United States Patent

[11] 3,537,513

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[54] **THREE-FLUID HEAT EXCHANGER**
9 Claims, 6 Drawing Figs.

[52] U.S. Cl. **165/70,** 165/104, 165/140, 165/134, 165/165, 165/166
[51] Int. Cl. **F28f 23/00,** F28f 3/00
[50] Field of Search 165/70, 104, 140, 166, 165, 134

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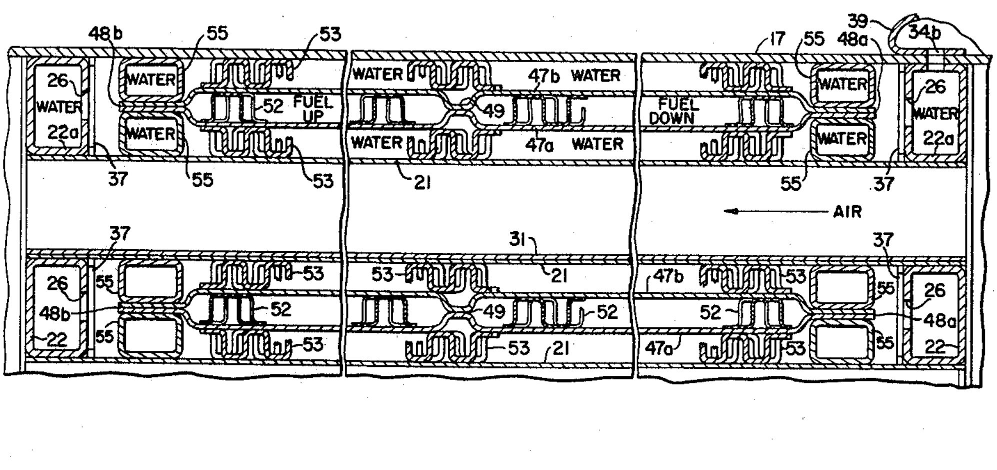
ABSTRACT: A heat exchanger utilizing a pressurized buffer fluid between the coolant and the fluid to be cooled, to reduce thermal stress, and to prevent the intermixing of the coolant with the fluid to be cooled.



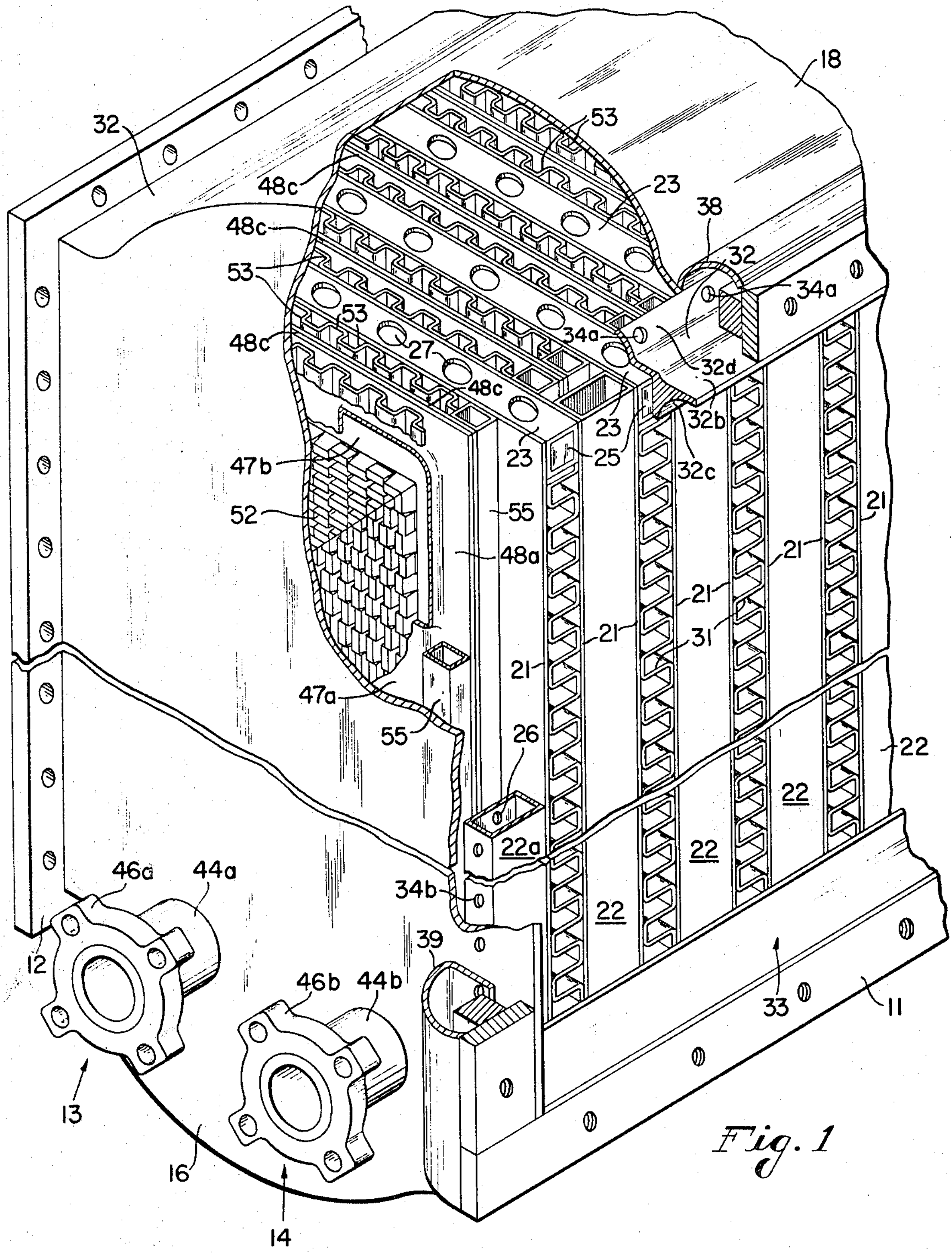


Fig. 1

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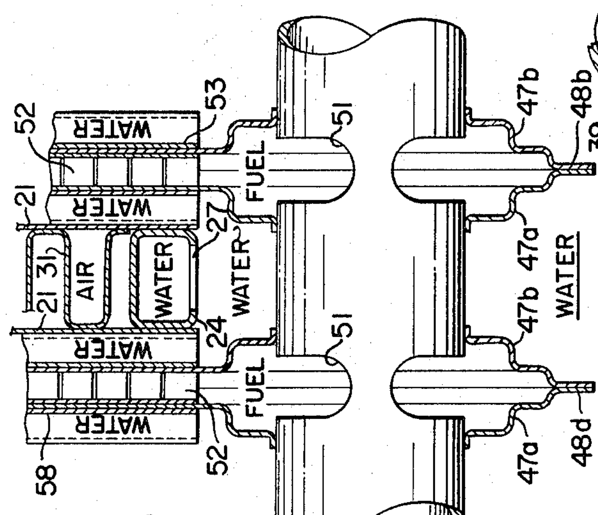


Fig. 3

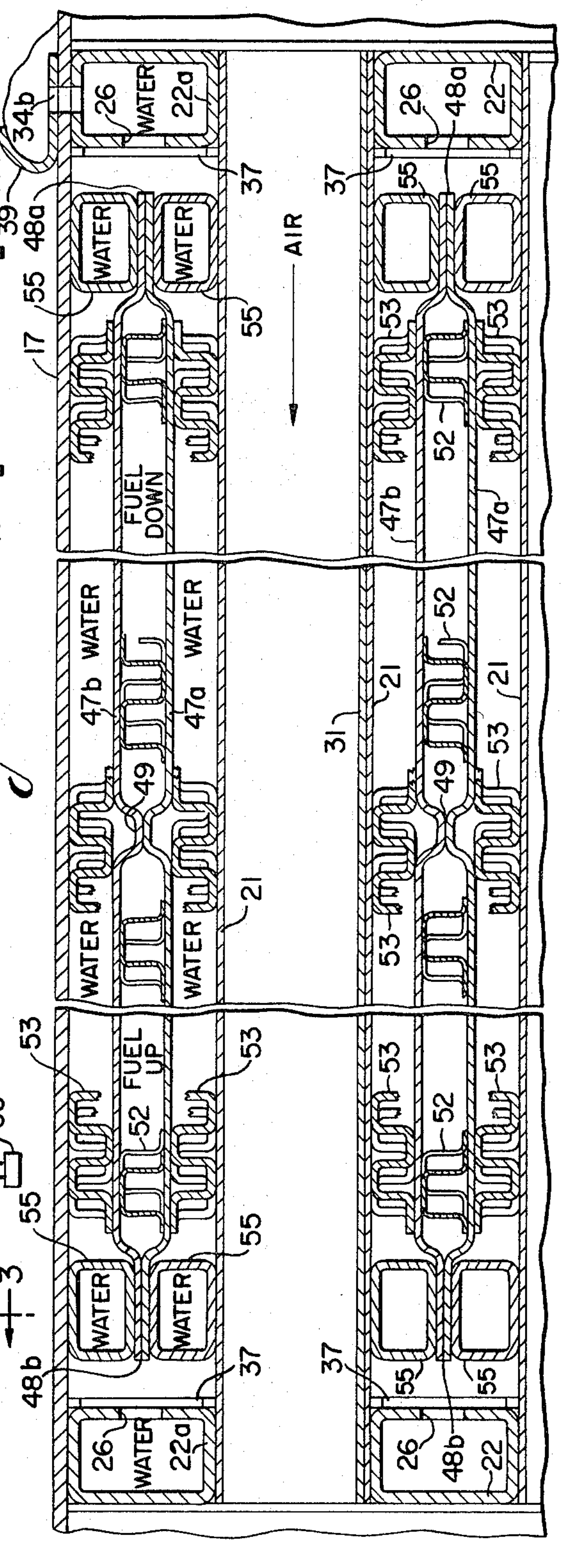


Fig. 4

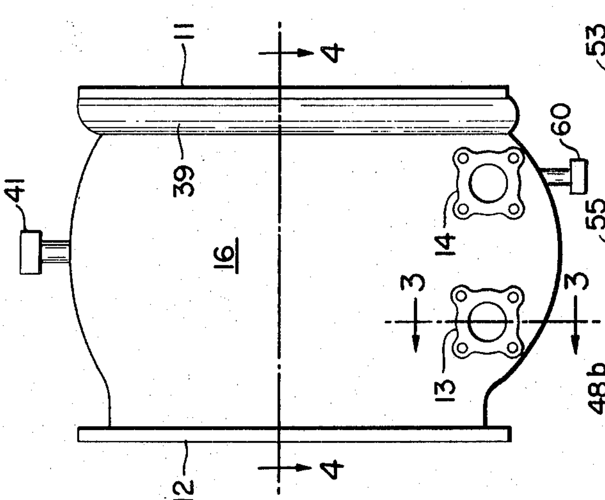


Fig. 2

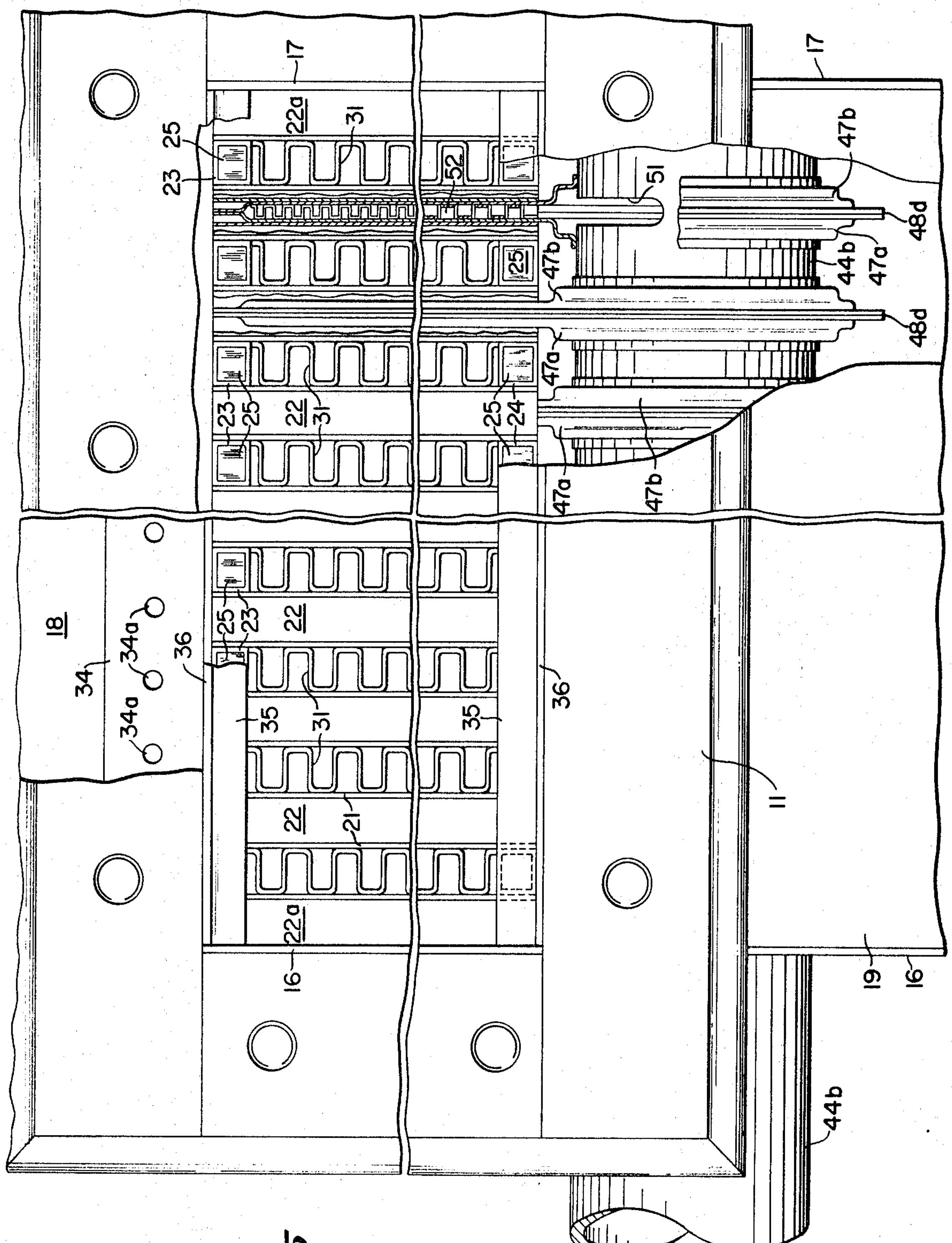
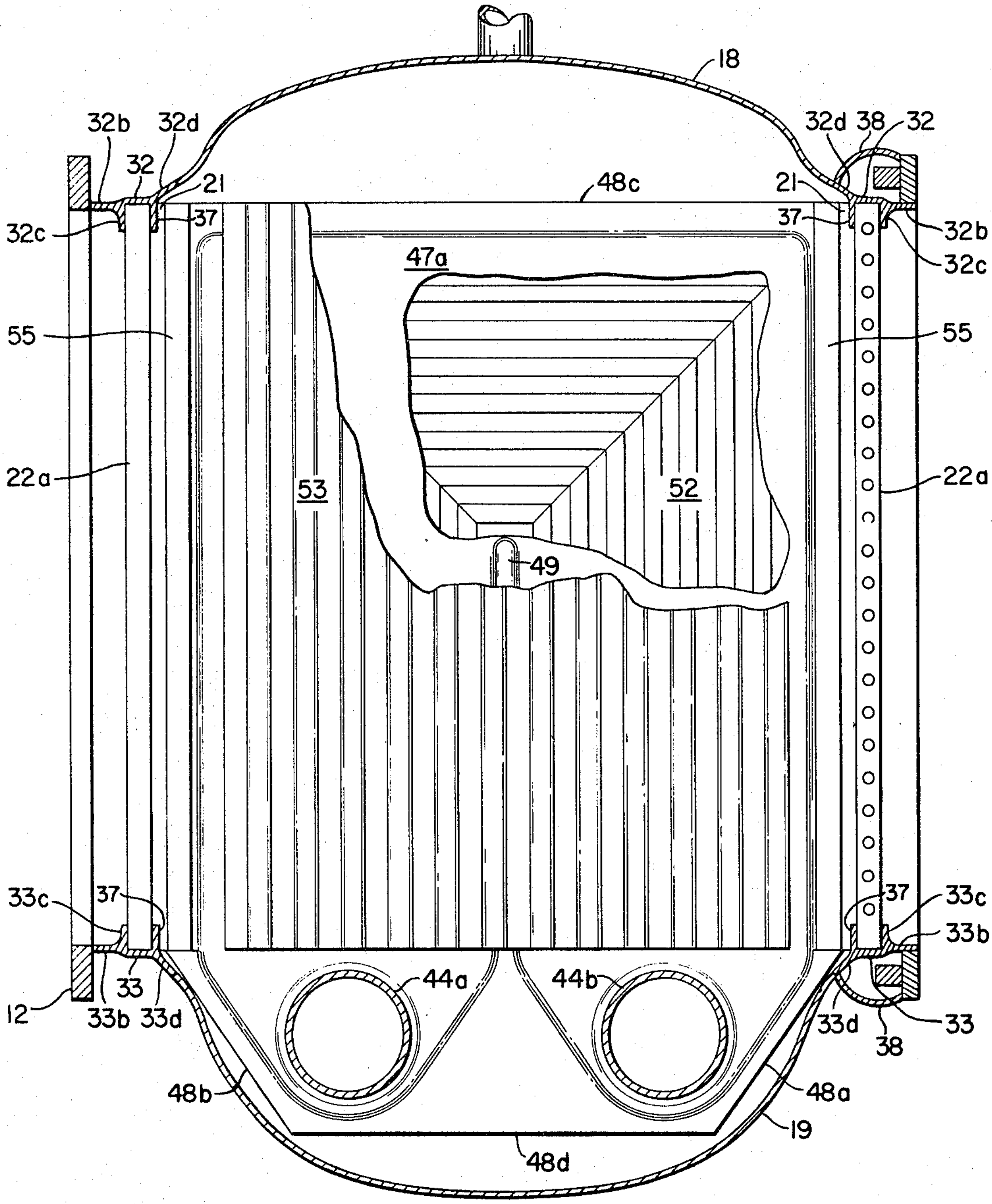

17
22a
31
25
23
52
51
47b
48d
44b
47a
25
24
22
18
34
34a
36
35
11
21
16
19

Fig. 5


18
32b
32d
32
21
48c
32d
38
32
21
32c
37
37
32b
32c
47a
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55
22a
53
52
22a
49
33c
37
37
33c
33b
44a
44b
12
33
33b
33d
33d
38
33
48b
48a
19
48d

Fig. 6

THREE-FLUID HEAT EXCHANGER

Up to now, heat exchangers are generally of the plate type comprising an assembly of flat platelike elements which are situated in spaced parallel relationship. Adjacent plate elements are separated at two opposite edges by spacer elements to define a plurality of crisscross passageways. Each passageway consists of two rectangular plate elements with two spacer elements disposed at opposite edges. Alternate passageways communicate with a first manifold and the remaining passageways communicate with a second manifold. The coolant fluid is fed into the first manifold and the fluid to be cooled is fed into the second manifold. Then obviously the two fluids would be disposed on opposite sides of the plate elements, and if any defects or leaks appear in the heat exchanger the two fluids would mix. Mixing of the fluids is undesirable and dangerous, especially if one fluid is hot engine bleed or ram air, which is to be cooled with liquid fuel, as could be encountered in the ventilation systems on supersonic aircrafts. In addition, if the heat exchangers of the prior art should break down, fuel leaking into the hot air passages would ignite making an inferno out of the passenger cabin.

Therefore, an object of this invention is to provide a fluid chamber between the coolant fluid of the heat exchanger and the fluid to be cooled, which fluid chamber is preferably pressurized above the level of the others.

Another object of this invention is to provide a buffer fluid in a heat exchanger to reduce severity of structural temperature gradients and thermal stresses which, in turn, prevent leakage.

Another object is to prevent flash heating of the fuel, which is also the coolant, during momentary stoppage of the fuel flow.

Another object of this invention is to prevent leakage and intermixing of the coolant and the fluid to be cooled.

Another objective is to prevent any external surface of the heat exchanger, including the hot air inlet duct, from reaching potential fuel ignition temperature.

Briefly, the invention provides parallel-spaced, plate elements shaped, for example, rectangular. Within alternate spaces between the plate elements are disposed hollow tubular members or headers preferably along the longer edges to form passageways for the hot fluid. In addition, within the remaining alternate spaces are disposed hollow headers along the shorter edges so that all plate elements are fastened together in a stack. Therefore, between the hot fluid passageways additional passageways are formed which communicate with manifolds disposed on opposite ends forming a closed vessel for the buffer fluid. A flat compartment is disposed within each passageway that communicates between the manifolds. The flat compartments are spaced from the plate elements and headers so that the buffer fluid completely surrounds the flat compartments. Each flat compartment has an inlet means and an outlet means so the coolant fluid passes through the flat compartment. In order to reduce thermal stresses to a minimum, suitable holes are formed in the hollow headers so that the buffer fluids flow freely in and out of the headers.

The foregoing and other objects, advantages and characterizing features of this invention will become apparent from the ensuing detailed description of the illustrative embodiment thereof, reference being made to the accompanying drawings wherein:

FIG. 1 is a pictorial view of a portion of the novel exchanger with portions broken sway;

FIG. 2 is a small scale side elevation of the heat exchanger shown in FIG. 1;

FIG. 3 is a section of a portion of the heat exchanger taken on line 3–3 in FIG. 2;

FIG. 4 is a section of a portion of the heat exchanger taken on line 4–4 on FIG. 2;

FIG. 5 is a partial elevation showing the air inlet of the heat exchanger with portions broken away to show the internal structure; and

FIG. 6 is the side elevation of the heat exchanger with the side plate removed and portions broken away to show the internal structure.

Referring to the drawings and to FIG. 1 in particular, a pictorial view of a portion of the novel heat exchanger is shown, portions of the unit being broken away to show its structure. The heat exchanger has a rectangular inlet flange **11** for the fluid to be cooled, for example, hot bleed air from a jet engine of a supersonic aircraft, and has a rectangular outlet flange **12** that forms the outlet for the cooled bleed air. Suitable ducting (not shown) could be bolted to flanges **11** and **12** to feed the hot air into and to guide the cooled air from the exchanger, respectively. Also a compartment firewall (not shown) could be placed between the inlet duct and flange **11** for reasons that will be hereinafter explained. The air leaving the exchanger has been cooled, for example, by relatively cold fuel, entering the exchanger through a fuel inlet **13** and leaving through a fuel outlet **14**. The fuel inlet and outlet extend through a side plate **16** that extends from and is brazed to flange **11** and to flange **12**. A similar side plate **17** (FIG. 5) is disposed on the other side of the exchanger and parallel to the side plate **16**. A semicylindrical plate **18** (FIG. 1) is disposed on the top of the exchanger and suitably welded to side plates **16** and **17** and flanges **32*d*** on members **32**, disposed at the inlet and outlet, to form a buffer fluid manifold at the top thereof. Another semicylindrical plate **19** (FIG. 6) is disposed on the bottom of the exchanger and welded to side plates **16** and **17** and flanges **33*d*** (FIG. 6) on members **33** (also disposed at the inlet and outlet) to form a buffer fluid manifold at the bottom thereof. There is disposed between the side plates **16** and **17** a plurality of heat transfer plates **21** in parallel relationship and spaced apart from each other. Plates **21** are preferably rectangular, and within alternate spaces formed therebetween and along both vertical edges are disposed vertical hollow headers or spacers **22** to form passageways extending vertically as viewed in FIG. 1. Top horizontal hollow headers or spacers **23** and bottom hollow horizontal headers or spacers **24** (FIG. 5) are disposed in the other interplate spaces along the top and the bottom edges, respectively, of plates **21** to form passageways extending right to left as viewed in FIG. 1. Horizontal and vertical passageways are thus formed between the plates **21**. For reasons that will be explained hereinafter, vertical hollow headers or spacers **22*a*** are disposed between the side plate **16** and the adjacent heat transfer plate **21** and between the side plate **17** and its adjacent heat transfer plate **21** to form vertical passageways. Both vertical and horizontal spacers **22**, **22*a***, **23** and **24** are rectangularly shaped tubes, to allow a buffer fluid to flow therethrough. Top and bottom spacers **23** and **24** have their ends sealed with suitable plugs **25** (FIGS. 1 and 5), and therefore to allow buffer fluid to flow therein, holes **27** are formed only on the top surface of top spacers **23** and only on the bottom surface of bottom spacer **24** (FIG. 3).

The hot bleed air enters the heat exchanger through flange **11**, and the vertical headers **22** and **22*a*** limit the passage of air to alternate horizontal passageways formed between the plates **21**. To increase the heat transfer rate suitable offset corrugations **31** FIG. **1** are placed between the respective plates **21** in the bleed air passages. Stiffener members **32** and **33** are preferably extruded sections having three flanges such as flanges **32*b***, **32*c*** and **32*d*** as shown on member **32**. As mentioned above, flanges **32 *d*** on both the inlet and outlet are butt-welded to top plate **18** as shown in FIG. 6; flanges **32*c*** extend downward over the plugged end of headers **23** and are brazed thereto; and flanges **32*b*** are welded to flanges **11** and **12** of the heat exchanger. The sharp corner is eliminated between flanges **32*b*** and **32*c*** by suitable fillet radius. The respective flanges on members **33** are butt-welded to bottom plate **19**, brazed to the bottom plugged end of the spacers **24**, and welded to the flanges **11** and **12**. Each member **32** and **33** has aligned spaced lugs **37** (more clearly shown in FIG. 6) disposed parallel to flanges **32*c*** and **33*c***. The lugs **37** are disposed behind vertical headers **22** so that the headers are held firmly between and brazed to the lugs **37** and flange **32*c*** and **33*c***, respectively. The vertical bars forming flange **11** are welded to the respective side plates **16** and **17** (FIG. 5). For reasons that will be explained hereinafter horizontal arcuated plates **38** (FIG. 6) are welded to the outside edge of the horizontal bars of flange **11** and to the respective top and bottom plates **18** and **19**, while vertical arcuated plates **39** (of which only one plate is shown in FIG. **1**) are welded to the outside edges of vertical bars of flange **11** and to respective side plates **16** and **17**.

Since the bleed air passes only through the horizontal passageways formed between alternate adjacent pairs of plates **21** and running substantially from flange **11** to flange **12**, a feature of this invention is to provide a buffer fluid on the opposite side of the plates **21** in contact with the bleed air. The buffer fluid is disposed within the vertical passageways communicating with a top manifold formed by the top plate **18** and with a bottom manifold formed by the bottom plate **19**. A pressure relief valve **41** (FIG. **2**) is suitably connected to the top manifold **18** to prevent excessive pressure from building up if, for example, the fuel (coolant) is shut off, the bleed air would cause some of the buffer fluid to heat up, causing the pressure thereof to rise. Preferably the buffer fluid is a liquid so that a thermal inertia is built into the heat exchanger to prevent excessive thermal gradients. The heat is removed from the bleed air by the cold fuel entering the fuel inlet **13** and leaving outlet **14**. The structure, that allows the fuel to extract heat from the buffer fluid and in turn the bleed air, will now be explained. The inlet **13** is made substantially the same as the outlet **14** and they include pipes **44*a*** and **44*b*** (FIG. **1**) respectively, to which are fixed flanges **46*a*** and **46*b***. Both pipes **44*a*** and **44*b*** pass through the side plate **16** and enter the bottom buffer fluid manifold, more clearly shown in FIG. **5**. The pipes then pass through a plurality of plates or walls **47*a*** and **47*b***. Plates **47*a*** and **47*b*** are suitably brazed to pipes **44*a*** and **44*b***. Plates **47*a*** and **47*b*** are contoured plates having the same configuration, and are placed face to face as shown in FIG. **4** so that the vertical edges **48*a*** and **48*b*** and the top and bottom edges **48*c*** and **48*d*** (FIG. **6**) respectively, on the two plates coincide face to face and are brazed together. Each plate has a center rib **49** that extends from the bottom edge **48*d*** and touches the center rib on its mating plate so that when the two ribs are brazed together, a flat U-shaped chamber is formed between the two plates **47*a*** and **47*b*** (more clearly shown in FIG. **6**). In the portion of the pipes **44*a*** and **44*b*** located in the chamber formed by the plates **47*a*** and **47*b***, suitable openings **51** are formed as shown in FIG. **3** for pipe **44*a***. These openings **51** allow the cooling fluid to leave pipe **44*a***, pass through the plurality of U-shaped chambers, enter pipe **44*b*** to leave the heat exchanger. Within the U-shaped chambers are disposed suitable offset corrugations **52** disposed so that heat is efficiently transferred from the plates **47*a*** and **47*b*** to the cooling fluid.

In addition to the corrugations **52** disposed between two adjacent plates **47*a*** and **47*b***, similar offset corrugations **53** (FIG. **1**) are disposed to transfer heat between plates **21** and the adjacent respective plates **47*a*** and **47*b***. The offset corrugations **53** are oriented to allow the buffer fluid to move freely in the vertical direction. In addition to increasing the flow of heat, the offset corrugations **53** provide structural support for the plates **47*a*** and **47*b***. Tubes **55** are disposed vertically and along both vertical edges **48*a*** and **48*b*** of plates **47*a*** and **47*b*** as shown in FIG. **4** to prevent the edges from distorting under pressure due to lack of support beyond the corrugations **53**. The tubes **55** are opened at the top and bottom thereof so that the buffer fluid flows freely through the tubes. As mentioned before, offset corrugations **31** are disposed between two adjacent plates **21**. Corrugations **31** are disposed to allow the air to move freely through the horizontal passageway and efficiently transfer its heat to the coolant fuel in the following sequence: hot air to corrugations **31**, corrugation to plates **21**, to corrugations **53**, to plates **47**, to corrugations **52** and to cold fuel.

When exchangers use highly flammable fuels as the heat sink medium, safety features are required. In normal operation, the flange **11** would be bolted against a firewall (not shown) so that the flammable fluids are disposed on the heat exchanger side and high temperature elements are disposed on the other side of the firewall. If a leak develops in some portion of the fuel system exterior to the exchanger, the fuel would be contained on one side of the firewall, and the firewall would prevent the fuel from contacting any of the hot duct surfaces supplying the hot bleed air. The fuel, since it is contained on one side of the firewall, would, in case of a leak, come in contact with the exterior surfaces of the heat exchanger which are maintained at a relatively low temperature by the buffer fluid. In addition, since holes **26**, **34*a*** and **34*b*** allow the buffer fluid to flow within curve plates **38** and **39**, these plates are also maintained at relatively low temperature by the buffer fluid. Therefore, at substantially any place, one would choose, on the exposed surface of the heat exchanger, except the outlet end which is always cool, the buffer fluid would be disposed on the opposite side. Since flange **11** is relatively wide any heat flowing outward through the flange would be extracted by the buffer fluid contained within the curved plates **38** and **39**.

In addition, since the air flowing through the heat exchanger would be supplied to the aircraft cabin, no fuel and air must mix for health and safety reasons. Since there could be a possibility of a leak in the heat exchanger, the leak would most likely occur either between the fuel and the buffer fluid or between the air and the buffer fluid. Therefore the buffer fluid keeps the air and fuel apart. If by the remote chance two leaks occur, one between the buffer fluid and the fuel and the other between the buffer fluid and the air, the fuel and air are prevented from mixing since the compartment containing the buffer fluid is pressurized, for example, by the buffer fluid accumulator **60** and the relief valve **41** to a pressure greater than both the fuel and the air. This causes the buffer fluid to flow outward and prevents the fuel and air from flowing inward into the buffer compartment. Therefore, by the use of a buffer fluid accumulator **60** the pressure and volume can be monitored and a loss in buffer fluids indicates a malfunction. In addition, if there is a short period of no fuel flow to draw away the heat, the device automatically makes use of the heat of vaporization of the buffer fluid to cool the air before it enters the passenger cabin. This feature should allow sufficient time to shut off the associated air-conditioning system before the cabin temperature rises to dangerous levels. The buffer fluid would preferably be water to obtain the best heat transfer properties. It may be necessary to add a freeze suppressant, such as glycol, in order to operate at low ambient temperature. An inert type gas, such as nitrogen, can also be considered as a buffer fluid in the event that it is not to be utilized as a secondary heat sink.

In the light of the above teachings, various modifications and variations of the present invention are contemplated and will be apparent to those skilled in the art without departing from the spirit and scope of the invention. Therefore, the invention is not limited to the exemplary apparatus or precedures described, but includes all embodiments within the scope of the claims.

We claim:

1. A heat exchanger comprising:

an enclosure for containing a buffer fluid;

a plurality of spaced parallel plates disposed within said enclosure;

a plurality of first spacer elements arranged between alternately spaced parallel plates to define a plurality of first ducts for the passage of a first fluid;

a plurality of second spacer elements arranged between the alternately spaced parallel plates not including said first spacer elements to define a plurality of second ducts, each of said second ducts opening into the enclosure and being disposed in relation to the enclosure to allow the flow of the buffer fluid therebetween; said first and said second spacer elements are tubular and provided with apertures for the buffer fluid to communicate with the interior thereof;

a plurality of third ducts for the passage of a second fluid, said third ducts disposed within said plurality of second ducts;

heat transfer elements disposed within said second ducts in a heat transfer relationship between said third ducts and the plates of said second ducts; and

manifold means disposed within said buffer fluid enclosure and operably connected to said plurality of third ducts to deliver and discharge the second fluid therefrom.

2. The heat exchanger of claim 1 wherein:

each of said third ducts comprises at least two plate walls disposed within each of said second ducts, said plate walls contoured to have the same configuration and disposed face-to-face with their contacting portions bonded together;

said manifold means disposed within said buffer fluid enclosure includes at least one pipe extending through each of said third ducts, said pipe having openings in the portions passing through said third ducts;

a reinforcement element disposed between at least one bonded portion of said contoured plate walls and the adjacent plate of said second duct to position said third ducts within said second ducts;

first corrugated elements disposed between said two plate walls of said third ducts;

said heat transfer elements comprise second corrugated elements disposed between said third ducts and said spaced parallel plates of said second ducts; and

third corrugated elements disposed within said first ducts.

3. The heat exchanger of claim 2 wherein:

stiffening elements are disposed on opposite sides of the inlets of said first ducts and are bonded to said buffer fluid enclosure;

each stiffening element has a first flange extending outwardly form the inlet of said first ducts and the two exterior plates have portions extending outwardly from the inlet of said first ducts, said outwardly extending flanges and said extending portions from an inlet conduit connected with the inlet of each of said first ducts;

a second flange is formed on the end of said inlet conduit;

plate members are bonded to the edges of the second flange and bonded to said buffer fluid enclosure and to both exterior plates to form a hollow annular compartment around said inlet ducts; and

means are provided to allow the buffer fluid to flow between said hollow annular compartment and said enclosure.

4. The heat exchanger of claim 2 wherein:

said contoured plate walls are further shaped so that, when they are disposed face-to-face, each of said third ducts is U-shaped;

two pipes extend through the buffer fluid enclosure and connect with the respective legs of said third ducts so that said second fluid flows into one leg of each of the U-shaped third ducts and flows out of the other leg thereof; and

means are operably associated with said buffer fluid enclosure to maintain said buffer fluid at a higher pressure than the pressure of both said first and said second fluids.

5. The heat exchanger of claim 3 wherein:

said plate walls are further shaped so that when they are disposed face-to-face each of said third ducts is U-shaped; and

said manifold means includes two pipes extending through said buffer fluid enclosure and connect with each of said third ducts so that said second fluid flows into one leg of each of the U-shaped third ducts and out of the other leg thereof.

6. The heat exchanger of claim 5 wherein a pressure relief valve is operably associated with said enclosure for the buffer fluid.

7. The exchanger of claim 1 wherein:

a first passageway communicates with said first ducts;

said first passageway is formed by an inner wall surrounded by an outer wall forming a hollow annular compartment; and

means are provided to allow the buffer fluid to flow between the hollow annular compartment and said enclosure.

8. A heat exchanger comprising:

an enclosure for containing a buffer fluid;

a plurality of spaced parallel plates disposed within said enclosure;

a plurality of first spacer elements arranged between alternately spaced parallel plates to define a plurality of first passageways within said enclosure to convey a first fluid;

a plurality of second spacer elements arranged between the alternately spaced parallel plates not including said first spacer elements to define a plurality of second passageways communicating with the buffer fluid within said enclosure;

a plurality of third passageways to convey a second fluid, one of said third passageways disposed within each of said plurality of second passageways; and

means to maintain said buffer fluid within said enclosure at a pressure higher than the individual pressure of either the first or second fluid.

9. The heat exchanger of claim 8 wherein said buffer fluid is a liquid.