Sept. 4, 1951 J. A. BURNS ET AL 2,566,310

TRAY TYPE HEAT EXCHANGER

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Fig. 1

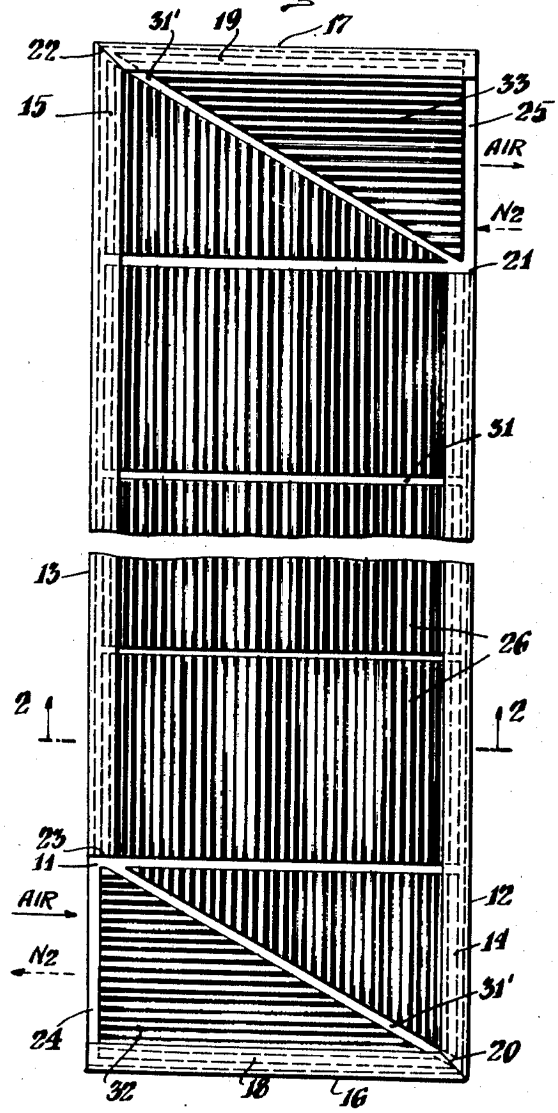


Fig. 3

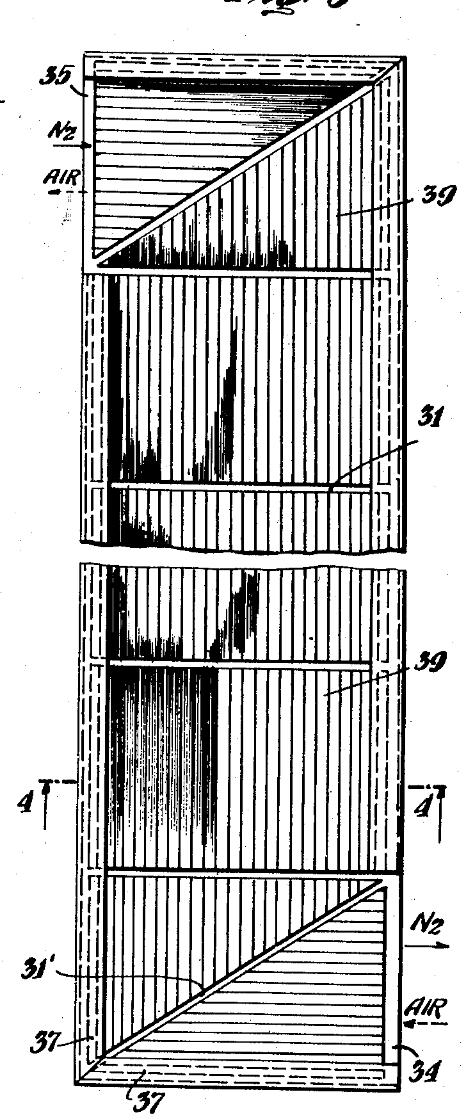


Fig. 2

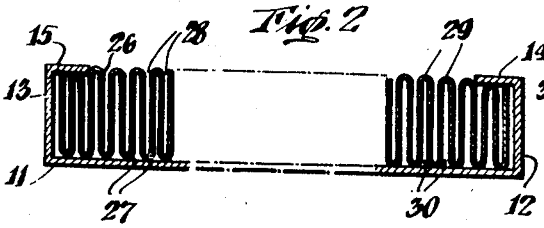
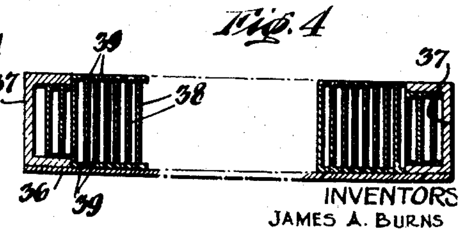


Fig. 4



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TRAY TYPE HEAT EXCHANGER

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Fig. 5

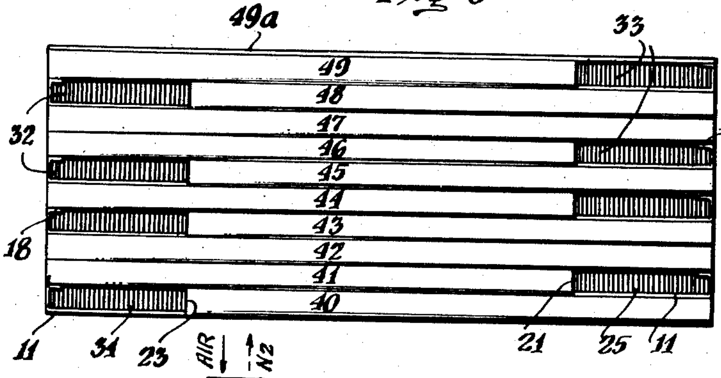
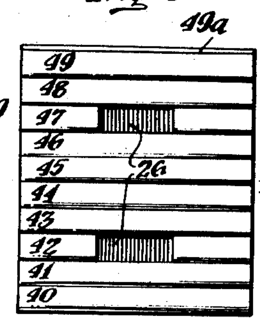


Fig. 6



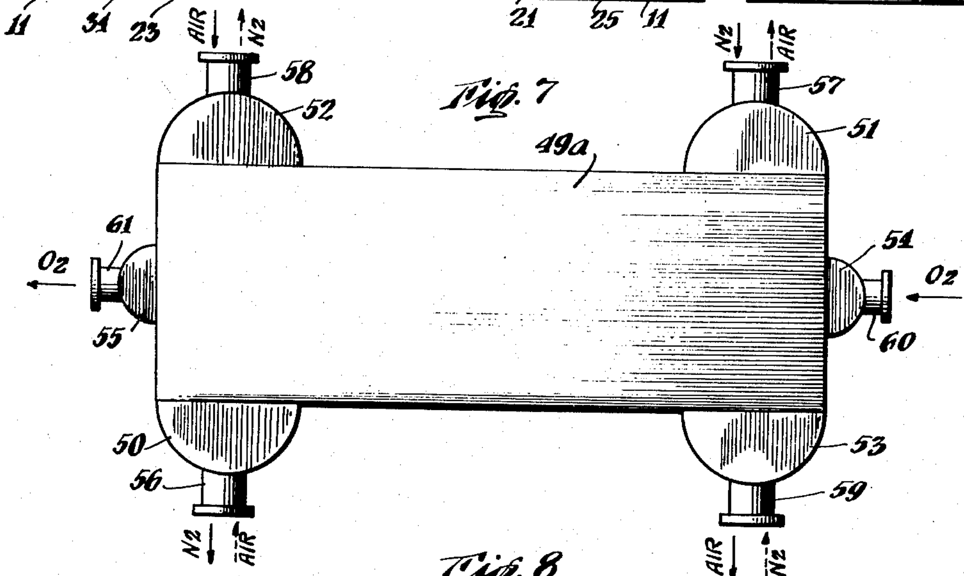


Fig. 8

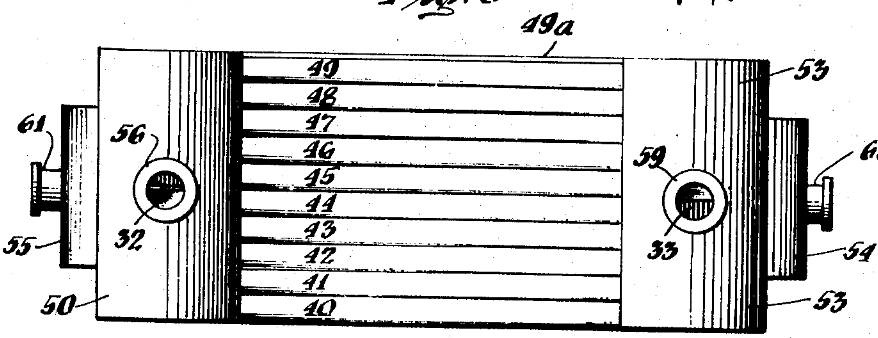


Fig. 9

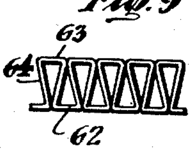
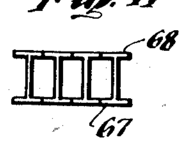


Fig. 10

Fig. 11



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2,566,310

UNITED STATES PATENT OFFICE

2,566,310

TRAY TYPE HEAT EXCHANGER

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Application January 22, 1946, Serial No. 642,594

15 Claims. (Cl. 257—245)

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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.

Heat accumulators or regenerators (hereinafter referred to as heat exchangers) of large cold-absorbing capacity are well known. The relatively warm incoming air, which may be at a pressure of from 70 to 85 pounds per square inch gauge or even higher pressures, and the relatively cold outgoing oxygen and nitrogen products of rectification at a pressure up to about 10 pounds gauge, usually up to about 5 pounds gauge, are alternately passed through these exchangers 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. Such heat exchangers must provide for high cold transfer efficiency and high throughputs and yet the volumetric space through which the fluids flow must be relatively small in order to minimize power loss since upon each reversal the volume of cold air in each exchanger is lost and must be again replaced and also in order to avoid undue dilution of (*a*) the compressed air stream flowing to the rectification system with nitrogen, and (*b*) the nitrogen stream with air, which dilution necessarily takes place upon each reversal of flow, causing the air stream to flow through the packing-filled spaces containing nitrogen, and the nitrogen stream to flow through the packing-filled spaces containing air left therein from the streams of nitrogen and air, respectively, passed therethrough during the preceding step of the process. Such heat exchangers as heretofore constructed have usually involved pipes or tubes provided with fins on the interior and/or exterior thereof to obtain the desired high cold transfer efficiency and hence have been relatively expensive in design and construction.

Among the objects of this invention are to provide a heat exchanger which is exceptionally inexpensive in design and construction, which does not involve the utilization of relatively expensive tubular or pipe-like members, which requires an exceptionally low weight of relatively expensive high heat conducting metal with respect to the

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amount of heat transferred, which has a relatively small overall volume thereby minimizing reversal losses, and which provides for the flow of oxygen and nitrogen and air in heat exchange relation with the periodic reversal of the nitrogen and air streams to effect removal of sublimation of any condensible matter removed from the air stream during the preceding step of the process.

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 plan view of one type of tray which may be used in building up an exchanger embodying this invention;

Figure 2 is a vertical section taken along line 2—2 of Figure 1;

Figure 3 is a plan view of another type of tray which may be used with the type of tray shown in Figure 1 to produce an exchanger embodying this invention; this figure also shows an alternative form of fin for effecting a higher rate of cold transfer and for reinforcing the bases of adjacent trays to enable them to withstand the pressure of the air stream flowing therethrough;

Figure 4 is a section through the tray of Figure 3 taken along the line 4—4;

Figure 5 is a side elevation of a stack of ten trays of the type shown in Figures 1 and 2, this figure in the interests of clarity omitting the inlet and outlet headers associated with the stack;

Figure 6 is an end view of the stack of trays forming the exchanger shown in Figure 5;

Figure 7 is a plan view of an exchanger embodying the invention showing the arrangement of inlet and outlet headers for flow of oxygen, nitrogen and air through the exchanger;

Figure 8 is a side elevational view of the exchanger shown in Figure 7; and

Figures 9, 10 and 11 are vertical sections through alternative forms of fins which may be used in lieu of those shown in Figures 2 and 4.

The exchanger of this invention is built up from a plurailty of trays or sections which may conveniently be regarded as of three types, one for the alternate flow of air and nitrogen therethrough having inlet and outlet ports in side walls near diagonally opposite corners of the tray, the second for the alternate flow of nitrogen and air therethrough having inlet and outlet ports in side walls near diagonally opposite sides of the tray which corners are on the opposite sides of the tray relative to the sides of the trays of the first type provided with inlet and outlet ports and the third for the flow of oxygen therethrough having inlet and outlet ports in the end walls thereof, the first and second trays being arranged in pairs for periodic reversal of flow, i. e., upon each reversal of flow the nitrogen is passed through the tray or section of each pair through which had previously passed the air and the air is passed through the tray or section of the pair through which had previously passed the nitrogen.

Figure 1 shows an air or nitrogen tray of the first type which may be of oblongular shape. This tray is made by bending or folding a flat metal sheet of high heat conductivity, the sheet being of a thinness such that without added support or reinforcement it is probably incapable of withstanding the pressure of the air stream passing thereover, which pressure may be of the order of 70 to 85 pounds per square inch gauge. This metal sheet forming the base 11 of the tray is desirably from 0.008 to 0.125 inch in thickness. The marginal side and end portions of the sheet are bent to form the sides 12 and 13 with associated flanges 14 and 15 and ends 16 and 17 with associated flanges 18 and 19, respectively. When the trays are assembled in a stack, as hereinafter more fully disclosed, the side walls 12 and 13 and end walls 16 and 17 form the outer walls of the exchanger. The flanges 14 and 18 form a miter joint 20 at one end thereof, the other end of flange 18 and side 16 terminating flush with the plane of side 13 of the tray and the other end of flange 14 as well as side 12 terminating short of end wall 17 as at 21. At one end, flanges 15 and 19 form a miter joint 22 at the corner of the tray diagonally opposite the corner at which the miter joint 20 is positioned. The other end of flange 15 as well as side 13 terminates short of end wall 16 as at 23 and the other end of flange 19 and side 17 terminates flush with the plane of side wall 12. Side wall 13 near one corner of the tray is cut away to provide a port 24 and side wall 12 is cut away at the diagonally opposite corner of the tray to form a port 25.

Sections of corrugated foil-like metal 26, the corrugations being closely spaced, having base portions 27 defining the base of channels 28 and portions 29 defining the tops of a second series of channels 30 are positioned in each tray with the portions 27 and 29 brazed or soldered, respectively, to the base of one tray and the underside of an overlying tray so that this foil-like member forms a firm bond at a multiplicity of closely spaced points with the base of one tray and the underside of the base of an overlying tray. The side walls of the fin sections 26 defining the channels 28 and 30 as well as the flat bottom and top portions 27 and 29 serve to conduct heat and also to reinforce and strengthen the bases of the trays so that they are capable of withstanding the pressure of the air stream flowing therethrough. The channels 28 and 30 are of such width that the distance from longitudinal center line of one channel to longitudinal center line of the next channel is desirably within the range of 0.06 to 0.40 inch, preferably about 0.10 inch.

The channels 28 and 30 extend in the same longitudinal direction as the tray and are interrupted at spaced intervals by narrow slots or spaces 31 which may be from 1/16 to 1/4 inch wide, preferably about 1/8 inch wide. Wider slots may be used but are wasteful of exchanger metal and volume. The distance between adjacent slots in the longitudinally extending channels 28 and 30 may be from 4 to 12 inches, preferably about 8 inches. The sections of foil-like metal forming the heat-conducting fin are disposed in position and secured in position by brazing or soldering the flat portions 27 and 29 to the trays. With this construction turbulent gas flow takes place through the channels 28 and 30. In other words, the spaced slots 31 induce turbulence in the gas streams which would otherwise have a streamlined or transitional flow. The distance between the slots 31 is such that at about the point where the turbulence induced by one slot 31 disappears, there is another slot to make the stream turbulent again.

The port 24 is provided with a fin section 32 of the same design and construction as the fin sections 26, hereinabove described, except that it is disposed at right angles to sections 26. Section 32 and the nearest section 26 are separated by a narrow diagonal slot 31' dimensioned like slots 31. It will be noted from Figure 1 that from top to bottom of section 32 its channels increase in length; the longest channel is contiguous to the end wall 16 and the shortest channel contiguous to end 23 of flange 15. In like manner, the port 25 is provided with a fin section 33 similar to section 32 but disposed so that the longest channel therein is disposed contiguous to end 17 and the shortest channel contiguous to end 21 of flange 14. With this arrangement of fin sections the flow paths formed by the channels 28 and 30 and the communicating channels of sections 32 and 33 at right angles thereto in the ports 24 and 25 are all of the same length since the longest channel in the port 24 is associated with the longitudinally extending channel which communicates with the shortest channel in the port 25, the difference in lengths of the channels in the port 24 being compensated for by the difference in lengths of the channels in the port 25 as is evident from Figure 1. The top and bottom flat portions of the fin sections 32 and 33 are brazed or soldered to the bases of the trays between which they are disposed, thus reinforcing the portions of these bases defining the ports 24 and 25, respectively.

The sections of foil-like metal forming the heat-conducting and reinforcing fins are made of high heat-conducting material and desirably are from 0.005 to 0.060 inch thick, preferably about 0.008 inch thick. Because of the thinness of the fins, their close spacing and high thermal conductivity, the exchanger has exceptionally high cold transfer capacity. Furthermore, as above indicated, the fins function as a support for the bases of the trays, reinforcing these bases so that they are capable of withstanding the pressure of the air stream flowing thereover, which stream is the stream of highest pressure. Hence in the construction of this invention, all parts of the exchanger have a cold transfer function, i. e., the parts which are necessary for structural reasons, for example, to reinforce the thin metal plates defining the walls of the passages through which the gases flow, are so designed that they not only serve this function, but also aid in the exchange of cold between the gaseous media flowing through the exchanger.

The trays of Figure 1 are arranged in a stack in alternate relation with other trays which differ from those of Figure 1 in that, as shown in Figure 3, the ports 34 and 35 near the diagonally opposite corners are disposed in side walls opposite to those having such ports in Figure 1. In the tray of Figure 3, port 34 is disposed on the opposite side relative to the side of the tray of Figure 1 having the port 24, and the port 35 is disposed on the opposite side relative to the side of the tray of Figure 1 having the port 25. Otherwise the construction of these two types of trays may be in the same. It will be noted that port 35 is in a corner diagonally opposite to that containing the port 34 in the tray of Figure 3, and likewise the port 25 of the tray of Figure 1 is diagonally opposite to port 24. It will be further noted that ports 24 and 34 of the trays of Figures 1 and 3 occur on opposite sides but at the same end of the trays, namely, the lower end as shown in these figures, and the ports 25 and 35 also occur at opposite sides but the same end, namely, the upper end.

In the modification shown in Figures 3 and 4, instead of making the tray by bending a flat sheet of metal to the shape shown in Figures 1 and 2, a thin metal sheet 36 is employed for the base of the tray, which metal sheet is desirably 0.008 to 0.125 inch thick, preferably about 0.030 inch thick. The side and end walls and flanges of the tray are formed by brazing or otherwise securing channel bars 37, such as shown in Figure 4, along the sides and ends of the base plate 36 leaving open the areas at the sides corresponding to the ports 34 and 35. The channel bars may have top and bottom flanges about ⅜ inch wide, the top flanges forming the flanges corresponding to flanges 14, 15, 18 and 19 of the tray of Figure 1 and the bottom flanges being welded or otherwise bonded to the flat plate 36 to form the tray assembly. These channel bars 37 desirably are from 0.06 to 0.40 inch, thick, preferably about 0.125 inch thick. The longitudinally extending channels corresponding to the channels 28 and 30 of Figure 2 are formed, as shown in Figure 4, by a multiplicity of individual channel bars 38, which desirably are from 0.005 to 0.006 inch thick, preferably about 0.008 inch thick, approximately ⅝ inch high, and have top and bottom flanges 39 approximately ⅛ inch wide. The bottom flanges are soldered or brazed to the base plate of one tray and the top flanges are soldered or brazed to the underside of an overlying tray, the channel bars 38 being so arranged that the flanges of one channel bar abut the back of a contiguous channel bar, as shown in Figure 4.

The third type of tray, namely, the oxygen tray may be of the same construction as shown in Figure 1 or 3 differing therefrom in that the side walls are completely closed throughout the full extent thereof and inlet and exit ports are provided in the opposite end walls. Also, of course, all of the fin sections are arranged so that the channels formed by them are parallel (none at right angles) to the length of the tray.

The trays are arranged in stacks, trays of the type of Figure 1 alternating with those having ports as shown in Figure 3 and, at spaced intervals, this alternate arrangement of trays is interrupted by the positioning in the stack of an oxygen tray which, as above described, has ports in the end walls only and not in the side walls. The height of each tray, i. e., the spacing between the base plates of contiguous trays within the stack desirably is within the range of ¼ to 1 inch, preferably about ½ inch. The side flanges 14 and 15 and the end flanges 18 and 19 of each tray may be welded or otherwise bonded to the underside of the overlying tray and a plate welded to the flanges of the top tray of the stack to complete the assembly of trays. Each tray may be formed from a single flat sheet of metal as described in connection with Figure 1, or by associating a flat sheet of thin metal with channel bars as described in connection with Figure 3 and may have the interrupted channels formed therein as described in connection with Figure 1 or Figure 3 or by use of other shaped fins such, for example, as those hereinafter described in connection with Figures 9, 10 and 11.

One possible arrangement of trays is shown in Figures 5 and 6. In this construction, the trays 40, 43, 45 and 48 correspond to a tray having ports as shown in Figure 3, the trays 41, 44, 46 and 49 in the stack have ports as shown in Figure 1, and trays 42 and 47 have ports in the end walls only as is evident from Figure 6. The trays 40 and 41, 43 and 44, 45 and 46 and 48 and 49 constitute pairs of trays for reversal of flow of air and nitrogen therethrough. A plate 49*a* is brazed to the top tray 49 to finish this tray.

As shown in Figures 7 and 8, headers are provided at the opposite side corners of the stack of trays. The ports 34 of trays 40, 43, 45 and 48 communicate with the header 50 which extends along one side wall of the stack of trays from top to bottom of the stack, and ports 35 of these trays communicate with a header 51 which extends along the other side wall of the stack from top to bottom thereof. The ports 24 of the trays 41, 44, 46 and 49 communicate with a header 52 disposed directly opposite header 50 at the other side wall of the stack of trays, and the ports 25 of these trays communicate with a header 53 disposed near the diagonally opposite corner of the stack of trays. As shown in Figure 8, the headers 50 and 53 as well as headers 51 and 52 extend from top to bottom of the stack. At the opposite ends of the stack, headers 54 and 55 are provided which communicate, respectively, with the inlet and outlet ports of trays 42 and 47. Each of the headers 50, 51, 52, 53, 54 and 55 is provided with a communicating main 56, 57, 58, 59, 60 and 61, respectively.

In lieu of the types of fins shown in Figures 2 and 4, other fins, such as shown in Figures 9, 10 and 11 may be used. Figure 9 shows a continuous type of foil of the same thickness as that of Figures 1 and 2 but shaped to provide two sets of longitudinally extending channels which are substantially triangular in cross-section. These channels are defined by bases 62 and 63 and sides 64, the bases 62 and 63 providing flat portions for soldering or brazing to, respectively, the base of one tray and the underside of an overlying tray thereby establishing a firm bond between the foil and contiguous trays.

The modification of Figure 10 involves individual elements of foil-like metal for forming the fin sections. Each element is of Z-shape in cross-section providing a flat base 65 and top 66 which can be soldered or brazed to contiguous trays, the elements being disposed in closely spaced relation as shown in Figure 10.

In the modification of Figure 11, an I-shaped member is shown having a flat base 67 and top 68 to permit ready soldering or brazing to the trays. These individual members may be arranged in closely spaced relationship as shown in this figure and may be dimensioned and of a thickness the same as the elements 38 of Figure 4.

The material of construction employed in making the trays and the fins, as above indicated, should be of good thermal conductivity. Copper is the preferred material; nickel steel containing approximately 8% nickel, aluminum or brass may be used.

In operation, as indicated by full line arrows, flow of oxygen takes place through main 60, into header 54, into and through the longitudinal channels in trays 42 and 47, and thence through header 55 at the other end of the exchanger, the oxygen leaving through main 61. This flow is continuous throughout the operation of the exchanger, i. e., no reversal of the oxygen flow takes place. During one period of operation, as indicated by the solid arrows, nitrogen enters through main 57 into header 51, flows through the channels in the trays 40, 43, 45 and 48, and exits through the header 50 and communicating main 56. At the same time, relatively warm air enters through main 58 and header 52, flows through the trays 41, 44, 46 and 49, and exits through the header 53 and main 59. Upon reversal during a succeeding period of operation, as shown by the dotted line arrows, air flows through main 56, header 50, the channels in trays 40, 43, 45 and 48, and exits through the header 51 and main 57, while nitrogen flows through the main 59, header 53, through the trays 41, 44, 46 and 49, and exits through the header 52 and main 58.

While in the drawings an exchanger having ten trays is shown, it will be understood that this is only for purposes of illustration and that a larger number of trays may be employed, the number used depending upon the desired capacity of the exchanger.

It will be noted the heat exchanger involving as it does the use of flat plates, which are comparatively inexpensive, to produce the trays and simple foil for the production of the fins defining longitudinally extending channels is exceptionally inexpensive to construct. With the design of fins herein described, with plates and fins of the thinness mentioned and with the trays spaced closely together as disclosed, namely, about ½ inch apart in the preferred embodiment, the fins also spaced closely together, namely, about 1/16 inch apart in the preferred embodiment, the exchanger may readily be built with a cold exchanger surface of from 250 to 500 square feet per cubic foot of exchanger volume. This factor and the turbulent flow caused by the spaced slots in the longitudinally extending channels and the flat surface contact between the fins and the trays results in an exchanger of exceptionally high cold transfer efficiency. Furthermore, the volumetric space through which the nitrogen and the air flow may be made very small thereby minimizing reversal losses.

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 for flow therethrough in indirect heat exchange relationship of oxygen, nitrogen and air, comprising a plurality of trays stacked in super-imposed relationship with the base of one tray defining the top of an underlying tray, each tray comprising a longitudinally extending base, a pair of side walls and a pair of end walls, the base portion of each tray being of thin metal of high heat conductivity, the thinness of the metal being such that the base is incapable of withstanding the pressure of the air stream unless added support is provided for said base, a multiplicity of fins of high heat conductivity disposed in each tray in closely spaced relationship to define a plurality of passages extending in the same longitudinal direction as the length of the tray, said fins in each tray having a multiplicity of closely spaced portions fastened to the base of the tray in which they are disposed and to underside of the base of an overlying tray to reinforce the base and enable it to withstand the pressure of said air stream, said trays of said stack through which oxygen flows having inlet and outlet ports in the opposite end walls thereof, the remaining trays in said stack being arranged in the stack in pairs with one tray of each said pair serving for flow of air therethrough and the other tray of the pair for flow of nitrogen during one period of operation and upon reversal the air flowing through the tray through which had flowed the nitrogen and the nitrogen flowing through the tray through which had flowed the air, one tray of said pair having a pair of ports in opposite side walls near diagonally opposite corners and the other tray in said pair having a pair of ports in opposite side walls near diagonally opposite corners, the said pair of trays thus having a pair of ports disposed on the same end of the stack but on opposite sides thereof and a second pair of ports disposed on the other end of the stack but on opposite sides thereof.

2. A heat exchanger as defined in claim 1, in which the fins are interrupted at spaced intervals along the length thereof to provide narrow slots which cause turbulent flow of the gaseous media flowing through trays.

3. A heat exchanger as defined in claim 1, in which reinforcing fins are disposed in said ports arranged to provide passage at right angles to and communicating with the passage in the trays, the flow paths thus formed in each tray be the intercommunicating passages being all of substantially the same length.

4. A heat exchanger for flow therethrough in indirect heat exchange relationship of oxygen, nitrogen and air, comprising a plurality of trays stacked in superimposed relation, the base of one tray defining the top of an underlying tray, each tray comprising a longitudinally extending base, a pair of side walls and a pair of end walls, the wall thickness of the base of each tray being within the range of 0.008 inch to 0.125 inch, a multiplicity of fins of high heat conductivity disposed in each tray to define a plurality of passages extending in the same longitudinal direction as the length of the tray, the distance between the longitudinal center line of one passage to the longitudinal center line of the next passage being within the range of 0.06 to 0.40 inch, said fins having flat portions securely bonded to the trays to reinforce the same, said trays of said stack through which oxygen flows having inlet and outlet ports in the opposite end walls thereof, the remaining trays in said stack being arranged in the stack in pairs with one tray of each said pair serving for flow of air therethrough and the other tray of the pair for flow of nitrogen during one period of operation and upon reversal the air flowing through the tray through which had flowed the nitrogen and the nitrogen flowing through the tray through which had flowed the air, one tray of said pair having a pair of ports in opposite side walls near diagonally op-

posite corners and the other tray in said pair having a pair of ports in opposite side walls near diagonally opposite corners, the said pair of trays thus having a pair of ports disposed on the same end of the stack but on opposite sides thereof and a second pair of ports disposed on the other end of the stack but on opposite sides thereof.

5. A heat exchanger as defined in claim 4, in which each tray is formed of a flat sheet as the base and channel bars secured along the edges of said flat sheet as the side and end walls of said tray.

6. A heat exchanger as defined in claim 4, in which the fins are interrupted at spaced intervals along the length thereof to provide narrow slots which cause turbulent flow of the gaseous media flowing through said trays and reinforcing fins are disposed in said ports of the nitrogen and air trays arranged to provide passage at right angles to and communicating with the passages in said trays, the flow paths thus formed in each tray by the intercommunicating passages being all of substantially the same length.

7. A heat exchanger for flow therethrough in indirect heat exchange relationship of oxygen, nitrogen and air, comprising a plurality of trays stacked in superimposed relation, the base of one tray defining the top of an underlying tray, each tray comprising a longitudinally extending base, a pair of side walls and a pair of end walls, the wall thickness of the base of each tray being about 0.03 inch, a multiplicity of fins of high heat conductivity disposed in each tray to define a plurality of passages extending in the same longitudinal direction as the length of the tray, the distance between the longitudinal center line of one passage to the longitudinal center line of the next passage being about 0.10 inch, said fins having flat portions securely bonded to the trays to reinforce the same, said trays of said stack through which oxygen flows having inlet and outlet ports in the opposite end walls thereof, the remaining trays in said stack being arranged in the stack in pairs with one tray of each said pair serving for flow of air therethrough and the other tray of the pair for flow of nitrogen during one period of operation and upon reversal the air flowing through the tray through which had flowed the nitrogen and the nitrogen flowing through the tray through which had flowed the air, one tray of said pair having a pair of ports in opposite side walls near diagonally opposite corners and the other tray in said pair having a pair of ports in opposite side walls near diagonally opposite corners, the said pair of trays thus having a pair of ports disposed on the same end of the stack but on opposite sides thereof and a second pair of ports disposed on the other end of the stack but on opposite sides thereof.

8. A heat exchanger as defined in claim 7, in which the trays and fins are of copper.

9. A heat exchanger comprising a plurality of trays stacked in superimposed relation, the base of one tray defining the top of an underlying tray, each tray comprising a longitudinally extending base, a pair of side walls and a pair of end walls, the base portion of each tray being of thin metal of high heat conductivity, a multiplicity of fins of high heat conductivity disposed in each tray in closely spaced relationship to define a plurality of passages extending in the same longitudinal direction as the length of the tray, said fins in each tray having a plurality of closely spaced portions fastened to the base of the tray in which they are disposed and to the underside of the base of an overlying tray to reinforce the trays, certain of said trays in said stack having inlet and outlet ports in the opposite end walls thereof, the remaining trays in said stack being arranged in the stack in pairs with one tray of each said pair having a pair of ports in opposite side walls near diagonally opposite corners and the other tray of said pair having a pair of ports in opposite side walls near diagonally opposite corners, the said pair of trays thus having a pair of ports disposed on the same end of the stack but on opposite sides thereof and a second pair of ports disposed on the other end of the stack but on opposite sides thereof.

10. A heat exchanger as defined in claim 9, in which each tray is formed of a flat sheet as the base and channel bars secured along the edges of said flat sheet as the side and end walls of said tray.

11. A heat exchanger as defined in claim 9, in which the thickness of the base of the trays is within the range of 0.008 to 0.125 inch, the thickness of the fins is within the range of 0.005 to 0.060 inch, the spacing between adjacent trays in the stack is within the range of ¼ to 1 inch, and the spacing between the center of one passage and the center of a contiguous passage formed by said fins is within the range of 0.06 to 0.40 inch.

12. A heat exchanger as defined in claim 9, in which the trays and fins are of copper.

13. A heat exchanger comprising a plurality of trays stacked in superimposed relation, the base of one tray defining the top of an underlying tray, each tray comprising a longitudinally extending base, a pair of side walls and a pair of end walls, the base portion of each tray being of thin metal of high heat conductivity, a multiplicity of fins of high heat conductivity disposed in the intermediate portion of each tray in closely spaced relationship to define a plurality of passages extending in the same longitudinal direction as the length of the tray and a multiplicity of fins of high heat conductivity disposed in the opposite end portions of each tray in closely spaced relationship to define a plurality of passages at right angles to and in communication with the first said passages in said intermediate portion, said fins in each tray having a plurality of closely spaced portions fastened to the base of the tray in which they are disposed and to the underside of the base of an overlying tray to reinforce the trays, the trays in said stack being arranged in pairs with one tray of each said pair having only two edgewise ports located near diagonally opposite corners and the other tray of said pair having only two edgewise ports located near diagonally opposite corners which are not the same as the diagonally opposite corners first mentioned, the said pair of trays thus having a pair of ports disposed at one end of the stack and a second pair of ports disposed at the other end of the stack.

14. A heat exchanger as defined in claim 13, in which each tray is formed of a flat sheet as the base and channel bars secured along the edges of said flat sheet as the side and end walls of said tray.

15. A heat exchanger as defined in claim 13, in which the trays and fins are of copper, the thickness of the base of the trays being about 0.03 inch, the thickness of the fins being about 0.008 inch, the spacing between adjacent trays in the stack being about ½ inch, and the spacing between the center of one passage and the center

of a contiguous passage formed by said fins being about 0.10 inch.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,680,145	Forssblad	Aug. 7, 1928
1,941,365	Patterson et al.	Dec. 26, 1933
2,321,110	Shipman	June 8, 1943
2,371,346	Morrow	Mar. 13, 1945
2,439,208	Gloyer	Apr. 6, 1948

FOREIGN PATENTS

Number	Country	Date
488,571	Great Britain	July 11, 1938
538,391	Sweden	July 31, 1941
494,525	France	June 2, 1919
96,981	Sweden	Aug. 3, 1939