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3,289,757

HEAT EXCHANGER

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2 Sheets-Sheet 1

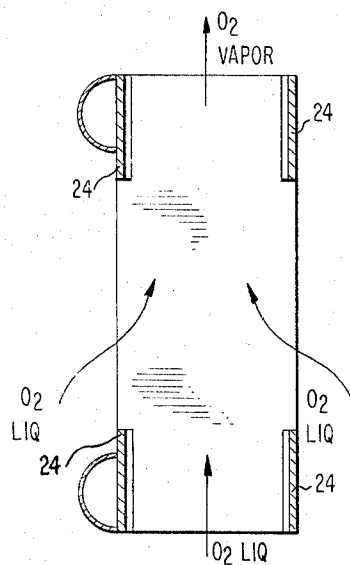
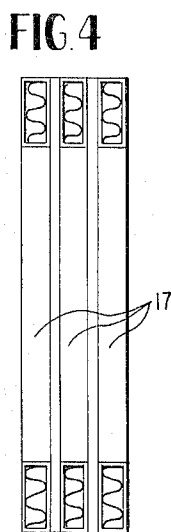
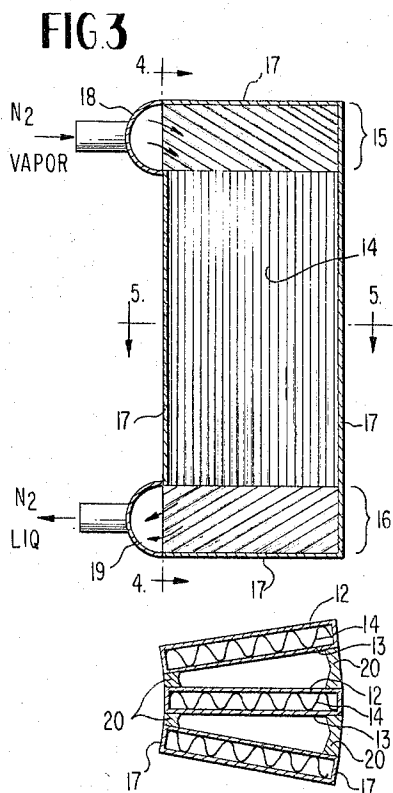
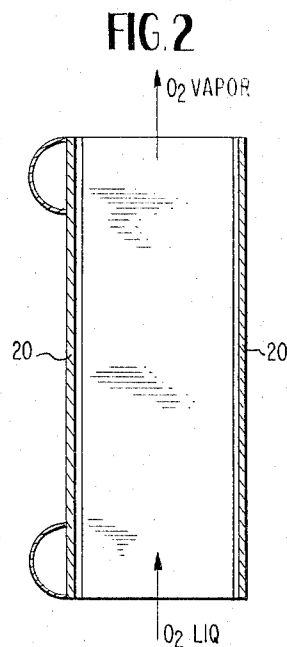
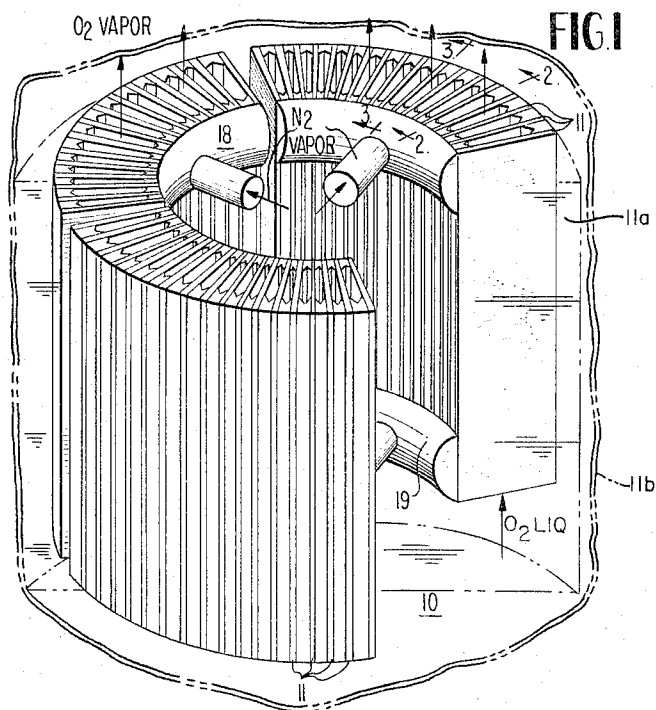


FIG. 2A

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FIG 6

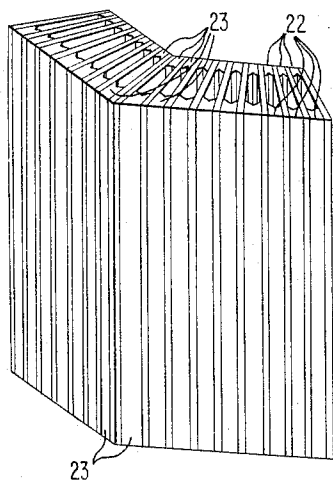


FIG 7

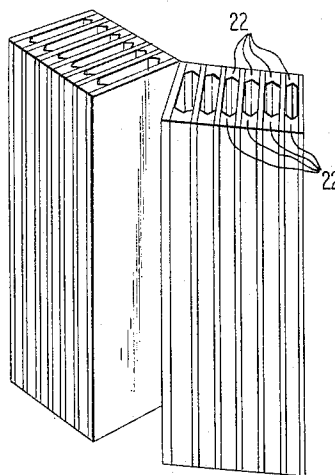


FIG 8

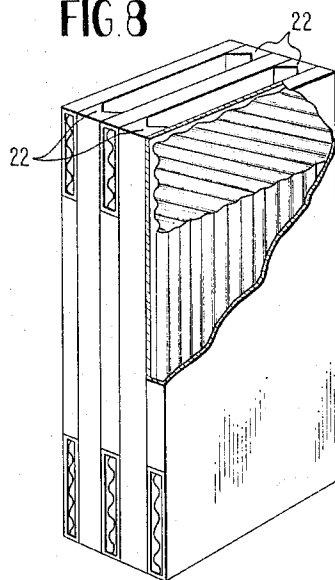
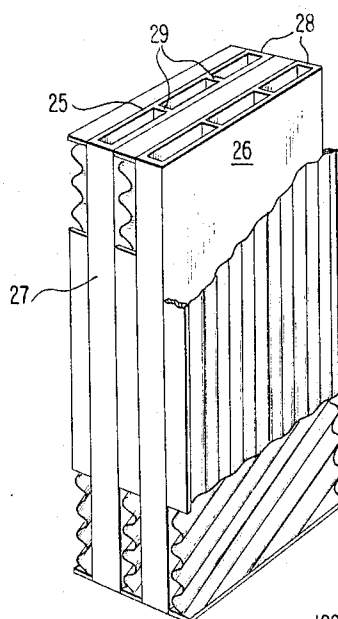


FIG 9



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HEAT EXCHANGER

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This invention relates to a heat exchanger, and more particularly to a heat exchanger of the type to be submerged into a body of a first heat transfer fluid and to contain the flow of a second heat transfer fluid with heat transfer occurring between the two fluids. The invention finds particular usefulness in exchange of heat between two cryogenic fluids, such as oxygen and nitrogen at the pressures and temperatures at which they may be in liquid form.

In processes of the type employing heat exchangers which must be submerged in one heat exchange fluid, contaminants from various sources may enter the process system and ultimately reach the heat exchange surfaces. For various reasons, the accumulation of contaminants at the heat exchange surface is considered undesirable, and the heat exchange surface must be cleaned when excessive accumulation occurs. For example, in a cryogenic process employing gaseous and liquid oxygen, hydrocarbon contaminants from the air may enter the process system and ultimately be deposited in a liquid oxygen evaporator. Should these hydrocarbon contaminants reach a significant concentration, the presence of the liquid oxygen might well result in an explosion.

In the prior art, the heat exchange structures used as oxygen boilers and nitrogen condensers in gaseous and liquid oxygen plants used small copper tubing, with the oxygen flowing inside of the tubing, permitting the structure to be relatively easily cleared of contaminants when necessary. More recently, these boiler-condensers have been formed from brazed aluminum plate-fin type exchange structures, in which the oxygen and nitrogen are in alternate passages of the multilayered plate-fin assembly. This latter type of exchanger is not as readily cleanable as the tubular structure of the earlier use, and the collection of hydrocarbons in the oxygen passages frequently is difficult and in some cases impossible to remove by mechanical cleaning. A primary problem in the more recent plate-fin type of exchanger is the retention of hydrocarbon contaminants by the densely packed fins in the oxygen boiler passages, which increases the danger of an explosive condition.

It is an object of the present invention to provide an improved heat exchanger for submersion in a heat exchange fluid which eliminates the need for contaminant retaining fins or similar surfaces.

A further object of this invention is to provide an improved heat exchanger for submersion in one heat exchange fluid having open passages to permit ease of mechanical cleaning.

A still further object of this invention is to provide a sandwich heat exchanger element suitable for assembly into any of several configurations of submersible heat exchangers and having internally defined flow distribution passages.

Other objects of the invention will be pointed out in the following description and claims and illustrated in the accompanying drawings, which disclose, by way of example, the principle of the invention and the best mode which has been contemplated of applying that principle.

In the drawings:

FIGURE 1 is a perspective view of a cryogenic heat exchanger constructed in accordance with the present invention.

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FIGURE 2 is a side view, along the line 2-2 of FIGURE 1, illustrating further detail of one modification of the present invention;

FIGURE 2a is similar to FIGURE 2, illustrating a second modification of the present invention;

FIGURE 3 is a side view, in section, along the line 3-3 of FIGURE 1;

FIGURE 4 is a side view, in partial section, along the line 4-4 of FIGURE 3;

FIGURE 5 is a top view of a portion of the heat exchanger of FIGURE 1;

FIGURE 6 is a perspective view of another embodiment of the heat exchanger of the present invention;

FIGURE 7 is a perspective view of a third embodiment of the heat exchanger of the present invention;

FIGURE 8 is a perspective view of a fourth embodiment of the heat exchanger of the present invention; and

FIGURE 9 is a perspective view similar to FIGURE 8, with the heat exchanger modified to use an extruded form.

Broadly, the heat exchanger of the present invention may be assembled in any desired one of several suitable forms from a number of unitary heat exchange elements, to provide an extended exchange surface for one heat exchange fluid flowing through the elements and a planar heat exchange surface for another heat exchange fluid into which the assembled heat exchanger is submersed. Where the heat exchanger is to be submersed in a liquid oxygen bath to serve as an oxygen boiler and nitrogen condenser, the planar surfaces provided for heat exchange with the liquid oxygen provide ease of mechanical cleaning and prevent accumulation of hydrocarbon contaminants, while the extended surfaces available for nitrogen flow maintain satisfactory heat transfer.

More specifically, FIGURE 1 illustrates a heat exchange 10 according to the present invention assembled into a cylindrical form from a number of unitary exchange elements or sandwiches 11. The heat exchanger 10 is shown partially submerged in a bath of liquid oxygen 11a with the bath carried by a container 11b having suitable means through which liquid oxygen is supplied and vapor extracted. Details of the individual exchange elements 11 are shown more clearly in FIGURES 2-5, and the construction of the individual sandwich elements will be detailed in conjunction with those figures.

Each individual exchanger sandwich element comprises two sheet members 12, 13 defining the outer surfaces of the sandwich and a corrugated spacer 14 separating and joining the sheet members. Each three members sandwich unit is formed in a rectangular shape, with the corrugations of a central portion of the spacer 14 extending longitudinally of the sandwich, as more clearly shown in FIGURE 3. Adjacent the two ends of the rectangular sandwich are header zones 15, 16 within which the corrugations are at an angle to those extending longitudinally of the sandwich, for purposes to be detailed shortly. Sealing strips 17 extend entirely along the top, bottom and one side of the three member sandwich, joining the sheet members 12, 13 in a fluid-tight manner so as to contain any fluid introduced into the interior of the sandwich element. An additional sealing strip 17 extends along the remaining side of the three member sandwich, in a manner similar to the sealing strips 17 on the other three sides, but extends only over that portion in which the corrugations extend longitudinally of the three member sandwich. This latter sealing strip does not extend over the portions of the corrugated spacer 14 defined as header zones 15, 16, as will now be made more clear.

When a sandwich element is to be employed in a heat exchanger structure, it is necessary to flow one heat exchange fluid into the interior of the three member sandwich 11, in order that the fluid may contact the extended

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heat exchange surface defined by the corrugated spacer 14 and the interior surfaces of the sheet members 12, 13. To perform this function, header structures 18, 19 may engage the header zones 15, 16 of the completed sandwich element 11. The headers 18, 19 may be of any desirable form, but engage the three member sandwich at the header zones left open by the sealing strip 17 extending partly along one side.

Considering the flow arrows indicated in FIGURE 3, the purpose of the varied angle corrugations in the header zones is now made more clear. Heat exchange fluid flowing in through a first header 18 is introduced into an inlet header zone 15. Within this header zone, the corrugations are angled so as to turn the incoming flow of heat exchange fluid and direct the fluid toward the longitudinal corrugations. Further, the corrugations in this area perform the function of distributing flow across the width of the three member sandwich 11 and thus may be referred to as inlet distribution corrugations. As the fluid flow is distributed across and enters into the zone in which the corrugations extend longitudinally of the three member sandwich, the extended surface offered by the corrugations promotes transfer of heat to or from the fluid flowing through this zone, and performs the main heat transfer function of the sandwich. These corrugations thus may be denominated as main heat transfer corrugations. On flowing through the main heat transfer corrugations, the fluid enters the outlet header zone 16, in which the corrugations are again angled from the longitudinal direction of the three member sandwich. These angled corrugations serve to collect the heat transfer fluid and direct it to an outlet header 19, which engages the outlet zone left open by the fourth side sealing strip 17. These corrugations may be defined as the outlet distribution corrugations.

In order to define the flow path for the fluid in which the exchanger is to be submersed, each individual heat exchange element 11 has, associated with it, separation strips 20 positioned to project laterally from one sheet member 12, along the sides of the rectangular member. When a complete heat exchanger, such as that of FIGURE 1, is assembled from a number of individual sandwich elements 11, adjacent sandwich elements 11 are positioned so that the sheet member 13 not carrying separation strips 20 abuts the separation strips 20 of the adjacent individual element 11. The planar surface passages for flow of a heat exchange fluid are defined by the sheet members of two adjacent individual elements 11 and the separation strips 20 which hold the sheet members apart. These planar surface heat exchange passages, extending longitudinally from one end of the adjacent elements to the other, may easily be mechanically scoured to remove any contaminant traces, and do not provide any surfaces or other trap areas to promote the accumulation of contaminants.

In order to permit the assembly of a variety of forms of heat exchangers from the individual sandwich elements 11, and to provide varying flow paths to accommodate varying demands which may be placed on the heat exchangers, the present invention contemplates that the separation strips 20 may take at least two forms. As such, the separation strips 20 constitute an important part of this invention. To assemble a cylindrical or part-cylindrical heat exchanger, such as that illustrated in the embodiment of FIGURE 1, the separation strips positioned on the individual sandwich elements 11 should have a uniform difference in width between those placed along the side of the three member sandwich adjacent the header openings and those placed along the side remote from the header openings. The difference in width should preferably be uniform both along the length of the sandwich element 11 and for all elements 11 to be assembled into the cylindrical heat exchanger 10. In such a cylindrical heat exchanger 10, the individual sandwich elements 11 are to lie along radial planes of the completed cylindrical or part-cylindrical solid body. The radius

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of the cylindrical or part-cylindrical body is determined by the uniform difference in width of the separation strips 20, and may be of any suitable length. Where a quite short radius is to be desired, the separation strip adjacent the inner radial, or manifold opening, side of the individual sandwich element 11 must still have sufficient width to permit the heat exchange fluid into which the completed exchanger is to be submersed to enter into contact with the entire planar surface of the sheet members 12, 13 of adjacent sandwich elements 11.

In order to obtain various other embodiments of completed heat exchangers, the separation strips 20 may be made of uniform width, or both uniform width and uniform difference in width separation strips 20 may be intermixed to obtain a desired result. For example, a polygonal or part-polygonal heat exchanger 21 such as that of FIGURE 6 may be assembled by selecting separation strips 22 of uniform width to define the straight line sides of the polygonal figure, while separation strips 23 of uniform difference in width are used to form the angles of the polygonal figure. This intermixture of types may be in any desired ratio to create any desired polygonal figure, such as a pentagon, hexagon or other multi-sided geometrical figure.

As an alternative to the embodiment of FIGURE 6, no separation strips may be employed, as in FIGURE 7, to terminate the series of sandwich elements having separation strips 22 of uniform width which define the straight side of a polygonal solid. In this embodiment, the assembled polygonal or part-polygonal heat exchange structure does not define a closed planar surface heat exchange flow path between the adjacent sandwich elements at the angle of the polygonal form, but this is not detrimental to the operation of the exchanger.

Finally, as illustrated in FIGURE 8, a number of separator strips 22 of uniform width may be assembled with sandwich elements to form a rectangular solid heat exchanger.

In any of these four embodiments, inlet and outlet manifolds 18, 19 extend across the inlet and outlet openings of a group of adjacent individual sandwich elements, as illustrated in FIGURES 1-3.

In order to provide variation in the flow paths available for the heat exchange fluid into which the completed heat exchanger is to be submersed, and accommodation to the various uses for or demands on the exchanger, the present invention encompasses two forms for the separation strips, as illustrated in FIGURES 2 and 2a.

In the modification of FIGURE 2, the separation strips 20 extend entirely along the sides of the sandwich elements 11, restricting the flow of the heat exchange fluid in which the exchanger is submersed to flow straight through the conduit defined by the separation strips 20 and sheet members 12, 13 of adjacent sandwich elements 11. The modification illustrated in FIGURE 2a employs separation strips 24 which extend only partly along the sides of the sandwich elements, thus permitting radially inward flow intermediate the height of the sandwich element, as illustrated by the flow arrows. The choice between the two modifications must be dependent upon the heat flow rates and transfer fluid involved, but either modification may be applied to any of the assembled heat exchanger embodiments of FIGURES 1 and 6-8.

As an alternative to the use of separate sheet members 12, 13 and separation strips 20 to assemble individual exchange elements and to complete heat exchange, the sheet members and separation strips may be extruded forms, as shown in FIGURE 9. Where this alternative is chosen, the broader or wider dimension surfaces 25, 26 of the extruded tube are used as the sheet members 12, 13 of adjacent individual exchange elements. The narrow end surfaces 27, 28 of the extruded tube are equivalent to the separation strips 20. As specifically taught with respect to the various exchange embodiments of FIGURES 1 and 6-8, the extruded tube may have a

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rectangular shape to provide separation strips of uniform width or a wedge shape to provide separation strips of uniform difference in width, and as used in this specification the term "separation strip" is to be construed to include the extruded form. In any exchanger assembled by use of extruded forms, the passage for the fluid in which the exchanger is submersed is defined by the interior of the tube.

Where greater structural strength of the extruded form is required, webs 29 extending across the tube interior will increase the rigidity and strength without seriously impairing mechanical cleaning of the fluid passages.

In operation as an oxygen boiler-nitrogen condenser, a heat exchanger assembled into any of the embodiments illustrated is submersed into a pool or other reservoir of liquid oxygen. Nitrogen vapor is introduced into the inlet manifold 18 which, in accordance with preferred practice, is the upper of the two manifolds 18, 19. Nitrogen vapor flowing into the inlet distribution corrugations is turned downwardly and directed into the main heat transfer corrugations, where the extended surface area of the corrugations enhances heat transfer from the nitrogen vapor. At the same time, oxygen liquid flowing upwardly in the planar surface heat transfer channels defined by the separation strips 20 and sheet members 12, 13 of adjacent sandwich elements 11 accepts the heat transferred from the nitrogen vapor. The resulting operation is vaporization of oxygen and liquefaction of nitrogen, with the liquid nitrogen being removed through the outlet distribution corrugations and the outlet manifold 19.

While the operation of the exchanger has been outlined as the practice of submerging the assembled heat exchanger into a pool or reservoir of liquid oxygen, holding the heat exchanger with the sides of the rectangular sandwich elements 11 vertical, an entirely similar result is obtained by forcing the flow of a heat exchange fluid through the planar surface channels, rather than relying on natural convection. In that event, the orientation of the heat exchanger need not necessarily be vertical, but can be at any other desired angle.

While there have been shown and described and pointed out the fundamental novel features of the invention as applied to the preferred embodiment, it will be understood that various omissions and substitutions and changes in the form and details of the device illustrated and in its operation may be made by those skilled in the art without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. A heat exchanger for use in a bath of a first liquid cryogenic fluid to provide heat transfer between said first cryogenic fluid and another cryogenic fluid, the improvement comprising: a plurality of closed sandwich elements each including a pair of spaced apart side walls having smooth planar outer surfaces and forming therebetween first axial flow passages, a pair of spaced separation strips extending axially along respective edges of opposed side walls of adjacent sandwich elements defining second axial flow passages, the strip of each pair being of different cross-sectional width and converging in the direction of a common axis, and a pair of axially spaced header structures connected to opposed ends of the heat exchanger and in fluid communication with said first axial passages for moving said second cryogenic fluid along a flow path

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parallel to the flow path of said first cryogenic fluid, said separation strips having smooth planar surfaces for defining, with said smooth planar outer surfaces of said closed sandwich elements a flow path of constant axial cross-section having smooth planar boundaries to minimize the deposit of contaminants upon submersion of said heat exchanger into said first cryogenic liquid bath.

2. The heat exchanger as claimed in claim 1 further including spaced lateral passageways coupled to opposite ends of each sandwich element in fluid communication with said first axial flow passages and means for coupling said axial spaced pair of header structures to the periphery of the heat exchanger in fluid communication with said lateral passageways.

3. A heat exchanger for use in a bath of a first liquid cryogenic fluid to provide heat transfer between said first cryogenic fluid and a vaporized second cryogenic fluid, the improvement comprising: an annulus formed of a plurality of juxtapositioned, closed sandwich elements, each including a pair of spaced apart side walls having smooth planar outer surfaces and forming therebetween first axial flow passages, a pair of spaced, separation strips extending axially along respective edges of opposed side walls of adjacent sandwich elements to form second axial flow passages, the strips of each pair being of different width and substantially converging in the direction of a common axis, lateral passageways positioned on opposite ends of said sandwich elements in fluid communication with said first axial flow passages, at least one pair of spaced header structures connected to the internal periphery of the heat exchanger and in fluid communication with said first axial flow passages for directing said first cryogenic fluid along an axial flow path, a corrugated spacer in each sandwich element extending longitudinally of said sandwich element, transverse end corrugations in said spacer lateral passageways for directing flow there-through, said separation strips having smooth planar surfaces for defining with the smooth planar outer surfaces of said sandwich elements a flow path for said first cryogenic fluid of axially constant cross-section to minimize the deposit of contaminants as a result of fluid flow, said second axial passages being open ended, with the surfaces of said separation strips being in direct communication with said first cryogenic liquid upon submersion of said heat exchanger in said first cryogenic liquid bath.

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