

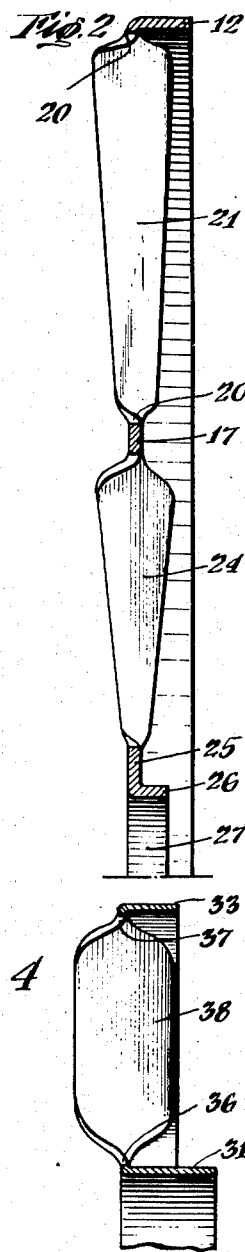
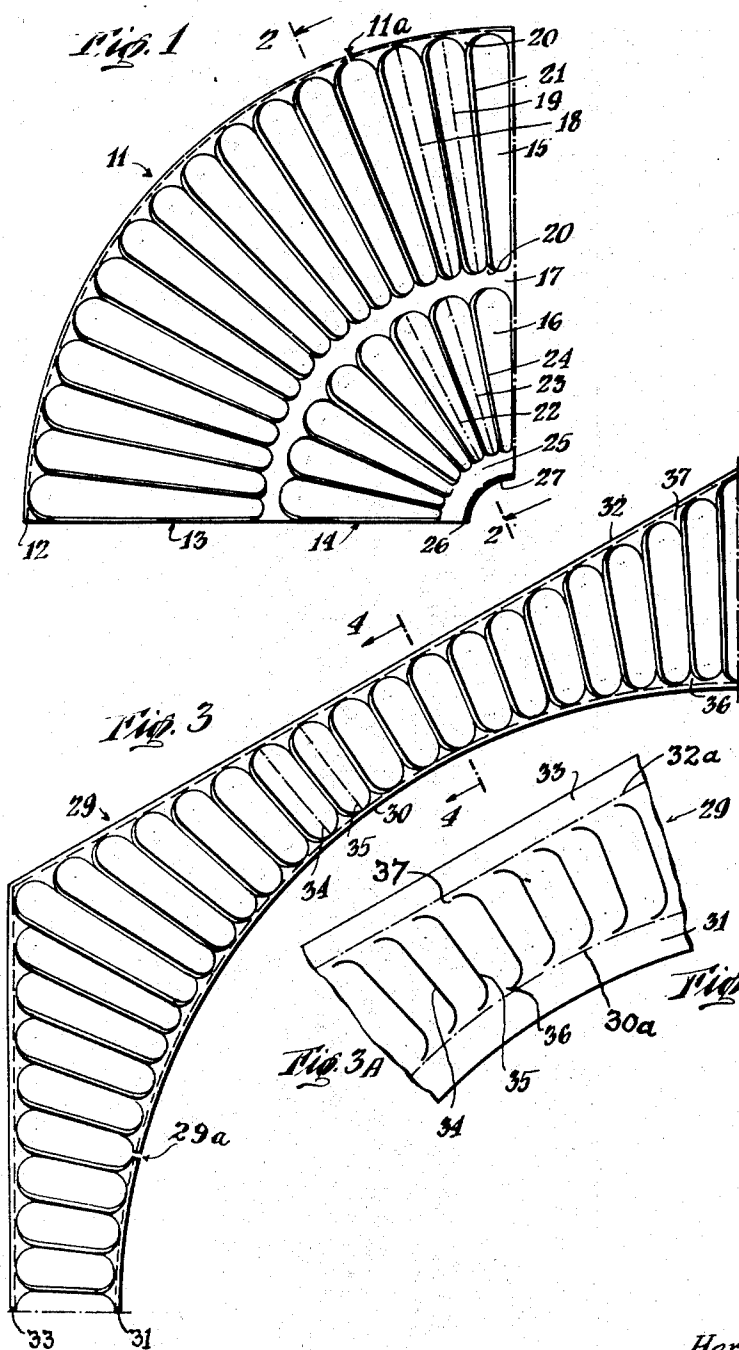
Dec. 5, 1950

H. F. BUSCHOW
HEAT EXCHANGE UNIT

2,532,288

Filed June 21, 1946

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

Fig. 5

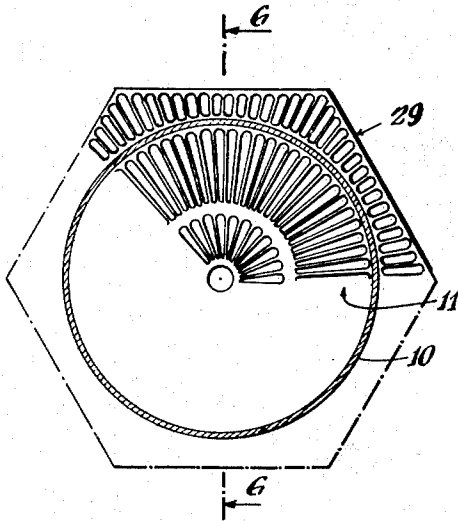


Fig. 6

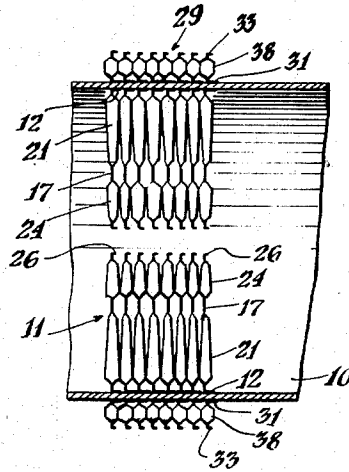


Fig. 7

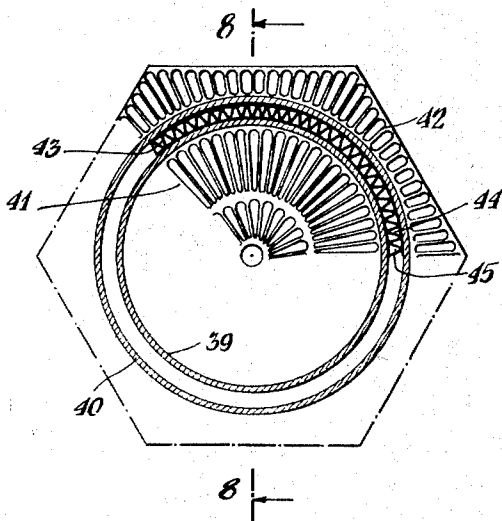
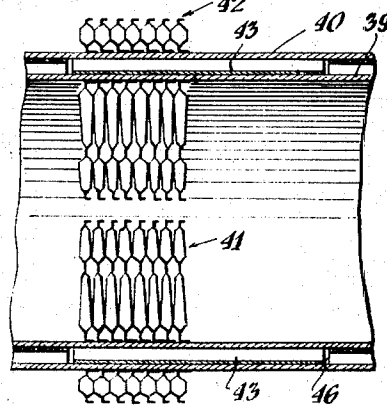


Fig. 8



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Fig. 9

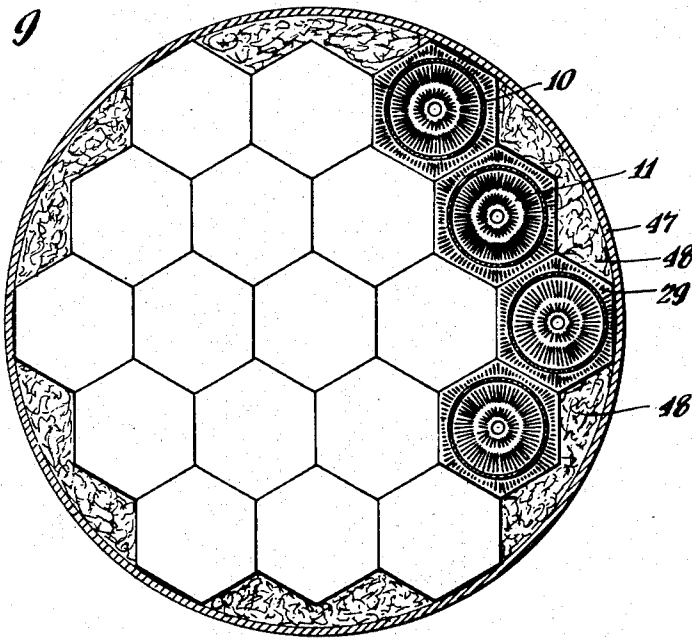
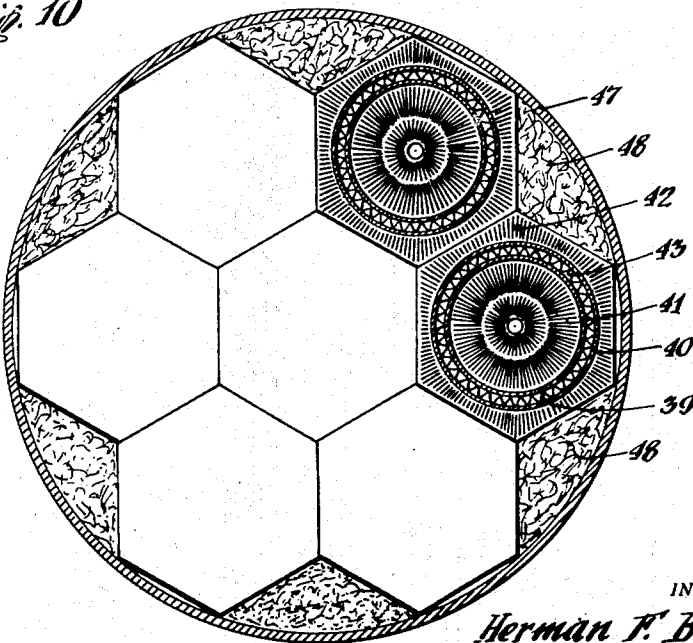


Fig. 10



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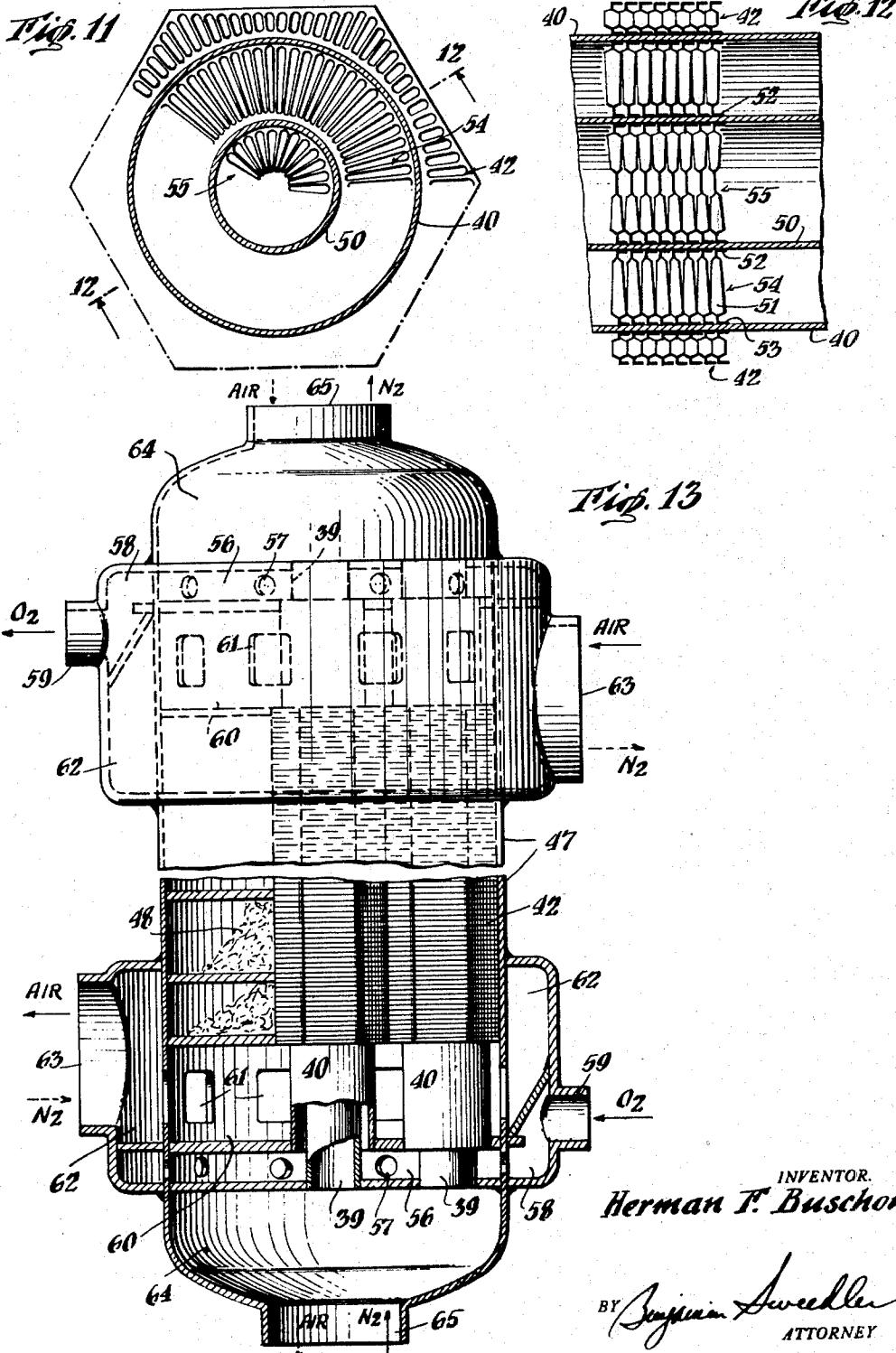
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HEAT EXCHANGE UNIT

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UNITED STATES PATENT OFFICE

2,532,288

HEAT EXCHANGE UNIT

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Application June 21, 1946, Serial No. 678,464

7 Claims. (Cl. 257-228)

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The present invention relates to an improved exchanger 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, and more particularly to the construction and design of the cold exchange surface areas providing for high cold transfer efficiency between the oxygen and nitrogen products of rectification on the one hand and the air on the other.

Cold accumulators or regenerators (hereinafter referred to as cold exchangers) of large cold-absorbing capacity are well known. In these cold exchangers, the relatively warm incoming air and the relatively cold outgoing oxygen and nitrogen 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 oxygen and nitrogen traversed during the preceding step in the process, the high-boiling impurities deposited in these spaces during the passage of the air therethrough being removed by sublimation during the subsequent flow therethrough of the products of rectification.

Heretofore, to provide for relatively high cold transfer efficiency, a cold exchanger has been employed comprising a cylindrical shell having therein a large number of tubes each provided with an interior accordion fin of foil-like metal and high heat conductivity disposed to form channels extending longitudinally through the tube and a somewhat similar accordion fin on the exterior thereof. These fins are usually made by folding thin sheets of copper into shape to produce the desired channels, and then bonding them to the interior and exterior walls of the tubes by coating these walls with soldering metal, placing the fin sections folded in the desired shape in contact with the solder coating, then placing the assembly in an oven and heating it to a temperature so that the solder on the tube walls wets the fins and later cooling, thereby obtaining a bond between the tube walls and the portions of the fins in flat contact therewith. This operation is arduous and time-consuming and greatly increases the cost of the exchanger.

Among the objects of this invention is to provide a cold exchanger having an exceptionally high area of cold exchanger surface per unit of volume and which can more readily be fabricated and assembled than heretofore known exchangers.

Another object is to provide a fin member

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which can readily be produced, for example, by a simple stamping operation, and this without waste of heat-conducting metal, and which can readily be assembled within a tubular unit to produce longitudinally extending channels for turbulent flow of gaseous media.

Still another object is to provide such exchanger which is more efficient in operation in that the cold transfer rate is considerably greater than in prior known exchangers.

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

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

Fig. 1 is a fragmentary (one-quarter) plan view of a preferred form of disk which may be arranged with other like disks to produce a fin for the interior of a tubular unit of a cold exchanger embodying this invention;

Fig. 2 is an enlarged section taken in a plane normal to the disk fin and passing through line 2-2 of Fig. 1;

Fig. 3 is a fragmentary (one-quarter) plan view of a preferred form of disk which may be arranged with other like disks to produce a fin on the exterior of a tubular exchanger unit embodying this invention;

Fig. 3A is a fragmentary plan view of the disk of Fig. 3 showing the disk as it appears after being cut from a foil-like sheet of metal and prior to the bending of the flanges and twisting of the vanes;

Fig. 4 is an enlarged section taken in a plane normal to the fin and passing through line 4-4 of Fig. 3;

Fig. 5 is a diagrammatic section through a preferred form of exchanger unit embodying this invention;

Fig. 6 is a fragmentary and diagrammatic vertical section through the exchanger unit of Fig. 5 taken through line 6-6 of Fig. 5;

Fig. 7 is a diagrammatic section through a modified form of exchanger unit embodying this invention;

Fig. 8 is a fragmentary and diagrammatic vertical section taken through line 8-8 of Fig. 7;

Fig. 9 is a diagrammatic section through a cold exchanger embodying this invention, involving a bundle or stack of the units of Figs. 5 and 6;

Fig. 10 is a diagrammatic section through a cold exchanger embodying this invention, in-

volving a bundle or stack of the units of Figs. 7 and 8;

Fig. 11 is a diagrammatic section through still another modified form of exchanger unit embodying this invention;

Fig. 12 is a fragmentary and diagrammatic vertical section through the exchanger unit of Fig. 11 taken through line 12—12 of Fig. 11; and

Fig. 13 is a composite view of a cold exchanger embodying this invention, the lower half being a vertical section through the exchanger and the upper half a front elevation.

The cold exchange fin embodying this invention may be formed on the interior or exterior, or both the interior and exterior, of a tube such as the oxygen, nitrogen or air tubes of a cold exchanger of the type disclosed and claimed in the Scheibel application Serial No. 641,276, filed January 15, 1946. Also such fins may be employed in the unit of the cold exchanger disclosed more fully in copending application of Keith, Serial No. 676,142, which unit involves two concentric tubes each provided with longitudinally extending channels for flow of gaseous media.

In accordance with this invention, such fins are made by assembling a multiplicity of plate-like members or disks by simply stacking them in desired relation on the interior or exterior of the tube, as hereinafter more fully described. Each plate-like member or disk may be made by stamping or otherwise shaping a foil-like sheet, say of a thickness of from .005" to .020", preferably about .008" to .010", of a material of high heat conductivity, preferably copper. For the fin adapted to be disposed within the interior of a tube such as tube 10, Figs. 5 and 6, which corresponds to an oxygen, nitrogen or air tube of the exchanger shown in the aforesaid Scheibel application, disks 11 of the type disclosed in Figs. 1 and 2 are employed.

Each disk 11 has an integral flange 12 on the periphery thereof and has in the face thereof two series 13 and 14 of radially-disposed closely-spaced passages 15 and 16. The two series of passages 15 and 16 are separated by a flat area or portion 17 of the disk of substantially circular outline, as indicated in Fig. 1. The passages 15 are each formed by cutting the disk along pairs of substantially radially disposed lines 18 and 19, and then deflecting or twisting the material between each pair of lines so as to move this material out of the plane of the disk about points 20 as pivots, thereby producing a vane or baffle 21 guiding the gaseous flow through each passage 15 forming the series 13. In like manner, the passages 16 are formed by deflecting the material between each pair of radial cuts 22 and 23 to form the baffles 24, one of which is provided for each passage 16 of the series 14. The central portion 25 of each disk is preferably shaped to provide a circular flange 26 defining a central relatively small circular opening 27 the cross sectional area of which is substantially less than that of the passages 15. The flange 26 defining this opening 27 increases the metal surface over which the gas sweeps and improves the heat transfer between the gas passing through the tube in which the disks are disposed and that passing outside of the tube of each unit forming the heat exchanger of this invention.

It will be noted each of the disks 11 may easily be fabricated by a simple stamping and cutting operation in which the radial cuts 18, 19, 22 and 23 are first produced, then the material there-

between deflected to form the series of radially disposed passages 15 and 16 and baffles 21 and 24 while concurrently producing the integral flanges 12 and 26. Further, it is important to note the production of these exchanger disks involves no waste of relatively expensive copper or other metal, all of the material being utilized, the portion deflected to form the baffles and to produce the passages functioning in the operation of the exchanger, as hereinafter described, to provide an exceptionally high surface area of heat exchanger metal per unit of volume.

The disks 11, as shown in Fig. 6, are disposed within tube 10 so that flange 12 on one disk substantially abuts the face of a contiguous disk within the tube 10. The two series 13 and 14 of openings 15 and 16, respectively, in effect, form longitudinally extending channels radially disposed within tube 10, flow through which is interrupted at closely-spaced intervals, i. e., between each pair of contiguous disks 11.

Fin 29 on the exterior of tube 10 is shown in detail in Figs. 3, 3A and 4. It is formed preferably of copper of foil-like thickness, say from .005" to .020" thick, and produced by a simple stamping operation. Each disk 29 has an interior circular outline 30 adapted to conform to the shape of the tube 10 on which it is mounted, the interior edge 30 having an integral flange 31. The opposite edge 32 of the disk is preferably of polygonal shape, e. g., a hexagonal shape as shown in Figs. 3 and 5. Edge 32 is provided with an integral flange 33. The face of the disk is cut along pairs of closely spaced lines 34 and 35, and the material between these lines deflected or twisted about points 36 and 37, as pivots, to produce baffles 38 which, as shown in Fig. 3, are at right angles to the plane of the disk fin 29. However, baffles 38 as well as baffles 21 and 24 of disk fin 11 may be set at an angle of from 60° to 90° with the plane of the disks. Preferably, the baffles are set at an angle of at least 85° with the plane of the disk. As shown in Fig. 3A, the cuts 34 and 35 have a slight curvature at their ends but straight cuts are frequently employed. For simplicity of exemplification, the baffles or vanes 21, 24 and 38 are shown as perfectly flat members attached to their respective disks at their ends. However, these vanes are usually not perfectly flat since they have volutes at their ends produced when the vanes are twisted out of the plane of the disks.

An economy of material may be effected by producing the disks 11 forming the fin for the interior of tube 10 and the disks 29 forming the fin for the exterior of the tube from the same sheet of copper or other foil-like material of high heat conducting properties, the disks 11 being formed from the material required to produce the circular opening 30 in the disks 29.

As shown in Figs. 5 and 6, a multiplicity of disks 29 are assembled on the exterior of tube 10 so that the flange 31 of one disk substantially abuts the face of a contiguous disk, thus producing a multiplicity of longitudinally extending channels formed by baffles 38.

The disks 11 may be readily disposed in the interior of the tube 10 by simply stacking them within the tube, it being only necessary to drop the disks 11 within the tubes since they are made of a diameter substantially the same as the internal diameter of the tube. In the case of the disks 29, it is only necessary to fit them over the exterior of the tube, the diameter of the circular opening defined by the circular edge 30 being sub-

stantially the same as the external diameter of tube 10. Since the disks are of foil-like metal of high heat conductivity, preferably copper, the flanges are flexible, i. e., have a certain amount of springiness. The spring-like character of the flanges permits them to accommodate small variations in the tube diameter, and yet result in substantially perfect contact between the flanges and the tube walls notwithstanding such variations. This feature reduces the cost of the exchanger since it reduces the tolerance which must be observed in producing the tubes and the time and labor expended in establishing good metal-to-metal contact between the walls of the tubes and the fins. Furthermore, to accommodate larger variations in the dimensions of the tubular member, the flange of the disk or plate-like fin which contacts the walls of the tubular member may be incised to permit contraction of interior fins or expansion of exterior fins. With disk 11, such a cut would be made between any two baffles 21 through flange 12 as indicated by 11a on Fig. 1, while with plate-like fin 29, such a cut would be made between any two baffles 38 through flange 31 as indicated by 29w on Fig. 3.

In the modification of Figs. 7 and 8, a tubular unit is shown forming one unit of a cold exchanger of the type disclosed in the aforesaid Keith application. This unit comprises a pair of concentric tubes 39 and 40. Inner tube 39 has therein a cold exchange fin 41 made by stacking within the tube a sufficient number of disks like disk 11 shown in Figs. 1 and 2. Outer tube 40 has on the exterior thereof a fin 42 produced in the same manner as the fin 29 on the exterior of tube 10, i. e., by stacking disks 42 on tube 40 with the flange of one disk abutting the face of a contiguous disk. Disposed in the annular space between tubes 39 and 40 is a fin 43 formed, for example, by folding, for each section of tube length, a strip of foil-like copper into the shape shown in Fig. 7 to provide alternate portions in contact with the inner wall of tube 40 and the outer wall of tube 39 connected by inclined portions, thereby forming two sets of substantially triangular longitudinally extending channels 44 and 45. Each strip of foil-like copper so folded may be approximately 2" wide and adjacent sections of folded strips 43 are preferably separated by narrow spaces or slots 46 to induce turbulence of the gas flowing through the longitudinally extending channels 44 and 45.

The exchanger units of Figs. 5 and 6 are assembled with other like units in a stack or bundle in a shell 47 (Fig. 9) provided with headers, as more fully disclosed in the aforesaid Scheibel copending application. The individual units within the shell 47 are in metal-to-metal contact with one another since the peripheries of the fins on the exterior thereof are disposed with metal-to-metal contact. The spaces between the units and the interior wall of the shell may be filled with packing 48, e. g., crumpled aluminum foil or wood blocks. The shell, if desired, may be made close-fitting, relative to the tube bundle, thereby eliminating such packing.

Similarly, the exchanger units of Figs. 7 and 8 are assembled with other like units in a stack or bundle in a shell 47 (Fig. 10) provided with headers, as more fully disclosed in the aforesaid Keith copending application as shown in Fig. 13. The individual units in the bundle of Figs. 10 and 13 have a small clearance between the peripheries of the fins on the exterior thereof, or may be in metal-to-metal contact.

In the heat exchanger unit of Figs. 7 and 8, the annular fin 43 of folded strips of foil-like metal may be replaced by fins of the disk type where the annular space between the concentric tubes is appreciable, say over about one-half inch. Such construction is shown in Figs. 11 and 12 in which 50 indicates an interior tube of high heat conductivity of smaller diameter than tube 39 of Figs. 7 and 8 thereby providing a larger annular space between inner tube 50 and exterior tube 40. Stacked on the exterior of tube 40, as in the case of Figs. 7 and 8, are a multiplicity of disks 42 with the flange of one disk abutting the face of a contiguous disk. Stacked within the annular space between tubes 40 and 50 are a multiplicity of disks 54 each having flanges 52, 53 along the two edges thereof, flange 52 of each disk being bonded, if desired, to the exterior of tube 50 and flange 53 to the interior wall of tube 40. Disks 54 are each provided with a series of radially disposed passages defined by vanes 51 in the same manner as the passages 15 are defined by the vanes 21 of the disk 11 hereinabove described. Stacked within the interior of tube 50 is a multiplicity of disks 55 with the flange of one disk in substantially abutting relation with the face of a contiguous disk as hereinabove more fully described in connection with the constructions of Figs. 5 to 8, inclusive.

Fig. 13 shows a preferred header and associated port arrangement for the exchanger units of Figs. 7 and 8. In the construction of this figure the shell 47 is provided at each end with (1) an oxygen header 56 communicating with the interior of tubes 40 and also communicating through ports 57 with a manifold 58 which is provided with a port 59, (2) a header 60 communicating with the channels formed on the exterior of tubes 40 by disks 42 and through ports 61 with a manifold 62 provided with a port 63, and (3) a header 64 communicating with the interior of tubes 39 and provided with a port 65. The flows of air and nitrogen during one cycle of the operation indicated by full line arrows in Fig. 13 take place through headers 60, 64, respectively, and upon reversal during the subsequent cycle of operation the flows of air and nitrogen, as indicated by the dotted line arrows, take place through the headers 64 and 60, respectively. Oxygen flows continuously through headers 56.

In the operation of the exchanger of Fig. 13, the flow of oxygen, as shown by the full line arrows, takes place through bottom port 59 into the manifold 58, thence through the ports 57 into the bottom header 56 through all of the tubes 40 in the assembly of units in the shell 47 into and through the top header 56, top ports 57 and manifold 58, the oxygen leaving through the top port 59. This flow is continuous throughout the operation of the exchanger, i. e., no reversal of oxygen flow takes place. During one period of operation, the nitrogen, as shown by the full line arrows on Fig. 13, enters through bottom port 65 into the header 64, flows through the interior of all of the tubes 39 and exits through top header 64 and top port 65. At the same time air enters through the top port 63, flows through manifold 62, through top ports 61 into the top header 60 into and through the channels formed by the disks 42 on the exterior of tubes 40 and exits through bottom header 60, bottom ports 61, manifold 62 and bottom port 63. The air, therefore, flows countercurrent to both the nitrogen and oxygen streams. Upon reversal, as indicated by the dotted line arrows, air flows through top port

65 into and through the top header 64, then through all of the tubes 39, exiting through the bottom header 64 and bottom port 65. During this reversal period nitrogen flows through bottom port 63, bottom manifold 62, bottom ports 61, bottom header 60, the channels formed by the disks 42 on the exterior of all of the tubes 40 and exits through top header 60, ports 61, manifold 62 and top port 63. As in the previous cycle of operation, air flows countercurrent to both the nitrogen and oxygen streams.

Exchangers made in accordance with this invention have been found to have a heat transfer rate of about 42 B. t. u.'s per square foot per hour, as compared to about 17 B. t. u.'s per square foot per hour of heat exchangers made with fins of the same metal (copper) but of the type employed prior to this invention.

The longitudinally extending passages produced by the disks when assembled within and without the tubes provide a symmetrical path for cold exchange between the air, the oxygen and nitrogen products of rectification flowing through each exchanger since, with the fins of this invention, these longitudinally extending passages are all disposed substantially radially relative to the tubes with which they are associated. This results in such greatly improved cold transfer between the gaseous media that it is not necessary to use copper tubes, but less expensive nickel steel tubes may be used and still obtain satisfactory cold exchange. The use of nickel steel tubes in an exchanger having a nickel steel shell, eliminates the necessity of providing such shell with expansion joints.

Where the disk fin 11 is required for tubes of small diameter, it may be made with a single series of radially disposed passages as shown in the case of disk 55 of Figs. 11 and 12 instead of two as shown in Fig. 1.

The tubes and fins of this invention may be bonded to each other by using tubes and/or fins which have been precoated with solder, heating the assembled tubes and fins to melt the solder and cooling after the liquid solder has established metal-to-metal contact between the tubes and fins.

It will be noted that exchangers with an exceptionally high surface area of heat transfer surface per unit of volume of exchanger space may be made with the fins of this invention. With these fins, employing tubes of from 1½ to 4" outside diameter, preferably about 2½" outside diameter, having a wall thickness of .035" to .125", preferably about .065", the exchanger may have from 300 to 500 square feet of exchanger surface per cubic foot of exchanger volume. The thorough contact between the flanges of the fins and the walls of the tubes results in high fin efficiency. The turbulent flow, caused by the interruptions in the passages at closely spaced intervals, i. e., between each pair of contiguous disks or plate-like fins, further improves the cold transfer efficiency of the exchanger. The exchanger is, therefore, of exceptionally high cold transfer efficiency. This makes it possible to have the volumetric space through which nitrogen on the one hand and air on the other flows relatively small, thereby minimizing reversal losses. Moreover, the flow through the interior of the tubes and in the channels defined by the fins on the exterior of the tubes takes place in a general longitudinal direction; hence, minimum pressure drop of fluid flowing there-through occurs.

In Figs. 5 and 7, the fins of this invention are shown associated with cylindrical tubes which are generally preferred. However, fins of this type may be made for use with hexagonal, square or other shaped tubes; hence, the terms "tube" and "tubular member" are used in a broad sense and are intended to include all such polygonal tubular members. Similarly, the external fins shown in Figs. 5 and 7 may assume any desired polygonal exterior outline other than the described hexagonal outline.

Since different embodiments of the invention can be made without departing from the scope of this invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A heat exchanger fin comprising a plate-like member of foil-like thickness of high heat conducting material having a central opening defined by an integral flange, a second integral flange on the periphery thereof and having in the face thereof a multiplicity of closely-spaced passages formed by cutting the plate-like member along closely spaced lines disposed substantially radially of said central opening and deflecting the material between contiguous lines to provide vanes defining the side walls of said passages, each of said vanes extending substantially equidistantly above and below the original plane of said plate-like member and having the opposite terminal ends thereof integral with the said flanges, substantially the entire surface of the face of said plate-like member being thus deflected without waste to produce said vanes and being thus utilized as a heat exchange surface, said member adapted to be stacked with at least one of said flanges of each member except one terminal member in substantially abutting relationship with the face of a contiguous member to provide a relatively large mass of high heat conducting material per unit of heat exchanger volume permeated by a multiplicity of said passages for flow of a fluid medium therethrough in surface contact with said vanes.

2. A heat exchanger fin comprising a disk from .005" to .020" thick of high heat conducting material, said disk having a central opening adapted to fit over a tube, an integral flange on the periphery thereof, a second integral flange defining said central opening and having in the face thereof a series of closely spaced passages disposed radially relative to said central opening, said passages being formed by cutting said disk along closely spaced lines disposed substantially radially of said central opening and deflecting the material between contiguous lines to provide vanes defining the side walls of said passages, each of said vanes extending substantially equidistantly above and below the original plane of said disk and having the opposite terminal ends thereof integral with said flanges, substantially the entire surface of the face of said disk being thus deflected without waste to produce said vanes and being thus utilized as a heat exchange surface, said disk adapted to be stacked with at least one of said flanges of each disk except one terminal disk in substantially abutting relationship with the face of a contiguous disk to provide a relatively large mass of high heat conducting material per unit of heat exchanger volume permeated by a multiplicity of said passages for flow of a fluid medium therethrough in surface contact with said vanes.

3. A heat exchanger fin comprising a plate of foil-like thickness of high heat conducting material having a periphery of hexagonal outline and a central opening adapted to fit over a tube, an integral flange about said central opening, a second integral flange defining said periphery of hexagonal outline, the face of said plate having a multiplicity of closely spaced passages formed by cutting the material of said plate along closely spaced lines disposed substantially radially of said central opening and deflecting the material between contiguous lines to provide vanes defining the side walls of said passages, each of said vanes extending substantially equidistantly above and below the original plane of said plate and having the opposite terminal ends thereof integral with said flanges, substantially the entire surface of the face of said plate in which said closely spaced lines are cut being thus deflected without waste to produce said vanes and being thus utilized as a heat exchange surface, said plate adapted to be placed with at least one of said flanges of each plate except one terminal plate in substantially abutting relationship with the face of a contiguous plate to provide a relatively large mass of high heat conducting material per unit of heat exchanger volume permeated by a multiplicity of said passages for flow of a fluid medium there-through in surface contact with said vanes.

4. A heat exchanger unit comprising a tubular member having thereon a multiplicity of disks of foil-like thickness of high heat conducting material, each disk having a central opening defined by an integral flange through which said tubular member passes and an integral flange on the periphery thereof, at least one of said flanges of each disk except one terminal disk being in substantially abutting relationship with the face of a contiguous disk and each disk having in the face thereof a series of closely spaced passages disposed substantially radially of said central opening, said passages being formed by cutting the disk along closely spaced lines disposed substantially radially of said central opening and deflecting the material between contiguous lines to provide vanes defining the side walls of said passages, each of said vanes extending substantially equidistantly above and below the original plane of said disk and having the opposite terminal ends thereof integral with the said flanges, substantially the entire face of said disk being thus deflected without waste to produce said vanes and being thus utilized as a heat exchange surface, the vanes of each disk having the edges thereof positioned close to the edges of the vanes of the disks on opposite sides thereof, thereby providing a relatively large mass of said high heat conducting material per unit of exchanger volume.

5. A heat exchanger unit comprising a tubular member having thereon a multiplicity of plate-like members, each of foil-like thickness and of high heat conducting material, each such member having a central opening defined by an integral flange through which said tubular member passes, a periphery of polygonal shape and an integral flange on said polygonal periphery, said members being arranged on the tubular member so that at least one of said flanges of each member except one terminal member is in substantially abutting relationship with the face of a contiguous member, the face of each member having a multiplicity of closely spaced passages separated by vanes, each of said vanes being formed by cutting the plate-like member along closely spaced lines disposed substantially radially of said central open-

ing and deflecting the material between contiguous lines, each of said vanes extending substantially equidistantly above and below the original plane of said plate-like member and having the terminal ends thereof integral with said flanges, substantially the entire surface of the portion of said plate-like member in which said closely spaced lines are cut being thus deflected without waste to produce said vanes and being thus utilized as a heat exchange surface, the vanes of each member having the edges thereof positioned close to the edges of the vanes of the plate-like members on the opposite sides thereof, thereby providing a relatively large mass of said high heat conducting material per unit of exchanger volume.

6. A heat exchanger comprising a shell, a multiplicity of individual units in said shell for flow of three fluid streams therethrough, the individual units each having an outer polygonal outline and being disposed in said shell in nested relation with the outer surface of interior units disposed close to and in alignment with the outer surfaces of contiguous units, each unit comprising a pair of concentric tubes in spaced relation for flow of one stream through the inner tube, a second stream through the annular space between the two tubes and a third stream through the space between the outer tubes and said shell, the inner tube of each unit having therein a multiplicity of disks of foil-like thickness of high heat conducting material, each disk having an integral flange on the periphery thereof, the disks being so arranged that the flange of each disk except one terminal disk is in substantially abutting relationship with the face of a contiguous disk, is in contact with the inner wall of the inner tube, and each disk having in the face thereof a multiplicity of closely spaced passages formed by cutting the disk along closely spaced lines disposed substantially radially of the periphery of said disk and deflecting the material between contiguous lines to provide vanes defining the side walls of said passages, each of said vanes extending substantially equidistantly above and below the original plane of said disk, substantially the entire surface of the face of said disk being thus deflected without waste to produce said vanes and being thus utilized as a heat exchange surface, the vanes of each disk having the edges thereof positioned close to the edges of the vanes of the disks on opposite sides thereof, thereby providing a relatively large mass of said high heat conducting material per unit volume of inner tube, each inner tube of each unit having on the exterior thereof a multiplicity of disks of foil-like thickness of high heat conducting material, each such disk having a central opening defined by an integral flange through which the inner tube passes and an integral flange on the periphery thereof, the disks being so arranged that at least one flange of each disk except one terminal disk is in substantially abutting relationship with the face of a contiguous disk and each disk having in the face thereof a multiplicity of closely spaced passages formed by cutting the disk along closely spaced lines substantially radially of its periphery and deflecting the material between contiguous lines to provide vanes defining the side walls of said passages, each of said vanes extending substantially equidistantly above and below the original plane of said disk and having the terminal ends thereof integral with said flanges, substantially the entire surface of the face of said disk being thus deflected without waste to produce

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said vanes and being thus utilized as a heat exchange surface, the vanes of each member having the edges thereof positioned close to the edges of the vanes of the members on opposite sides thereof, and the outer tube of each unit having on the exterior wall thereof a multiplicity of plates of foil-like thickness of high heat conducting material, each plate having an outer polygonal outline defined by an integral flange and a central opening defined by an integral flange through which the outer tube passes, the plates being so arranged that at least one flange of each plate except one terminal plate is in substantially abutting relationship with the face of a contiguous plate and each plate having in the face thereof a multiplicity of closely spaced passages formed by cutting the plate along closely spaced lines substantially radially of the central opening therein and deflecting the material between contiguous lines to provide vanes defining the side walls of said passages, each of said vanes extending substantially equidistantly above and below the original plane of said plate and having the terminal ends thereof integral with said flanges, substantially the entire surface of the face of said plate being thus deflected without waste to produce said vanes and being thus utilized as a heat exchange surface, the vanes of each plate having the edges thereof positioned close to the edges of the vanes of the plates on opposite sides thereof.

7. A heat exchanger comprising a shell, a multiplicity of individual units in said shell for flow of three fluid streams therethrough, the individual units each having an outer hexagonal outline and being disposed in said shell in nested relation with the outer surfaces of interior units disposed close to and in alignment with the outer surfaces of contiguous units, each unit comprising a pair of concentric tubes in spaced relation, the inner tube of each unit having a multiplicity of circular metallic disks thereon each having a thickness of from .005" to .020", each disk having an integral flange on the periphery thereof, the disks being so arranged that the flange of each disk except one terminal disk is in substantially abutting relationship with the face of a contiguous disk and is in contact with the inner wall of the inner tube and each disk having in the face thereof a multiplicity of closely spaced passages formed by cutting the disk along closely spaced lines disposed substantially radially of the periphery of said disk and deflecting the material between contiguous lines to provide vanes defining the side walls of said passages, each of said vanes extending substantially equidistantly above and below the original plane of said disk, substantially the entire surface of the face of said disk being thus deflected without waste to produce said vanes and being thus utilized as a heat exchange surface, the vanes of each disk having the edges thereof positioned close to the edges of the vanes of the disks on opposite sides thereof; each inner tube of each unit having on the exterior wall thereof a multiplicity of circular metallic disks each hav-

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ing a thickness of from .005" to .020" and each disk having a central opening defined by an integral flange through which the inner tube passes and an integral flange on the periphery thereof, the disks being so arranged that at least one flange of each disk except one terminal disk is in substantially abutting relationship with the face of a contiguous disk and each disk having in the face thereof a multiplicity of closely spaced passages formed by cutting the disk along closely spaced lines substantially radially of its periphery and deflecting the material between contiguous lines to provide vanes defining the side walls of said passages, each of said vanes extending substantially equidistantly above and below the original plane of said disk and having the terminal ends thereof integral with said flanges, substantially the entire surface of the face of said disk being thus deflected without waste to produce said vanes and being thus utilized as a heat exchange surface, the vanes of each member having the edges thereof positioned close to the edges of the vanes of the members on opposite sides thereof; and the outer tube of each unit having on the exterior wall thereof a multiplicity of metallic plates of a thickness of from .005" to .020", each plate having an outer hexagonal outline defined by an integral flange and a central opening defined by a flange through which the outer tube passes, the plates being so arranged that at least one flange of each plate except one terminal plate is in substantially abutting relationship with the face of a contiguous plate and each plate having in the face thereof a multiplicity of closely spaced passages formed by cutting the plate along closely spaced lines substantially radially of said central opening and deflecting the material between contiguous lines to provide vanes defining the side walls of said passages, each of said vanes extending substantially equidistantly above and below the original plane of said plate and having the terminal ends thereof integral with said flanges, substantially the entire surface of the face of said plate being thus deflected without waste to produce said vanes and being thus utilized as a heat exchange surface, the vanes of each member having the edges thereof positioned close to the edges of the vanes of the plates on opposite sides thereof.

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