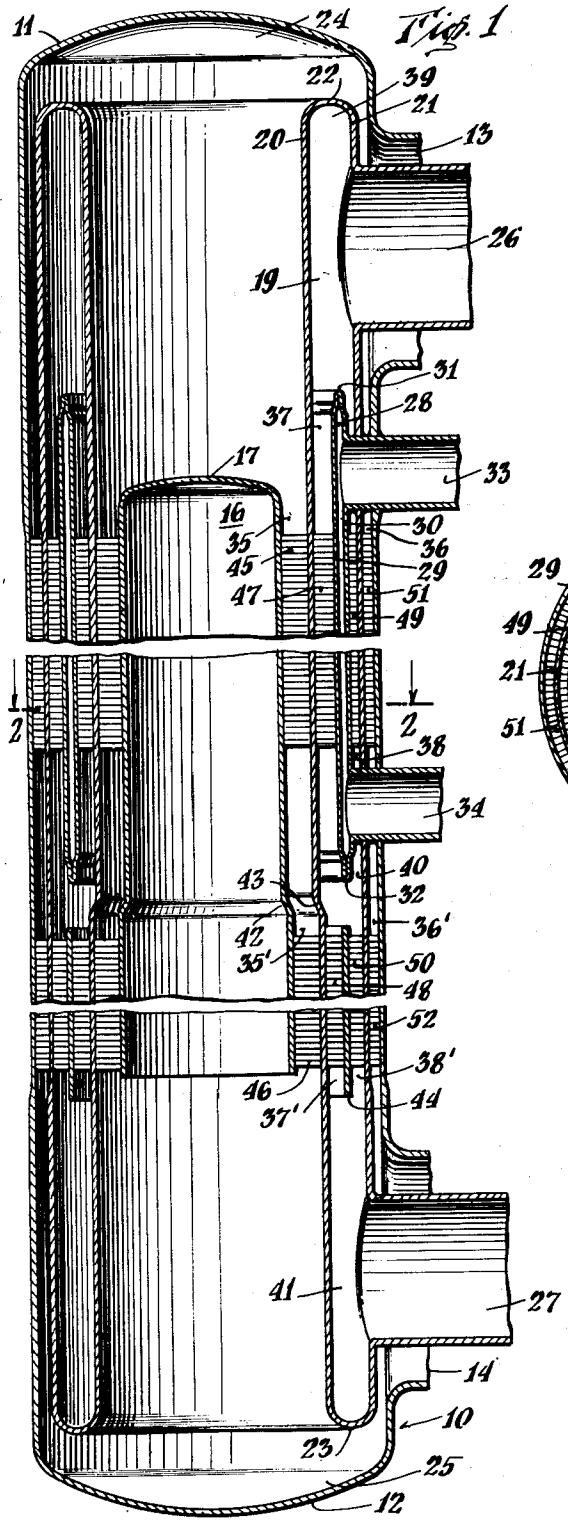
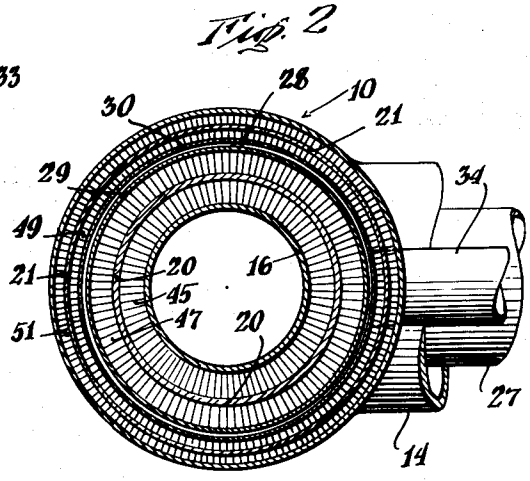


Fig. 2



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ANNULAR FLOW HEAT EXCHANGER

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Fig. 3

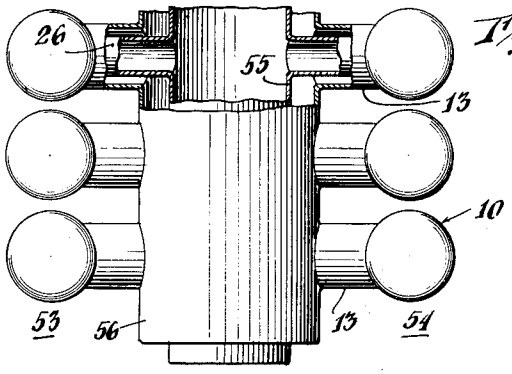


Fig. 4

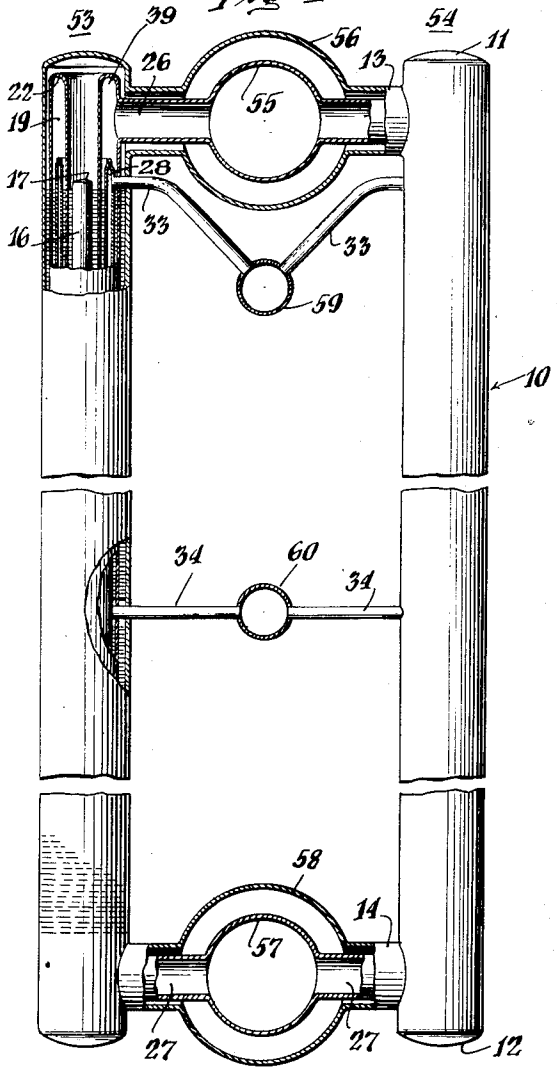


Fig. 5

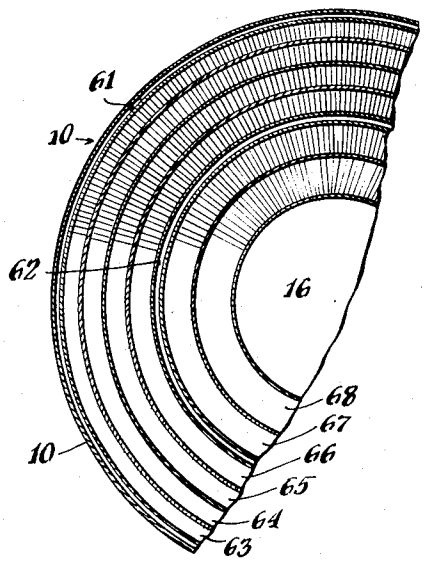
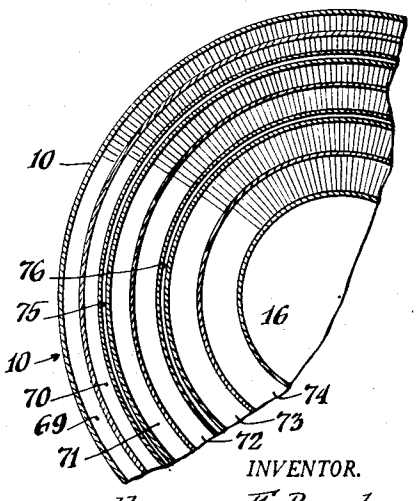


Fig. 6



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ANNULAR FLOW HEAT EXCHANGER

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Fig. 5A

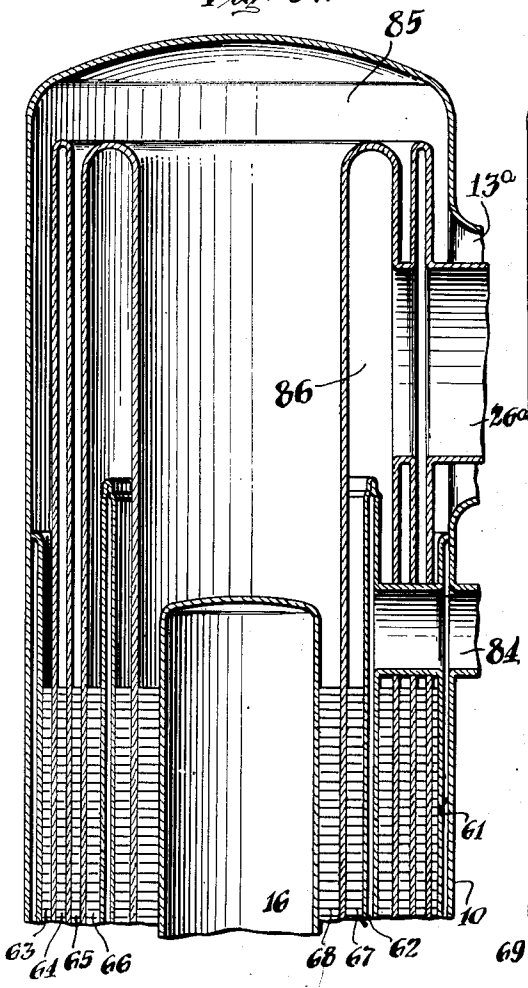


Fig. 6A

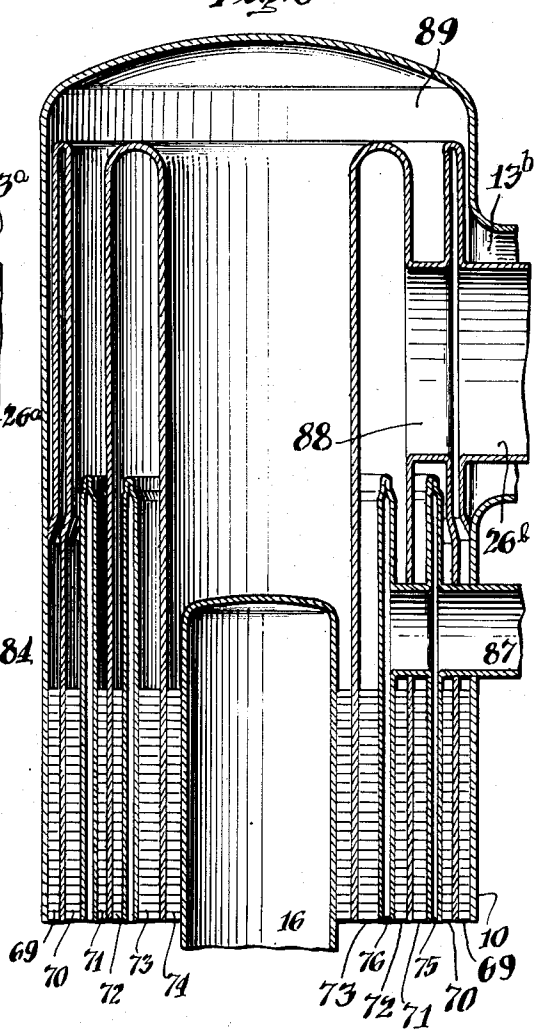


Fig. 7

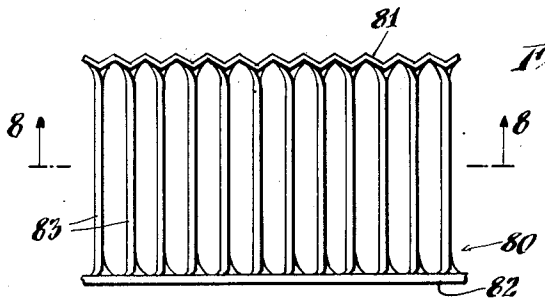
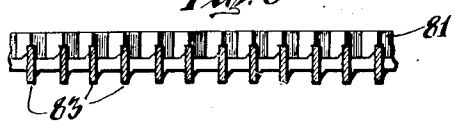


Fig. 8



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UNITED STATES PATENT OFFICE

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ANNULAR FLOW HEAT EXCHANGER

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Application January 21, 1949, Serial No. 71,953

10 Claims. (Cl. 257—246)

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This invention relates to recuperative heat exchangers, especially to such exchangers for recovering the cold content of the outgoing oxygen and nitrogen products of rectification which may be at a temperature of about —280° F. in the production of oxygen by the liquefaction and rectification of air. More particularly this invention relates to improved recuperative exchangers of high cold transfer efficiency, in the operation of which efficient purging takes place permitting continuous operation.

Cold exchangers are well known in which the relatively warm incoming air and the relatively cold outgoing products of rectification are alternately passed with periodically reversed operation, so that streams of warm air are flowed through the same packing-filled spaces as the cold rectification products traversed during the preceding step of the process, the condensibles deposited in these spaces during the passage of air therethrough being removed by sublimation and evaporation during the subsequent flow therethrough of the products of rectification. To provide for relatively high cold transfer efficiencies, cold exchangers heretofore employed have consisted of cylindrical shells having therein a large number of tubes, each provided with an interior accordion-type fin of foil-like metal of high heat conductivity disposed to form channels extending longitudinally through each tube and a somewhat similar accordion-type fin on the exterior thereof.

In my copending application, Serial No. 678,464, filed June 21, 1946, now Patent No. 2,532,288, there is disclosed an improved type of exchanger representing an important advance in the exchanger art, in which fins in the form of discs, each of foil-like thickness, produceable by a simple stamping operation without waste of heat conducting material are readily assembled by insertion on the inside or outside of each tube in substantially abutting relationship, thus producing a multiplicity of longitudinally extending passages defined by the foil-like high heat conducting material of the discs deflected by the stamping operation to form the passages. In my copending application Serial No. 48,508 filed September 9, 1948, an improved type of exchanger is disclosed in which the fins are produced by winding on each interior tube of the assembly of tubes forming the exchanger, a helix of high heat conducting material, each convolution of the helix comprising a crimped flanged portion in contact with the periphery of the tube and an integral body portion disposed substantially

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in a plane at right angles to the axis of the tube and having closely spaced passages extending therethrough defined by vanes produced by cutting the body portion along closely spaced lines extending substantially the full depth of the body portion and deflecting the material between each such pair of lines, the successive convolutions being at least in nearly abutting relationship to each other.

In the construction of my aforesaid copending application Serial No. 48,508 three concentric tubes are employed to form each exchanger unit, the inner tube being used for the flow therethrough of a non-reversing stream, this tube being positioned in at least the cold end of the heat exchanger. The annular paths of flow between the inner tube and the intermediate tube serve for the alternate flow therethrough of air and a rectification product, the flow of these two streams being periodically reversed so the air flows through the path through which had previously flowed the rectification product and the rectification product flows through the path through which had previously flowed the air, the rectification product thus effecting the removal of carbon dioxide deposited in the heat exchanger during the preceding step of the process. The flow of a non-reversing stream through at least the cold end of the exchanger, where deposition of carbon dioxide takes place, in indirect heat exchange relation with the air and the rectification product passing through their respective flow paths results in the maintenance of temperature conditions within this cold end of the exchanger such that efficient purging thereof takes place during each reversal period.

Among the objects of this invention is to provide an exchanger having in the flow paths through which the reversing streams of air and rectification product pass in heat exchange relation with each other an exceptionally high area of fin surface per unit of volume of these flow paths.

Still another object is to provide such exchanger which is relatively simple to construct, which provides for the flow of the reversing streams of air and rectification product in indirect heat exchange relation with a non-reversing stream passing through at least the cold end of the exchanger so that efficient purging of the exchanger takes place upon each reversal of flow and which is exceptionally efficient in operation.

Other objects and advantages of this invention will be apparent from the following detailed description thereof.

In the accompanying drawings forming a part of this specification and showing for purposes of exemplification preferred forms of this invention without limiting the claimed invention to such illustrative instances:

Figure 1 is a vertical section through an exchanger embodying this invention;

Figure 2 is a horizontal section taken in a plane passing through line 2—2 of Figure 1;

Figure 3 is a fragmentary plan view showing an assembly of exchanger units embodying this invention; this figure is a fragmentary plan view of the assembly of exchangers shown in Figure 4;

Figure 4 is an elevational view, partly in section, of an assembly of exchangers embodying this invention;

Figure 5 is a fragmentary horizontal sectional view corresponding to the showing of Figure 2 illustrating a modified form of exchanger embodying this invention;

Figure 5A is a fragmentary vertical section of the type of exchanger depicted in Figure 5 showing a preferred form of headers and ports associated with the flow paths in this exchanger;

Figure 6 is a fragmentary horizontal sectional view showing still another modified form of exchanger embodying this invention;

Figure 6A is a fragmentary vertical section of the type of exchanger depicted in Figure 6 showing a preferred form of headers and ports associated with the flow paths in this exchanger;

Figure 7 is a fragmentary plan view of one form of strip of high heat conducting material which may be used to form the heat exchange fins in the flow paths of the exchangers; and

Figure 8 is a vertical section taken in a plane passing through line 8—8 of Figure 7.

As disclosed in Figures 1 and 2, the recuperative exchanger of this invention comprises an elongated cylindrical housing 10 closed at its ends 11 and 12 and provided in the side wall near its ends with ports 13 and 14. Disposed within this housing 10 coaxial with the axis thereof is an elongated cylindrical core 16 having its top end closed or capped, as at 17. While the bottom end of this core 16 is shown open, this end may be capped or otherwise closed, if desired. Positioned within the annular space thus produced between the cylindrical core 16 and the inner wall of housing 10 is an annular chamber 19. This chamber is defined by two spaced side walls 20 and 21 which are joined at their ends 22 and 23, which ends are spaced from the ends 11 and 12, respectively, of the housing 10. There is thus produced at each end of the housing headers 24, 25 which communicate with the ports 13 and 14, respectively. Ports 26, 27 lead from the wall 21 of the annular chamber 19 near the ends thereof. These ports, it will be noted from Figure 1, are disposed within and concentric to ports 13 and 14, respectively.

A second annular chamber 28 is positioned in the upper portion of the annular chamber 19. This second annular chamber comprises side walls 29, 30 suitably joined at their ends 31, 32 to form a gas tight chamber. Ports 33, 34 communicate with wall 30 of chamber 28 near the ends thereof passing through outer wall 21 of annular chamber 19 and the housing 10.

The exchanger of Figure 1 may be dimensioned so that it has an outside diameter of 10 to 24 inches, preferably 10 to 15 inches, and a length of from 10 to 40 feet, preferably 15 to 25 feet. In the interests of clarity, i. e., to enable showing the interior structure on a larger scale then would otherwise be possible, Figure 1 shows only a small part of the flow paths in the upper and lower parts of the exchanger. It will be noted from Figure 1 that the annular chamber 19 cooperates with the periphery of the cylindrical core 16 and the inner wall of housing 10 to produce two annular flow paths 35, 36 in the upper part of the exchanger and two flow paths 35' and 36' disposed below the base of annular chamber 28 and which form respectively substantially linear extensions of flow paths 35 and 36. The flow paths 35, 35', 36, 36' substantially completely envelop the annular chamber 19, the flow paths 35, 35' connect the headers 24, 25 on the inner side of annular chamber 19 and the annular flow paths 36, 36' connect the headers 24, 25 on the outer side of annular chamber 19.

The second annular chamber 28 disposed within the first-mentioned chamber 19 has its walls 29, 30 spaced, respectively, from the side walls 20, 21 of the annular chamber 19 forming two annular flow paths 37, 38 completely enveloping the annular chamber 28. The flow paths 37 and 38 communicate with the header space 39 at the top of annular chamber 19, which header space in turn communicates with the port 26. These two flow paths 37, 38 communicate with an annular space 40 disposed just below the base of the annular chamber 28. A cylindrical skirt or baffle member 44 is disposed directly below the annular chamber 28 to divide the lower portion of the annular chamber 19 into two annular flow paths 37' and 38' which extend in substantial alignment with flow paths 37 and 38 and communicate at one end with header space 40 and at the other end with header space 41. The latter header space is provided with the port 27. If desired, baffle 44 could be omitted, in which case the two annular flow paths 37 and 38 would communicate with a common annular flow path which in turn communicates with header space 41.

Desirably, the cylindrical core 16 is expanded, as at 42. Also wall 21 is expanded or deflected, as at 43, in the area thereof directly opposite the expanded portion 42 of the core 16. By expanding the cylindrical core 16 and the wall 21 of annular chamber 19, as at 42, 43, the annular flow path 35' is of approximately the same volumetric capacity per unit of length as 35, 37' the same as 37, 38' the same as 38 and 36' the same as 36; also the volumetric capacity of paths 35, 35' is the same as 37 and 37' and paths 36, 36' the same as 38, 38'. In other words, the expansion of the lower portion of the cylindrical core and the shaping of the annular chamber, as shown in Figure 1, compensates for the fact the second annular chamber 28 is positioned only in the upper part of the exchanger, i. e., at the cold end of the exchanger where the non-reversing stream is passed to maintain temperature conditions resulting in the most effective purging of carbon dioxide and other condensibles deposited in this portion of the exchanger by the air stream passing therethrough and results in the formation of annular flow paths in indirect heat exchange relation of substantially the same volumetric capacity. These annular flow paths may be from ¼ to 1½ inches wide, preferably they are of a width falling within the range of from ⅜'' to 1''.

Each of the flow paths 35, 35', 36, 36', 37, 37', 38 and 38' is provided with fins in the form of a mass of high heat conducting material having narrow passages therein for fluid flow therethrough. The fins may be the well known ac-

cordion-type fins of foil-like metal of high heat conductivity disposed to form channels. Alternatively, the fins may be of the type disclosed in my Patent No. 2,532,288 involving discs each of foil-like thickness produceable by a simple stamping operation. These discs may, for example, be of copper, aluminum or other material of high heat conductivity of foil-like thickness, say from .010 to .040 inch thick, preferably from .014 to .020 inch thick, stamped to form annuli having the central openings of a diameter such that one set of discs may readily be slipped over the central core 16, and other sets of discs dimensioned so that they may be inserted in the annular flow paths hereinabove described with their edges in substantial abutment with the side walls defining each such flow path. As indicated in Figure 1 these discs are disposed in stacks or piles with the individual discs substantially in abutting relationship. As disclosed in my aforesaid Patent No. 2,532,288 the face of each disc is cut along pairs of closely spaced lines and the material between these lines deflected to produce baffles which are substantially at an angle of from 60° to 90°, preferably an angle of at least 85° to the plane of the disc, the baffles defining passages for the flow of a fluid therethrough.

Preferably, the fin in each flow path is produced in accordance with the invention disclosed and claimed in my copending application Serial No. 48,508. For example, a strip of aluminum, copper or other high heat conducting material may be wound on the central core 16 to produce a fin 45 in the form of a helix. A like helical fin as hereinafter more fully described may be formed in each of the annular flow paths. One form of strip which may be employed to form such helical fins is shown in Figures 7 and 8, and comprises a body portion having a crimped flange 81 along one longitudinal edge thereof and a flange 82 along the opposite longitudinal edge. The crimped flange 81 allows for the difference in the circumferential extent of the inner and outer flange portions of the strip when wound in the form of a helix to form the fin. The inner flange portion refers to the flange portion contacting the wall on which the strip is wound to form the helical fin. The outer portion refers to the flange portion of the strip remote or spaced from said wall. The body portion of the strip is provided with a plurality of closely spaced passages extending therethrough produced by cutting the body portion along closely spaced lines and deflecting the material between each pair of the closely spaced lines to provide vanes or baffles 83 defining the passages. The convolutions of each helix are at least substantially in abutting relationship.

A like helix 46 may be wound on the lower portion of the central core 16 substantially completely occupying the annular flow path 35'. Thereafter the core containing the helices wound thereon is inserted within a cylinder corresponding to wall 20 of annular chamber 19 and two additional helices 47, 48 wound thereon in the manner hereinabove described in connection with helix 45. Annular chamber 28 is then positioned so that the wall 29 thereof is in contact with the edges of the convolutions of helix 47 and the baffle 44, if employed, is positioned so that the edges of the convolutions of helix 48 contact the inner wall thereof. Helices 49 and 50 are then wound, respectively, on the wall 30 of the annular chamber 28 and the outer wall of baffle 44. A cylinder corresponding to wall 21 is then placed over the resultant assembly and the ends of this cylinder welded to those of the cylinder forming wall 20, thus producing the annular chamber 28 having the closed ends 22 and 23. The resultant assembly then has wound thereon the helices 51 and 52. Thereafter the assembly is disposed within cylindrical housing 10, thus completing the exchanger having the helical fins disposed in each of the annular flow paths.

Alternatively, the exchanger may be produced by forming two sections, one consisting of core 16 having the helical fins 45 and 46 wound thereon, disposed within a cylinder corresponding to wall 20 having the helical fins 47 and 48 wound thereon and the other consisting of cyclindrical housing 10 having the fins 51 and 52 wound therein and a cylinder corresponding to wall 21 having the helical fins 49 and 50 wound therein. The two sections are assembled with annular chamber 28 secured as by brazing to the edges of helical fins 47 and 49, with cylindrical baffle 44 secured as by brazing to the edges of helical fins 48 and 50, and welding the contacting edges of walls 20 and 21 to form the annular chamber 19 having the closed ends 22 and 23.

In the structure of Figure 1, the weight of the exchanger is borne by the cylindrical housing 10. The cylindrical core 16, and the annular chambers 19 and 28 and the cylindrical baffle 44, if used, are all supported by this housing 10 through the medium of the helical fins which have the edges of each convolution brazed or otherwise bonded to the walls of core 16, the annular chambers 19 and 28, the cylindrical baffle 44 and the housing 10.

The fins whether of the helical, disc or other type desirably have their edges brazed or otherwise in good thermal contact with the walls defining each annular flow path in which they are disposed. In this way efficient heat exchange between the different gaseous streams passing through adjacent, annular passages takes place. The heat conducting material from which the helices are formed may be .010 to .040 inch thick, preferably .014 to .020 inch thick, and of a width necessary to completely fill the annular space in which the helix is disposed plus that required to form narrow flanges on the opposite edge portions of each convolution of the helix. The baffles or vanes produced in the body portion of each convolution to form the fluid passages may have a depth of from $\frac{1}{16}$ to $\frac{1}{4}$ of an inch, preferably $\frac{1}{16}$ to $\frac{1}{8}$ of an inch, and the flanges at the edges of each convolution generally may be of from .005 to .010 inch wider than the vanes so that, as the several convolutions of the helical fin are brought into abutting relation with one another along the flange portions, the vanes of contiguous convolutions remain spaced with clearances of from .005 to .010 inch. The walls of the central core 16 and the walls forming the annular chambers 19 and 28 and the housing 10 may be aluminum, copper or other metal or alloy of good heat conductivity. Preferably, the same metal is used for these walls and the fins so that all parts of the exchanger will expand or contract equally upon being subjected to changes in temperature, minimizing stresses due to differential expansion. Aluminum is the preferred construction material.

Each exchanger unit hereinabove described and shown in section in Figure 1 is a self-contained unit. Thus, for example, a non-reversing stream may be caused to flow through the annular chamber 28 and nitrogen product of rectification caused to flow during one cycle of operation

through the annular flow paths 35, 35', 36, 36', while air is caused to flow through the annular flow paths 37, 37', 38, 38' disposed within annular chamber 19, the flow of air and nitrogen being periodically reversed through their respective flow paths. Hence, each exchanger unit may be tested under the flow conditions in which it will be used in practice to determine whether it is entirely satisfactory.

Desirably, a plurality of exchanger units constructed as hereinabove described are connected with suitable mains to provide an exchanger assembly having any desired capacity. As shown in Figures 3 and 4, two rows 53 and 54 of exchangers each of the type hereinabove described are disposed on opposite sides of the mains hereinbelow described. A pair of concentric header mains 55, 56 for the alternate flow of air and nitrogen therethrough may be connected with the ports 26, 13 of each of the two rows 53 and 54 of the exchangers. A second pair of concentric mains 57, 58 is connected to ports 27, 14, respectively. A main 59 for flow of a non-reversing stream therethrough is connected to ports 33 of each exchanger of the two rows and a second main 60 is connected with the ports 34.

In the operation of the exchangers of Figures 3 and 4, air, for example, during one period of operation flows through main 57, ports 27, up through the annular flow paths 37', 38', 37 and 38 over the surface of the fins therein and exits through headers 39, ports 26 into main 55. Simultaneously nitrogen flows through main 56, ports 13 of all the exchangers down through the annular flow paths enveloping the annular chamber 19, exiting through ports 14 into the main 58. Oxygen, nitrogen and other rectification product, such as argon, neon, etc. air or an extraneous gas is supplied to main 59, flows through ports 33, the interior of annular chamber 28, exiting through ports 34 into the main 60.

Upon reversal, which may take place every three to fifteen minutes, air flows through main 58, ports 14, the annular flow paths communicating therewith and exits through ports 13 into the main 56. Nitrogen then flows through main 55, ports 26, through the annular flow paths communicating therewith, exiting through ports 27 and main 57. The flow through the annular chamber 28 remains unchanged.

The exchangers shown in Figures 3 and 4 are in a vertical position, the air entering the base headers and the product of rectification the top headers. If desired, the exchangers may be inverted so that the air enters at the top and flows down and the rectification product enters at the base and flows up. Also, the exchangers may be disposed in other positions than the vertical position shown.

In the modification of Figures 5 and 5A, instead of having the annular chamber 28 disposed between annular flow paths through which streams of air or rectification product flow, two annular chambers 61, 62 are employed for flow of non-reversing streams therethrough. Annular chamber 61 is disposed contiguous to housing 10, and annular chamber 62 disposed in the annular space between the central core 16 and housing 10 between annular flow paths employed for the flow of reversing streams of air and nitrogen product of rectification therethrough. Both chambers 61 and 62 communicate with a port 84. The construction of Figure 5 involves six annular flow paths 63, 64, 65, 66, 67 and 68 containing fins of high heat conducting material, which flow paths are disposed in the annular space between the central core 16 and the cylindrical housing wall 10. These flow paths may be produced as hereinabove described. As shown in the embodiment of Figure 5A, they are arranged so that air flows through the paths 63, 65 and 68, which paths lead into common headers 85 at the top and bottom of the cylindrical chamber and a rectification product, such as nitrogen, flows through the annular paths 64, 66 and 67, which paths at opposite ends thereof likewise lead into a header 86 connected therewith. Header 85 is provided with a port 13*a* and 86 with a port 26*a* corresponding to ports 13 and 26 of Figure 1. The non-reversing flow path formed by annular chamber 62 is disposed between the flow paths 66 and 67 which during one period of operation serves for flow of air therethrough and upon reversal during a succeeding period of operation serves for flow of nitrogen therethrough.

The modification of Figures 6 and 6A shows still another arrangement of annular paths containing fins of high heat conducting material therein and annular paths devoid of such fins for the flow of a non-reversing stream therethrough. In the modification of Figure 6, six annular paths 69, 70, 71, 72, 73 and 74 having fins therein are disposed in the annular space defined by the central core 16 and cylindrical housing 10. Two annular chambers 75 and 76 are provided in this modification for flow of a non-reversing stream therethrough. Chamber 75 is disposed between annular paths 70 and 71 and chamber 76 is disposed between the annular paths 72 and 73. Chambers 75 and 76 communicate with a common port 87. Flow paths 69, 72 and 73 lead into a common header 88 and the flow paths 70, 71 and 74 lead into a common header 89. Header 89 is provided with a port 13*b* and header 88 with a port 26*b* corresponding to ports 13 and 26 of Figure 1.

In the modification of Figure 6A, flow paths 69, 72 and 73 are employed for the flow of air therethrough during one period of operation, and flow paths 70, 71 and 74 for the flow of nitrogen. Upon reversal nitrogen passes through flow paths 69, 72 and 73 and the air through flow paths 70, 71 and 74. All the flow paths containing fins are desirably of the same volumetric capacity; thus, the radial dimension of the flow paths gradually diminishes, the flow path contiguous to core 16 having the greatest radial extent and that contiguous to housing 10 the smallest, the difference in radial extent being graduated so as to result in flow paths of uniform volumetric capacity.

In the modification of Figure 6A, for example, flow paths 70 and 71 may be employed for flow of oxygen rectification product therethrough in which case, of course, these flow paths would be provided with headers and ports individual thereto.

Where brazing is desired to improve the metal-to-metal contact between the fins and the walls defining the annular flow paths in which these fins are disposed, the brazing material may be in the form of a coating applied to such walls prior to the winding of the helical fin thereon. Also one side of each strip thus wound may have a coating of brazing material so that the outer faces of flanges 81, 82 have the brazing material thereon to effect bonding to the adjacent walls defining the annular flow path in which the fin is disposed. Satisfactory metal-to-metal con-

tact may be achieved by swaging the metal walls or the fin surfaces where they contact the metal walls or both. Satisfactory metal-to-metal contact may also be achieved by expanding a metal wall contacting a fin wound thereon or by contracting a cylindrical wall having a fin wound in contact with the inner surface thereof as by passage through a set of rolls to reduce the diameter and thus establish good contact between the helix and the surfaces of the cylindrical wall with which the helical fin is in contact.

It will be noted that in the exchanger of this invention a central core, at least about 4 inches in diameter, is employed through which core no gaseous flow takes place during the operation of the exchanger. Desirably, this core is of a diameter of about 5 inches in the case of an exchanger having an outside diameter of about 11". The use of this core results in the formation of annular flow paths having a maximum of fin surface area per unit of linear length for the flow therethrough of any given quantity of air or rectification product resulting from the liquefaction and rectification of this air and volume of non-reversing stream employed to effect the maintenance of the optimum conditions to effect purging of the paths through which the reversing stream of air and rectification product pass. In one design of this exchanger involving a helical type fin produced by winding a strip of aluminum on the core and the other cylindrical walls within the exchanger, there are about 400 square feet of surface area of fin per cubic foot of exchanger (the core volume having been deducted from the total exchanger volume). For purposes of comparison it is noted that in prior designs of exchangers involving flow of a non-reversing stream through an inner path and reversing streams of air and rectification product through two concentric paths in heat exchange relation with this inner path employing helical aluminum fins, the surface area of heat exchange fin per cubic foot of exchanger is approximately 260 square feet. Since it is the surface area of the fin over which the air and rectification products pass that is chiefly responsible for the heat transfer efficiency, it will be recognized that the exchanger of this invention is of exceptionally high heat transfer efficiency.

The expressions "reversing" and "reversal" are used herein in the sense commonly employed in this art, namely, to mean the switching of the flow of two streams, for example, the air and the nitrogen streams, so that upon each "reversal" the air flows through the path through which had previously flowed the nitrogen and the nitrogen through the path through which had previously flowed the air.

It will be understood embodiments of the invention can be made differing from the embodiments herein disclosed without departing from the scope of this invention. For example, while the drawings show certain of the annular flow paths devoid of fins, it will be understood all of the flow paths may be provided with such fins.

What is claimed is:

1. A recuperative heat exchanger comprising an elongated cylindrical housing having ports at the opposite ends thereof, an elongated cylindrical core disposed wholly within said housing with its axis substantially coincident with the axis of said housing and positioned to form an annular space defined by the periphery of said cylindrical core and the inner wall of said housing, an elongated annular chamber disposed wholly within said annular space and having the walls thereof spaced from the inner wall of said cylindrical housing and the periphery of said cylindrical core thereby defining annular flow paths on opposite sides of said annular chamber, said annular flow paths merging at the opposite ends of said annular chamber and communicating with said ports at the opposite ends of said cylindrical housing, ports communicating with the opposite ends of said annular chamber, and masses of high heat conducting material having passages therein for flow of a fluid therethrough disposed in said flow paths, said elongated cylindrical core being supported within said cylindrical housing entirely by the mass of high heat conducting material disposed in the annular flow path between said cylindrical core and said elongated annular chamber.

2. A recuperative heat exchanger as defined in claim 1, provided with a second annular chamber disposed wholly within the first-mentioned annular chamber and having its walls spaced from the walls of the first-mentioned annular chamber thereby defining annular flow paths on opposite sides of said second annular chamber which last-mentioned flow paths merge at the opposite ends of said second annular chamber and communicate with the ports communicating with the opposite ends of the first-mentioned annular chamber, said second annular chamber having ports communicating with the opposite ends thereof.

3. A recuperative heat exchanger comprising an elongated cylindrical housing having ports at the opposite ends thereof, an elongated cylindrical core disposed wholly within said housing with its axis substantially coincident with that of said housing and positioned to form an annular space defined by the periphery of said cylindrical core and the inner wall of said housing, a plurality of elongated annular chambers disposed wholly within said annular space with their axes coincident with that of said cylindrical housing and with each end spaced adjacent the corresponding end of said cylindrical housing, one of said annular chambers being disposed wholly within another of said annular chambers and at least one of said annular chambers having a mass of high heat conducting material therein provided with passages for flow of a fluid therethrough, ports connected with the opposite ends of each of said annular chambers, and a mass of high heat conducting material provided with passages for flow of a fluid therethrough attached to the periphery of said cylindrical core and to the nearest wall of one of said annular chambers, thereby providing the sole support for said cylindrical core within said housing.

4. A recuperative heat exchanger comprising an elongated cylindrical housing, an elongated cylindrical core disposed wholly within said housing with its axis substantially coincident with that of said housing and positioned to form an elongated annular space defined by the periphery of said cylindrical core and the inner wall of said housing, a plurality of nested elongated annular chambers disposed within said annular space with their axes coincident with that of said cylindrical housing, their ends spaced from the ends of said housing and their walls spaced from each other and from the walls defining said annular space, said nested annular chambers cooperating with each other and with the said cylindrical core and said cylindrical housing to define a plurality of annular flow paths in

indirect heat exchange relationship with each other, the annular flow paths outside of and immediately adjacent the opposite sides of at least one of said nested annular chambers merging at the opposite ends of, and thereby enveloping, such nested annular chamber, a helix of high heat conducting material in some of said annular flow paths, each convolution of each helix having the opposite edge portions in contact with the walls defining the annular flow path in which the helix is disposed, the body portion of each convolution being provided with a plurality of closely spaced passages extending therethrough produced by cutting the body portion along closely spaced radial lines and deflecting the material between each pair of said closely spaced lines to provide vanes defining said passages, the convolutions of each helix being at least substantially in abutting relationship with one another.

5. A recuperative heat exchanger comprising an elongated cylindrical housing having ports at the opposite ends thereof, an elongated cylindrical core disposed wholly within said housing with its axis coincident with the axis of said housing and positioned to form an annular space defined by the periphery of said cylindrical core and the inner wall of said housing, an annular chamber disposed within said annular space with the walls of said annular chamber spaced from the inner wall of said housing and from the periphery of said cylindrical core, thereby forming annular flow paths on opposite sides of said annular chamber, said annular chamber having its ends spaced from the ends of said housing, said annular flow paths merging at the opposite ends of said annular chamber and thereby completely enveloping said annular chamber, headers at the ends of said housing communicating with said annular flow paths, ports connected with said headers, separate ports connected with the opposite ends of said annular chamber, and a mass of high heat conducting material in each of said flow paths consisting of successive layers of thin metal of high heat conductivity in substantially abutting relationship having openings therein for flow of a fluid therethrough, the edge portions of each of said layers of each said mass being in substantial abutment with the walls defining the annular flow path in which said mass is disposed, said cylindrical core being supported within said housing entirely by the mass of high heat conducting material disposed in the annular flow path between said cylindrical core and said annular chamber.

6. A recuperative heat exchanger as defined in claim 5, in which at each end of the exchanger, ports from the said header and annular chamber are disposed in concentric relationship with the port from the annular chamber passing through that connected with the header, and a second annular chamber is disposed wholly within the first-mentioned annular chamber, said second annular chamber having ports at the opposite ends thereof passing through the outer wall of the first-mentioned annular chamber and the wall of said cylindrical housing and having its walls spaced from the walls of the first-mentioned annular chamber thereby defining annular flow paths on opposite sides of said second annular chamber which last-mentioned flow paths merge at the opposite ends of said second annular chamber and communicate with the ports connected with the opposite ends of the first-mentioned annular chamber.

7. A recuperative heat exchanger comprising an elongated cylindrical housing having ports at the opposite ends thereof, an elongated cylindrical core disposed wholly within said housing with its axis coincident with the axis of said housing and positioned to form an annular space defined by the periphery of said cylindrical core and the inner wall of said housing, an annular chamber disposed within said annular space with the walls of said annular chamber spaced from the inner wall of said housing and from the periphery of said cylindrical core, thereby forming annular flow paths on opposite sides of said annular chamber, said annular chamber having its ends spaced from the ends of said housing, said annular flow paths merging at the opposite ends of said annular chamber and thereby completely enveloping said annular chamber, headers at the ends of said housing communicating with said annular flow paths, a second annular chamber disposed within the first-mentioned annular chamber spaced from the walls thereof and forming annular flow paths which merge at opposite ends of said second annular chamber, thereby completely enveloping said second annular chamber, the annular flow paths completely enveloping the first-mentioned annular chamber and those completely enveloping the second-mentioned chamber being respectively used for the flow of two fluid streams therethrough, the interior of said second-mentioned annular chamber being adapted for the flow of a third fluid stream therethrough in indirect heat exchange relation with said two fluid streams passing through said annular flow paths, ports connected with the opposite ends of the first-mentioned annular chamber, still other ports connected with the opposite ends of the second-mentioned annular chamber, and a mass of high heat conducting material in each of said annular flow paths consisting of successive layers of thin high heat conducting material substantially in abutting relationship having openings therein for fluid flow therethrough, the edge portions of each of said layers of each said mass being in substantial abutment with the walls defining the annular flow path in which said mass is disposed.

8. A recuperative heat exchanger as defined in claim 7, in which the mass of high heat conducting material in each of the annular flow paths consists of a helix of high heat conducting material, each convolution of said helix having the opposite edge portions in contact with the walls defining the flow path in which the helix is disposed and having in its body portion a plurality of closely spaced, radially disposed vanes defining narrow passages through said body portion, the convolutions of said helix being at least substantially in abutting relationship.

9. A recuperative heat exchanger for flow of air and a rectification product thereof through separate flow paths in heat exchange relation, the flow of air and rectification product through their respective flow paths being reversed from time to time and said exchanger having another flow path for flow of another fluid stream in indirect heat exchange relation with the air and rectification product, comprising, in combination, a cylindrical housing, an annular chamber disposed wholly within said housing having each end spaced adjacent the corresponding end of said housing, a central cylindrical core disposed wholly within said housing, the space between said core and the inner wall of said annular chamber and between the outer wall of said

annular chamber and the inner wall of said housing defining a flow path completely enveloping the opposite ends and sides of said annular chamber, a second annular chamber within the first-mentioned annular chamber disposed with its walls spaced from the walls of said second annular chamber to provide a flow path which completely envelops the opposite ends and sides of said second annular chamber, the volumetric capacity of the two first-mentioned flow paths being substantially the same and these two flow paths being alternately employed for the passage of air and rectification product therethrough, and a mass of high heat conducting material in each of the two first-mentioned flow paths comprising a plurality of thin layers of heat conducting material substantially in abutting relationship, the edge portions of each of said layers being in substantial contact with the walls defining the two first-mentioned flow paths, said layers having flow passages therethrough, said second annular chamber being adapted to have said other fluid stream pass therethrough in heat exchange relation with the air and rectification product passing through their respective flow paths, the walls of said two annular chambers being of high heat conducting material.

10. A recuperative heat exchanger as defined in claim 9, in which the mass of high heat conducting material in each of the annular flow paths consists of a helix of aluminum, each convolution of said helix having the opposite edge portions in contact with the walls defining the flow path in which the helix is disposed and having in its body portion a plurality of closely spaced, radially disposed vanes defining narrow passages through said body portion, the convolutions of said helix being at least substantially in abutting relationship with one another.

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