June 24, 1969 D. M. COX 3,451,474

CORRUGATED PLATE TYPE HEAT EXCHANGER

Filed July 19, 1967 Sheet 1 of 2

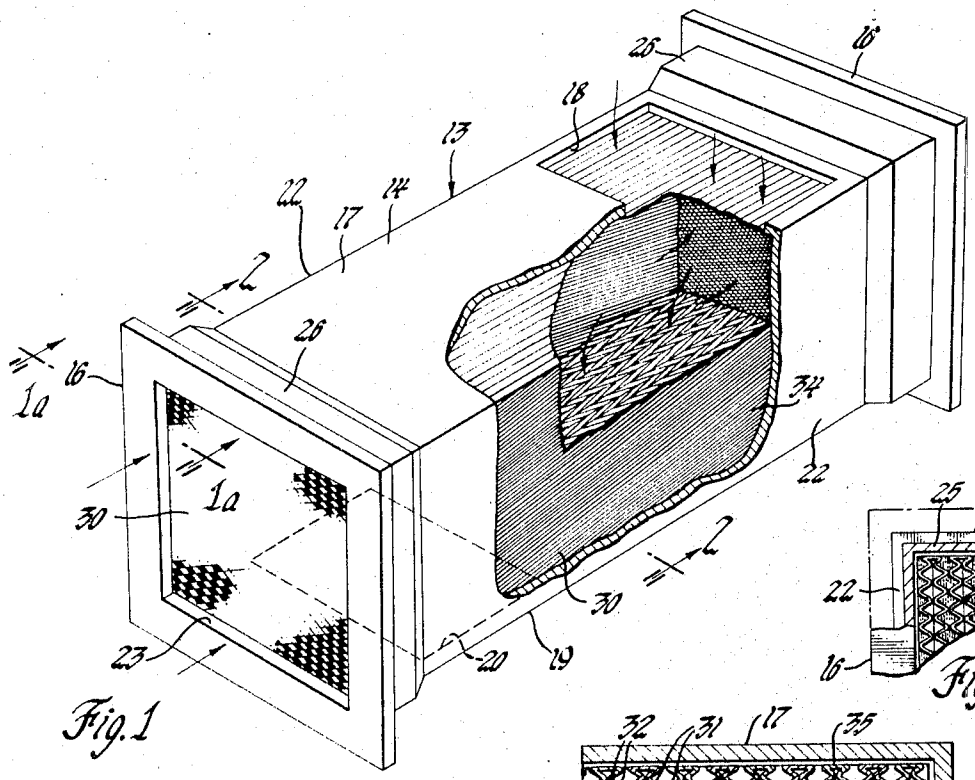


Fig. 1

Fig. 1a

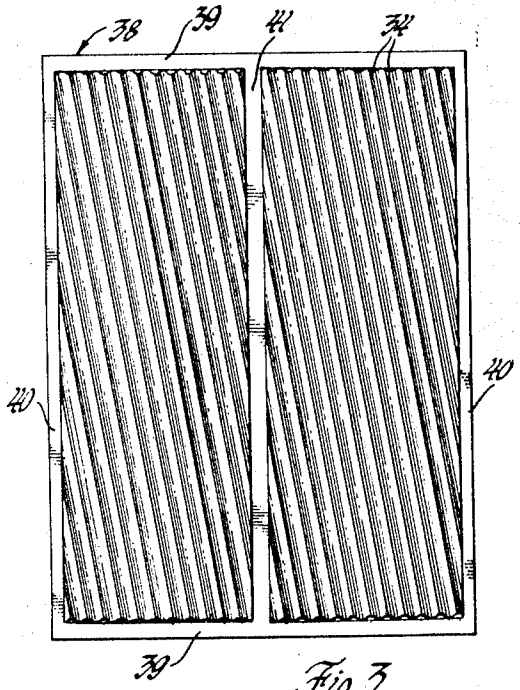


Fig. 3

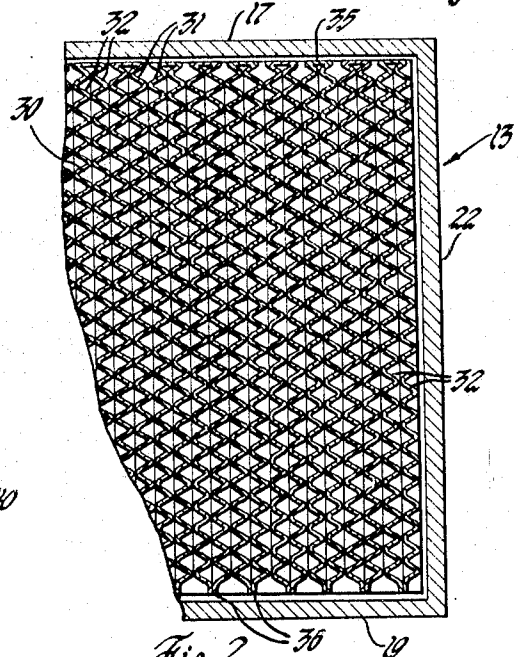


Fig. 2

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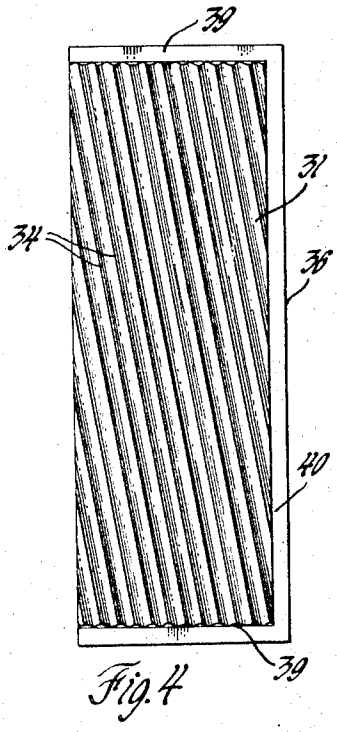


Fig. 4

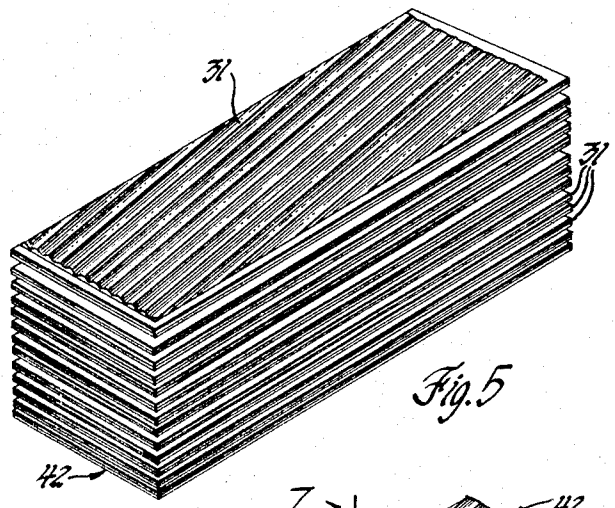


Fig. 5

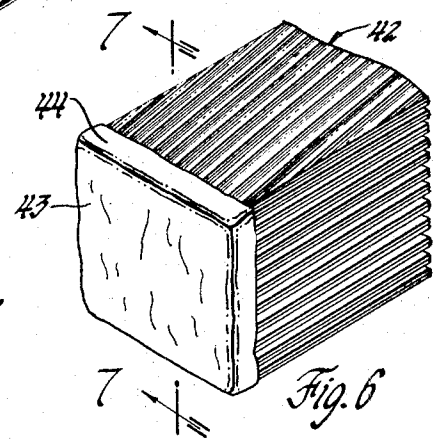


Fig. 6

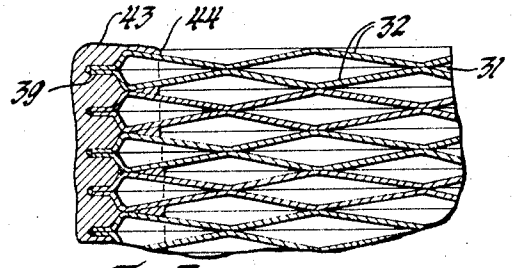


Fig. 7

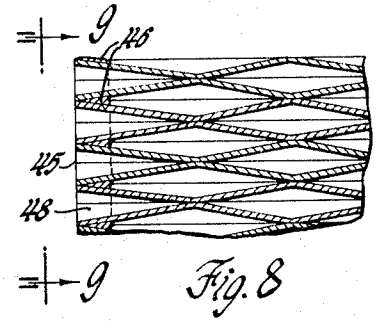


Fig. 8

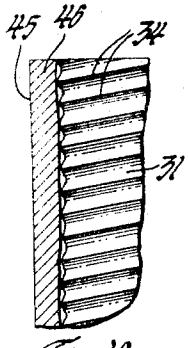


Fig. 10

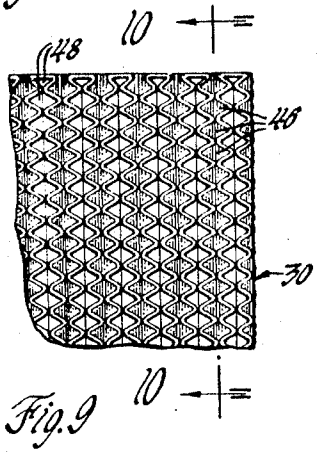


Fig. 9

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CORRUGATED PLATE TYPE HEAT EXCHANGER

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Filed July 19, 1967, Ser. No. 654,606
Int. Cl. F28f 3/04
U.S. Cl. 165—166 9 Claims

ABSTRACT OF THE DISCLOSURE

A heat exchanger structure including corrugated sheets. The sheets are folded into wafers, sealed, stacked, brazed together at the ends, and the brazed metal and ends of the folded sheets are cut away to open passages through the wafers from end to end. This stack is enclosed in a pressure-containing case which confines a fluid which flows between the wafers. A method of making the heat exchanger is also disclosed.

My invention is directed to improved heat exchangers of the fixed or recuperator type. While my invention is capable of various uses, it is particularly suited to provision of a recuperator for use in gas turbines and other systems in which a large heat transfer area is required to transfer heat from a gas at relatively low pressure to another gas at relatively high pressure.

In a typical regenerative gas turbine system air is compressed by a compressor, heated in a heat exchanger, further heated by combustion of fuel, expanded in one or more turbines, and then flows through the heat exchanger to transfer heat from the turbine exhaust gas to the compressed air. Both fixed heat exchangers, which I call recuperators, and rotary heat exchangers, which I call regenerators, have been employed for this purpose. The regenerators present very considerable problems of sealing, and ordinarily the recuperators are both bulky and difficult to make leakproof. One reason for this difficulty lies in the provision of high pressure passages formed from light weight sheet metal. Thin metal sections are employed for high heat transfer in a device of reasonable volume.

According to my invention, a heat exchanger is provided in which there are no high pressure passages in the ordinary sense, the high pressure path extending between a number of wafers each defining a low pressure path through the heat exchanger, the high pressure gas being confined by a casing which encloses the heat exchange pack made up by the wafers.

The principal objects of my invention are to provide a compact and leak-free heat exchanger particularly adapted for use with gases at substantially different pressures, to provide a heat exchanger of small weight and volume for its heat transfer capacity, and, more specifically, to provide a heat exchanger in which the structures defining the low pressure passages are wafer-like in configuration and are formed of corrugated sheets such that the corrugations engage to preserve the separation of the sheets of the wafer and also to define passages between the wafers for the other fluid.

The nature of the invention will be more clearly apparent from the succeeding detailed description of a heat exchanger which is the preferred embodiment of my invention and of the preferred embodiment of a process for manufacturing such a heat exchanger.

FIGURE 1 is an axonometric view, with parts cut away, of a heat exchanger of a cross-counterflow type.

FIGURE 1A is a fragmentary sectional view taken on its plane indicated by the line 1A—1A in FIGURE 1.

FIGURE 2 is a partial cross section of the same on a plane indicated by the line 2—2 in FIGURE 1.

FIGURE 3 is a view of a corrugated sheet.

FIGURE 4 is a view of the same after folding and seam welding to form a wafer.

FIGURE 5 is an axonometric view of a stack or pack of wafers.

FIGURE 6 is a partial view of the same after brazing the end of the pack.

FIGURE 7 is a fragmentary cross-sectional view of the same to an enlarged scale as indicated by the line 7—7 in FIGURE 6.

FIGURE 8 is a view similar to FIGURE 7 after opening the ends of the wafers.

FIGURE 9 is a partial end view of the pack as indicated by the line 9—9 in FIGURE 8.

FIGURE 10 is a fragmentary sectional view of the same taken on the plane indicated by the line 10—10 in FIGURE 9.

Referring first to FIGURES 1, 2, and 3, the heat exchanger comprises a pressure containing casing 13 in the general form of a rectangular tube 14 having end flanges 16 fixed to the ends of the tube. The tube includes an inlet side wall 17 having an inlet at 18 for high pressure gas and an outlet side wall 19 opposite to side 17 defining a high pressure gas outlet 20, and includes two intermediate walls 22. One end flange 16 defines a rectangular inlet 23 and the other defines a similar outlet at the other end of the casing. Each end flange is of L section including a radially extending portion and an axially extending portion 25 which fits within the flared end 26 of the tubular casing section 14. These parts are brazed or otherwise bonded and sealed together.

The interior of the casing is filled by a heat exchange pack 30. This heat exchange pack is made up of a stack of wafers 31, each wafer being a folded corrugated sheet to be described, having parallel walls 32. The walls of the wafers are parallel to the casing sides 22 and thus the wafers present their ends to the end flanges 16 and their edges to the sides 17 and 19 of the casing. The wafers have walls with corrugations as indicated at 34 in FIGURES 1, 3, and 4 which extend generally from end to end of the wafer but are preferably inclined about 10 degrees to the endwise direction of the wafer. The corrugations on opposite walls of a particular wafer are inclined oppositely to the axial direction so that the corrugations cross and engage each other where they cross. Each wafer has a folded edge 35 and a sealed (preferably seam welded) edge 36.

As will be more clearly apparent from FIGURES 3 and 4 each wafer preferably is made from a rectangular sheet 38 having ends 39 and sides 40 and which is provided with corrugations over substantially the entire surface, the corrugations extending at about a ten degree angle to the sides 40. Preferably the margin of the sheet adjacent the sides and ends and a strip 41 through the center between the sides of the sheet are not corrugated.

The sheet is made into a wafer by folding the sheet along the central uncorrugated line 41 so that the two sides 40 meet as shown in FIGURE 4. After the folding, the two edges 40 are seam welded together and the ends 39 are closed by seam welding so that the wafer becomes temporarily a sealed capsule. When the sheet is folded, the corrugations on the opposite walls of the wafer are inclined to each other by about twenty degrees. Thus, they cross over at numerous points to abut each other and hold the walls of the wafer apart. Also, when the wafers are stacked to form a pack 42 as illustrated in FIGURE 5, the corrugations of adjacent wafers cross so that the peaks of the corrugations contact each other. The wafers 31 are stacked to provide a sufficient size heat exchange pack 42 to fill the rectangular casing 13. Each wall of the wafer may be considered to

be a corrugated plate, and the wafer is thus a set or pair of plates.

The seamed ends of the pack are then filled with braze metal at each end as indicated at **43** in FIGURES 6 and 7. This material covers the ends **39** of the wafers and also fills the space between the wafers to the plane **44** indicated in FIGURE 7 to hold the wafers together. The braze metal does not enter the wafers because these are closed at the fold and at the seamwelded side and ends.

The next step in making the heat exchange pack is to machine away the ends of the pack as shown in FIGURES 8 and 9 to a plane face **45** back of the end seam so that the ends of the wafers are opened. However, the machining does not remove the braze metal remaining at **46** between the ends of adjacent wafers. This braze metal not only holds the matrix pack assembled, but it also blocks the ends of the passages between adjacent wafers as indicated at **46** in the FIGURES 8 to 10.

The structure of the heat exchange pack should be clear from the foregoing description of the assembly and of the process of manufacture. The lower pressure gas can flow into the wafers through openings **48** at one end of the pack **30** and out the similar openings at the other end. The high pressure gas can come into the entrance **18** and flow out the entrance **20**, flowing both across and lengthwise of the matrix pack between adjacent wafers **31**. The high pressure gas is confined by the casing **13**. The end flanges **16** of the casing are brazed or otherwise sealingly assembled to the matrix pack either at the same time that the braze metal **43** is applied, or later. The outer casing **13** may be wrapped around the flanges **25** and welded or brazed to the flanges to complete the fluid-tight casing. Alternatively, the flanges **16** may be initially provided on the casing portion **14** and the heat exchange pack thereafter slipped into the casing and sealed at the ends to the wall of the casing by any appropriate means to prevent leakage of the higher pressure gas around the exterior of the heat exchange pack at the ends of the heat exchanger.

Ducts to conduct the hot and cold gases to and from the heat exchanger may be of any suitable configuration and attached by any suitable conventional means (not illustrated). As will be apparent, the relatively inclined corrugations of the heat exchange wafers provide a means whereby each wall has an array of points at which it abuts the adjacent wall and also provides a very substantial gas passage between it and the adjacent wall, whether this be a hot gas or a cold gas passage. Also, the relatively inclined corrugations promote turbulence and good heat conduction from the gas to the thin sheet metal wall, or vice versa. Because of the type of structure described, the walls between the hot low pressure gas and the cold high pressure gas may be quite thin, thus promoting compactness, light weight, and efficiency of the heat exchanger.

It may be noted that the drawings are not intended to show the structure to scale since the walls may be very thin as a practical matter. In a particular embodiment it is considered desirable to have the corrugations **34** on the sheet **38** and on the wafer formed from it to be approximately 0.043 inch from peak to peak with the depth of corrugations approximately 0.0143 inch. The sheet is of suitable high temperature and oxidation-resistant metal such as stainless steel, approximately 0.003 inch thick in this embodiment.

The process described above provides for a very easy and economical manufacture of such a heat exchanger pack.

Obviously, the water can be made from two sheets each corresponding to half of sheet **38**, the wafers being seam welded together around the entire margin.

Attention is called to my divisional application Ser. No. 770,921 for Heat Exchanger Manufacture filed Oct. 28, 1968.

The detailed description of the preferred embodiment of the invention for the purpose of explaining the principles thereof is not to be considered as limiting or restricting the invention, since many modifications may be made by the exercise of skill in the art within the scope of the invention.

I claim:

1. A heat exchanger comprising, in combination,

a pressure-containing casing having ends and sides, having an inlet and an outlet for one fluid at the ends of the casing, and having an inlet and an outlet for another fluid at higher pressure in opposite sides of the casing,

a heat exchange pack mounted in the casing defining separate flow paths for the fluids between the respective inlets and outlets,

the heat exchange pack being an assembly of a plural number of heat exchange wafers,

each wafer having two parallel walls sealingly joined at the edges and at least partially spaced at the ends of the wafer so as to define a passage from end to end of the wafer for the said one fluid,

the walls having corrugations inclined differently to the direction from end to end of the wafer, with the corrugations of the two walls abutting at points where the peaks of the corrugations cross each other, to prevent collapse of the wafer under external pressure,

a plural number of said wafers being stacked together in abutment with their edges directed toward the sides of the casing which provide the inlet and outlet for the other fluid, the abutting walls of adjacent wafers having their corrugations relatively inclined so that a conduit for the said other fluid is defined between adjacent wafers,

and wall means at the ends of the wafers blocking the said conduits and providing a seal between the wafers and the casing to prevent communication between the flow paths for the two fluids.

2. A heat exchanger as defined in claim **1** in which corrugations in adjacent walls are oppositely inclined.

3. A heat exchanger as defined in claim **1** in which the walls are less than 0.005 inch thick.

4. A heat exchanger as defined in claim **1** in which the depth of the corrugations is about one third of the width of the corrugations.

5. A heat exchanger as defined in claim **1** in which the said wall means includes braze metal between the wafers blocking the said conduits.

6. A heat exchange structure comprising a plural number of heat exchange plates in stacked relation with each plate except the plates at the top and bottom of the stack engaging two adjacent said plates and the top and bottom plates abutting an adjacent plate, the plates being of generally rectangular form with two sides and two ends and being stacked with the sides of the plates at the sides of the stack and the ends of the plates at the ends of the stack, the plates having corrugations covering substantially the entire surface of each plate defining substantially parallel ridges on each face of each plate, the ridges of alternate plates extending in one common direction and the ridges of the plates interleaved between said alternate plates extending in a second common direction at an angle to the first common direction so that the ridges of each plate engage the ridges of adjacent plates in a two-dimensional array of points to preserve a spacing between adjacent plates over the major portion of the surface of said plates, the plates of the stack being divided into sets with each set consisting of two adjacent plates, the plates of each set being joined together along the sides to define a fluid passage through the set from end to end of the stack, and the sets being joined together across the ends to define fluid passages from side to side of the stack between the sets.

7. A heat exchange structure as defined in claim **6** in which the said plates are all substantially identical and alternate plates are inverted.

8. A heat exchange structure as defined in claim 6 in which the walls are less than 0.005 inch thick.

9. A heat exchange structure as defined in claim 6 in combination with a casing enclosing the said structure defining inlets to and outlets from the passages through the sets and the passages between the sets.

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