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(54) Heat exchanger with compound plates

(57) A heat exchanger 30, for donating heat from one fluid stream to another fluid stream, comprising a plurality of compound heat exchanger plates 2, each plate having a corrugated heat exchange portion 4 and a header portion 6 which is not corrugated, the heat exchange portion 4 being a separate component from the header portion 6, and being joined permanently to the header portion 6, respective plates 2 being joined together to form heat exchanger cells 16.

A heat exchanger plate 2 may be formed in a method having the following steps:

- (a) forming a heat exchange portion 4, which is of corrugated cross section;
- (b) forming a header portion 6, which is not corrugated;
- (c) joining the header portion 6 permanently to the heat exchange portion 4 to form a compound plate 2.

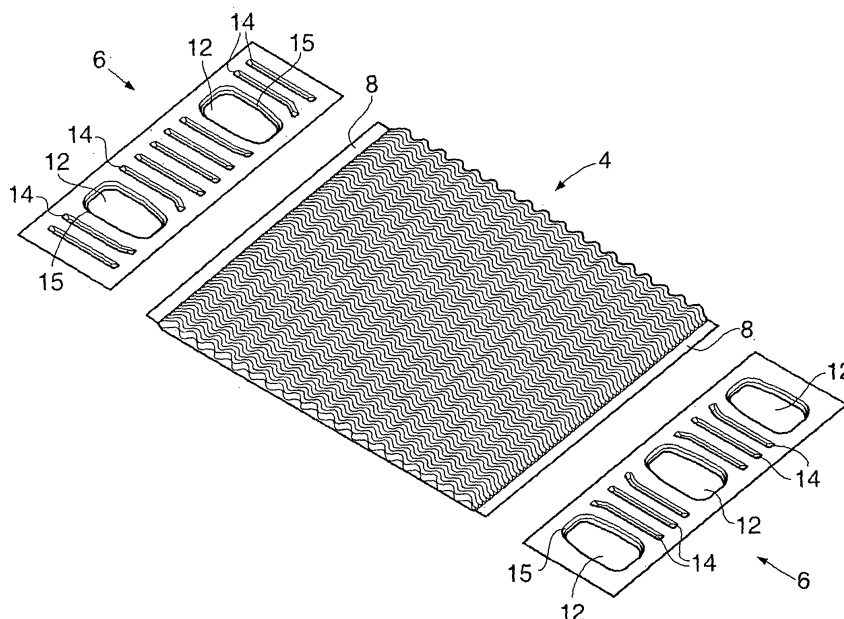


Fig. 2

Description

TECHNICAL FIELD

[0001] This invention relates to a heat exchanger with compound heat exchanger plates.

BACKGROUND

[0002] Heat exchangers are used in gas turbine engines as a means of increasing efficiency by extracting heat from the exhaust gas and donating this heat to the compressed air leaving the compressor prior to its entering the combustion chamber. Conventional heat exchangers are of two main types, firstly the rotating disc type, commonly known as the regenerator, and secondly the static plate type, commonly known as the recuperator, to which this invention is directed.

[0003] Such heat exchangers have to withstand the considerable temperature experienced by the exhaust gases, which might be up to 700°C, and the high pressure of the compressed air, which might be up to eight times atmospheric pressure.

[0004] The present invention seeks to provide a heat exchanger which is compact, cheap to manufacture and technically reliable.

SUMMARY OF INVENTION

[0005] According to a first aspect of the present invention, there is provided a heat exchanger, for donating heat from one fluid stream to another fluid stream, comprising a plurality of compound heat exchanger plates, each plate having a corrugated heat exchange portion and a header portion which is not corrugated, the heat exchange portion being a separate component from the header portion, and being joined directly and/or permanently to the header portion.

[0006] The term "joined permanently" as it is used in this specification means joined by welding, brazing, adhesive, riveting or by any other physical interconnection, other than releasable fasteners.

[0007] In accordance with a preferred embodiment of the present invention, respective pairs of compound plates are sealed to one another at their edges to define respective heat exchanger cells, respective cells being joined together by holes, formed in the header portion of the compound or combined plates and sealed around their edges, such holes providing fluid inlets and/or outlets to each cell.

[0008] Preferably, the header portion of each compound plate is substantially planar. Preferably, the material thickness of the header portion is greater than the material thickness of the corrugated heat exchange portion.

[0009] The corrugations at an end of the heat exchange portion are preferably crushed to the centre line of the heat exchange portion, forming a planar surface

to which the header portion may be joined. Preferably, the portions of the compound plates are joined together by welding, which may be seam welding.

[0010] Preferably, each compound plate has two header portions, disposed at opposite ends of a heat exchange portion. Preferably, only one side of each header portion has a plurality of projections. In a preferred embodiment, the projections comprise ribs, which are so arranged as to constitute flow guides, such that fluid flowing in the cells occupies substantially the full extent of the cells.

[0011] If the projections are formed on one side only of each header portion, the surface of the header portion without projections presents no obstruction to the free flow of the fluid stream (preferably high pressure gas) which passes over that header portion, so that the fluid stream can spread out from the inlet holes over the full extent of the heat exchanger portion.

[0012] Preferably, the corrugations of the heat exchange portion are pressed around the remaining edges of the heat exchange portion, and respective pairs of compound plates are welded or otherwise fixed around their perimeters to form the said matrix of heat exchanger cells.

[0013] The fluid inlet hole into a respective cell of the heat exchanger may be provided at one end of the matrix and the fluid outlet hole from the said cell is preferably provided at the opposite end of the matrix. The holes in the cells at one end of the matrix may be staggered relative to the holes in the cells at the other end of the matrix in order to equalise flow distribution. Preferably, the holes are elongated in a direction parallel to the corrugations.

[0014] Preferably, the inlet holes are welded or otherwise fixed around their perimeters and the outlet holes are preferably also welded or otherwise fixed around their perimeters to join together adjacent cells. The holes in the cells at the extremity of the matrix may be welded or otherwise fixed to a support structure within which the two streams of gas are separated and directed.

[0015] In accordance with the preferred embodiment of the invention, heat is extracted from a first gas stream at a first temperature and donated to a second gas stream at a second temperature lower than the first temperature by heat conduction through the said heat exchanger plates. The two gas streams preferably flow in a substantially counter direction along the corrugations of the matrix. Preferably, the second gas stream enters through the fluid inlets, spreads out across the unobstructed header portion to occupy substantially the full extent of the heat exchange portion and leaves through the fluid outlets respectively, and the first gas stream spreads out, directed by the flow guides, and passes in between adjacent cells in a counter flow direction. Preferably, the first gas stream comprises the exhaust gases of a gas turbine and the second gas stream comprises the compressed air of the said gas turbine prior to its entering the combustion chamber of said turbine.

[0016] The cells of the heat exchanger matrix may be

substantially flat. Alternatively, the cells of the heat exchanger matrix may be curved, and may be arranged together to form an annulus.

[0017] Preferably, the corrugations of the heat exchange portions of the compound plates follow an oscillating path, so that the corrugations define a wave pattern when viewed in a direction normal to the surface of the plate. The compound plates may be arranged such that the wave pattern of plates in adjacent cells criss-crosses, thus allowing greater turbulence in the gas stream and consequently greater heat transfer. Additionally, criss-crossing the wave pattern of adjacent plates avoids the possibility of plates interlocking and provides improved support against pressure forces.

[0018] A particular advantage of the compound plates of the present invention is that the header portions, being of a greater thickness, can exhibit a greater stiffness than the corrugated heat exchange portions. The stiffer header portions require a reduced number of projections to support them against pressure differences between the two gas streams when compared with conventional heat exchanger plates. The reduced number of projections leads to a reduced pressure drop across each heat exchanger cell and hence greater efficiency for the heat exchanger.

[0019] According to another aspect of the present invention, there is provided a method of forming a heat exchanger plate comprising the steps of:

- (a) forming a heat exchange portion, which is of corrugated cross section;
- (b) forming a header portion, which is not corrugated;
- (c) joining the header portion directly and/or permanently to the heat exchange portion to form a compound plate.

[0020] Preferably, the step (c) comprises crushing the corrugations at an end of the heat exchange portion to the centre line of the heat exchange portion, forming a planar surface to which the header portion may be joined.

[0021] Preferably, the method further comprises forming a second header portion and joining a header portion to opposite ends of the heat exchange portion.

[0022] Preferably, the portions of the plates are joined together by welding, which may be seam welding.

[0023] Preferably, the method further comprises the step of forming holes through the header portion or portions. The method may also comprise the step of forming projections on the header portion or portions. The projections may be formed in the shape of ribs and may be so formed as to act as flow guides, such that the fluid flowing in the cells occupies substantially the full extent of the cells.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] For a better understanding of the present invention, and to show more clearly how it may be carried into

effect, reference will now be made, by way of example, to the accompanying drawings, in which:-

Figure 1 is a perspective view of a heat exchanger plate;

Figure 2 is an exploded view of the plate of Figure 1;

Figure 3 is a plan view of a heat exchanger cell;

Figure 4a is an end view of the cell of Figure 3;

Figure 4b is a sectional view along the line XX of Figure 3;

Figure 5a is an end view of two of the cells of Figure 3;

Figure 5b is a sectional view of the cells of Figure 5a

Figure 6 is a perspective view of a heat exchanger matrix showing an alternative embodiment of inlet and outlet ports.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0025] Referring to Figure 1, a compound heat exchanger plate 2 comprises a central heat exchange portion 4 and two header portions 6. The heat exchange portion 4 is corrugated, the corrugations following an oscillating path so that they define a wave pattern when viewed in a direction normal to the surface of the plate. The corrugations at opposite ends 8 of the heat exchange portion 4 are crushed to the centreline of the heat exchange portion so as to present a planar surface. The header portions 6 are substantially planar and are formed from a material of greater thickness than that of the heat exchange portion 4. The header portions 6 thus exhibit a greater stiffness than the heat exchange portion 4. The header portions 6 are sealed to the crushed edges 8 of the heat exchange portion 4 by welds 10, which are preferably seam welds.

[0026] A plurality of holes 12 extend through the header portions 6 to permit the passage of fluid. The holes 12 are elongated in a direction parallel to the corrugations. Holes 12 in opposite header portions 6a and 6b are staggered relative to each other such that no one hole is directly opposite a corresponding hole. A plurality of projections 14 are formed on one side of the header portions 6 in the shape of ribs. At least one rib 14 is disposed on either side of each hole 12, extending in a direction substantially parallel to the corrugations of the heat exchange portion 4. Those ribs 14a which are disposed adjacent one of the holes 12 have a slight curvature, following the shape of the adjacent hole. In use, ribs 14 act as both support for the plate 2 and as flow guides, directing fluid passing over the plate into the corrugated heat exchange portion 4.

[0027] With reference to Figure 2, the compound plate 2 may be assembled by first stamping out a metal sheet to form a corrugated heat exchange portion 4, having oscillating corrugations which form a wave pattern when viewed from a direction normal to the side of the heat exchange portion. Opposite edges 8 of the heat exchange portion 4 are then crushed to the centre line of the corrugations so as to provide a planar surface for attachment to header portions. Two substantially planar header portions 6 are then stamped out or otherwise formed from a material of greater thickness than that used to form the heat exchange portion 4. In the illustrated embodiment, projections are formed on one side of the header plates 6 in the form of ribs 14 and depressions 15, which may later be cut away to form holes 12. The ribs 14 are formed so as to act as flow guides, such that in use, they will direct fluid passing over the compound plate to occupy substantially the full extent of the heat exchange portion. The header portions 6 are then welded, preferably by seam welding, to the crushed end portions 8 of the heat exchange portion 4.

[0028] With reference to Figures 3, 4a and 4b, a heat exchanger cell 16 comprises a pair of compound plates 2. The plates 2 are welded together or otherwise sealed around their peripheries 20 to form the cell 16. The free edges 18 of the heat exchange portions 4 of the two plates 2 are crushed to the level of the header portions 6, thus presenting planar surfaces for attachment to the adjacent plate.

[0029] Referring to Figure 6, a heat exchanger matrix 30 comprises a plurality of heat exchanger cells 16 which are stacked one on top the other. The respective heat exchanger cells are welded or otherwise fixed together around the perimeter 24 of each hole 12 as shown in Figures 5a and 5b. Each set of welded together holes 12 comprises an inlet port 22 or an outlet port 24 which is in fluid communication with the interior of each of the cells 16.

[0030] In the illustrated embodiment, the heat exchanger matrix 30 comprises a recuperator for use in a gas turbine engine. Cold high pressure air C from the compressor of the gas turbine engine is directed into the inlet ports 22 by means of a manifold (not shown). From the inlet ports, the cold high pressure air C is directed between the corrugated heat exchange portions 4 of the compound plates 2 of each heat exchanger cell 16 and makes its way along the heat exchanger matrix 30 into the outlet ports 24, which are themselves connected to an outlet manifold (not shown).

[0031] As the projections 14 are formed on only the outside surface of the plates of a respective heat exchanger cell, the inside surfaces of the plates are clear of obstructions in the vicinity of the holes 12, so that the cold high pressure air entering the cell through the holes 12 can spread out unimpeded to occupy substantially the full extent of the heat exchanger matrix.

[0032] Hot low pressure exhaust gas E from the gas turbine engine is directed into an end of the heat exchang-

er matrix 30 and is forced between the cells 16 of the heat exchanger matrix 30. The gas E is directed by the ribs 14 to occupy substantially the entire area of the heat exchange portion 4 of each cell 16. As the exhaust gas E is forced between the heat exchanger cells 16 and the colder high pressure air C is forced through the interior of the heat exchanger cells 16, heat is donated from the exhaust gas E to the colder high pressure air C. Preferably, the two gas streams flow in a substantially counter direction. The corrugations of the heat exchange portions 4 cause the air C to follow a tortuous path. Consequently, heat transfer occurs over a greater surface area and over a greater time than if the heat exchange portions were planar, and the overall heat transfer is thus improved.

[0033] Preferably, the compound plates 2 of each heat exchanger cell 16 are arranged so that the corrugations of the heat exchange portions 4 of the plates 2 criss-cross, such that the corrugations of one compound plate are out of phase with the corrugations of an adjacent compound plate. Preferably the corrugations are 180° out of phase. This enables gas entering the cells to traverse sideways across the corrugations thereby to occupy substantially the whole volume of the cells 16. Additionally, this arrangement prevents intermeshing of adjacent compound plates, ensuring the entire matrix remains rigid and stable.

[0034] Although the heat exchanger of the present invention has been described with reference to substantially flat, planar cells, in an alternative embodiment, the heat exchanger is formed from curved compound plates and may be formed from a single, spirally wound cell.

Claims

1. A heat exchanger, for donating heat from one fluid stream to another fluid stream, comprising a plurality of compound heat exchanger plates, each plate having a corrugated heat exchange portion and a header portion which is not corrugated, the heat exchange portion being a separate component from the header portion, and being joined to the header portion.
2. A heat exchanger as claimed in claim 1, in which respective pairs of compound plates are sealed to one another at their edges to define respective heat exchanger cells, respective cells being joined together by holes, formed in the header portion of the compound plates and sealed around their edges, such holes providing fluid inlets and/or outlets to each cell.
3. A heat exchanger as claimed in any claim 1 or 2 in which the header portion is substantially planar.
4. A heat exchanger as claimed in any one of the preceding claims, in which the material thickness of the header portion is greater than the material thickness

of the corrugated heat exchange portion.

5. A heat exchanger as claimed in any one of the preceding claims, in which the portions of the compound plates are joined together by welding.
6. A heat exchanger as claimed in any one of the preceding claims, in which the portions of the compound plates are joined together by seam welding.
7. A heat exchanger as claimed in any one of the preceding claims, in which the corrugations at an end of the heat exchange portion are crushed to the centre line of the heat exchange portion, forming a planar surface to which the header portion is joined.
8. A heat exchanger as claimed in any one of the preceding claims, in which one side of the header portion has a plurality of projections.
9. A heat exchanger as claimed in claim 8, in which the projections are ribs.
10. A heat exchanger as claimed in claim 8, in which the projections are so arranged as to constitute flow guides.
11. A heat exchanger as claimed in any one of the preceding claims, in which each compound plate has two header portions, disposed at opposite ends of a heat exchange portion.
12. A heat exchanger as claimed in claim 11, in which the corrugations of the heat exchange portion are pressed around their remaining edges, and respective pairs of compound plates are welded or otherwise fixed around their perimeters to form the said matrix of heat exchanger cells.
13. A heat exchanger as claimed in any one of the preceding claims, in which the fluid inlet hole into a respective cell is provided at one end of the matrix and the fluid outlet hole from the said cell is provided at the opposite end of the matrix.
14. A heat exchanger as claimed in any one of the preceding claims, in which the holes in the cells at one end of the matrix are staggered relative to the holes in the cells at the other end of the matrix.
15. A heat exchanger as claimed in any one of the preceding claims, in which the holes are elongated in a direction parallel to the corrugations.
16. A heat exchanger as claimed in any one of the preceding claims, in which the inlet holes are welded or otherwise fixed around their perimeters and/or the outlet holes are welded or otherwise fixed around

their perimeters to join together adjacent cells.

17. A heat exchanger as claimed in any one of the preceding claims, in which heat is extracted from a first gas stream at a first temperature and donated to a second gas stream at a second temperature lower than the first temperature by heat conduction through the said heat exchanger plates.
18. A heat exchanger as claimed in claim 17, in which the two gas streams flow in a substantially counter direction along the corrugations of the matrix.
19. A heat exchanger as claimed in claim 17 or 18, in which the second gas stream enters through the fluid inlets and leaves through the fluid outlets respectively and the first gas stream passes in between adjacent cells in a counter flow direction.
20. A heat exchanger as claimed in any one of claims 17 to 19, in which the first gas stream comprises the exhaust gases of a gas turbine and the second gas stream comprises the compressed air of the said gas turbine prior to its entering the combustion chamber of said turbine.
21. A heat exchanger as claimed in any one of the preceding claims in which the cells are substantially flat.
22. A heat exchanger as claimed in any one of claims 1 to 20, in which the cells are curved.
23. A heat exchanger as claimed in any one of the preceding claims, in which the matrix is made from a single spirally wound cell.
24. A heat exchanger as claimed in any one of the preceding claims, in which the corrugations of the heat exchange portions of the compound plates follow an oscillating path, so that the corrugations define a wave pattern when viewed in a direction normal to the surface of the plate.
25. A heat exchanger as claimed in claim 24, in which the wave pattern of plates in adjacent cells criss-crosses thus allowing greater turbulence in the gas streams and consequently greater heat transfer.
26. A method of forming a heat exchanger plate comprising the steps of:
 - (a) forming a heat exchange portion, which is of corrugated cross section;
 - (b) forming a header portion, which is not corrugated;
 - (c) joining the header portion to the heat exchange portion to form a compound plate.

27. A method as claimed in claim 26, wherein the step (c) comprises crushing the corrugations at an end of the heat exchange portion to the centre line of the heat exchange portion, forming a planar surface to which the header portion is joined. 5
28. A method as claimed in claim 26 or 27, wherein the step (b) further comprises forming a second header portion. 10
29. A method as claimed in claim 28, wherein the step (c) comprises joining a header portion to opposite ends of the heat exchange portion.
30. A method as claimed in any one of claims 26 to 29, wherein the portions of the plates are joined together by welding. 15
31. A method as claimed in any one of claims 26 to 30, wherein the portions of the plates are joined together by seam welding. 20
32. A method as claimed in any one of claims 26 to 31, further comprising the step of forming a plurality of holes in the header portion or portions. 25
33. A method as claimed in any one of claims 26 to 32, further comprising the step of forming a plurality of projections on the header portion or portions. 30
34. A method as claimed in claim 33, wherein the projections are formed in the shape of ribs.
35. A method as claimed in claim 34, wherein the ribs are formed as flow guides, such that fluid flowing past the plate occupies substantially the full extent of the heat exchange portion. 35

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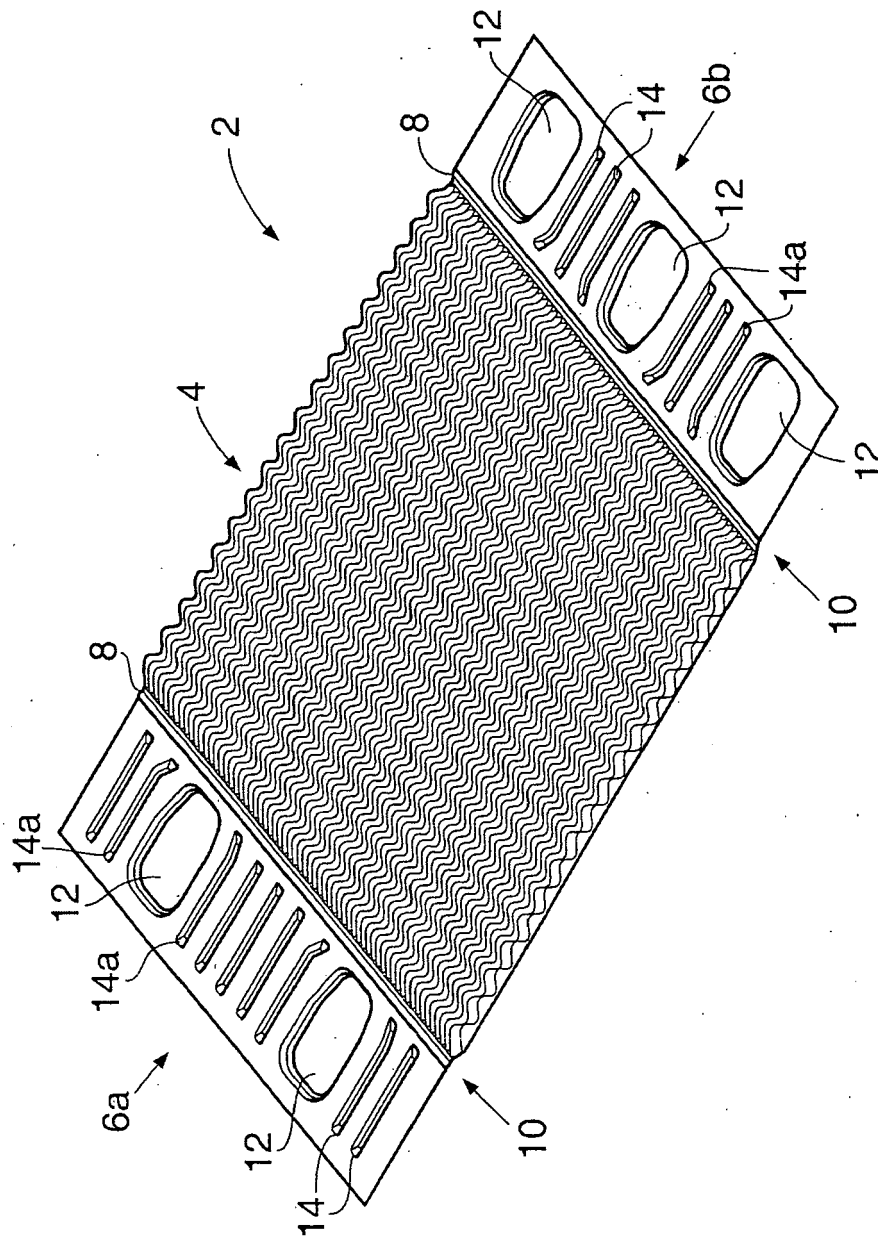


Fig. 1

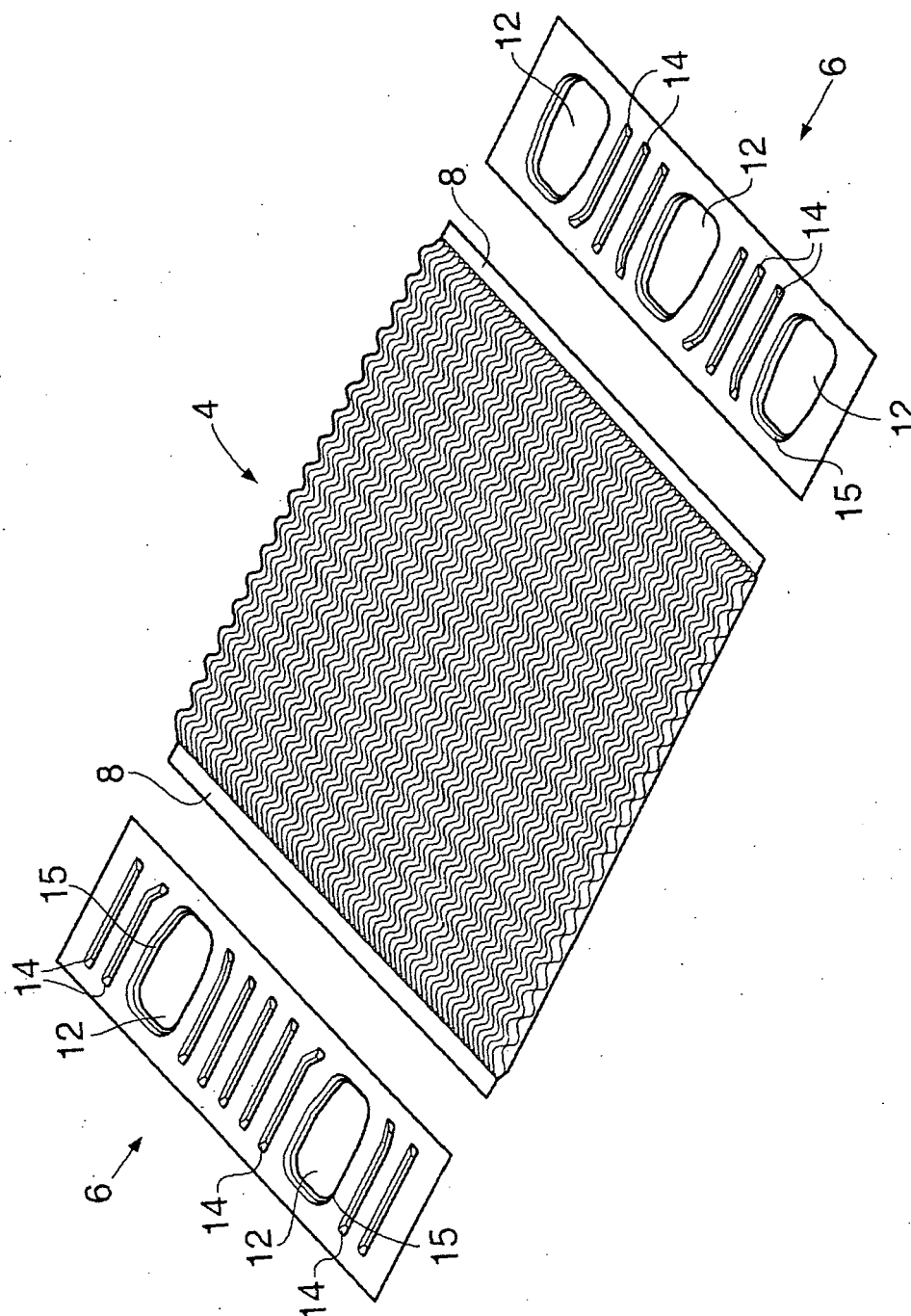


Fig. 2

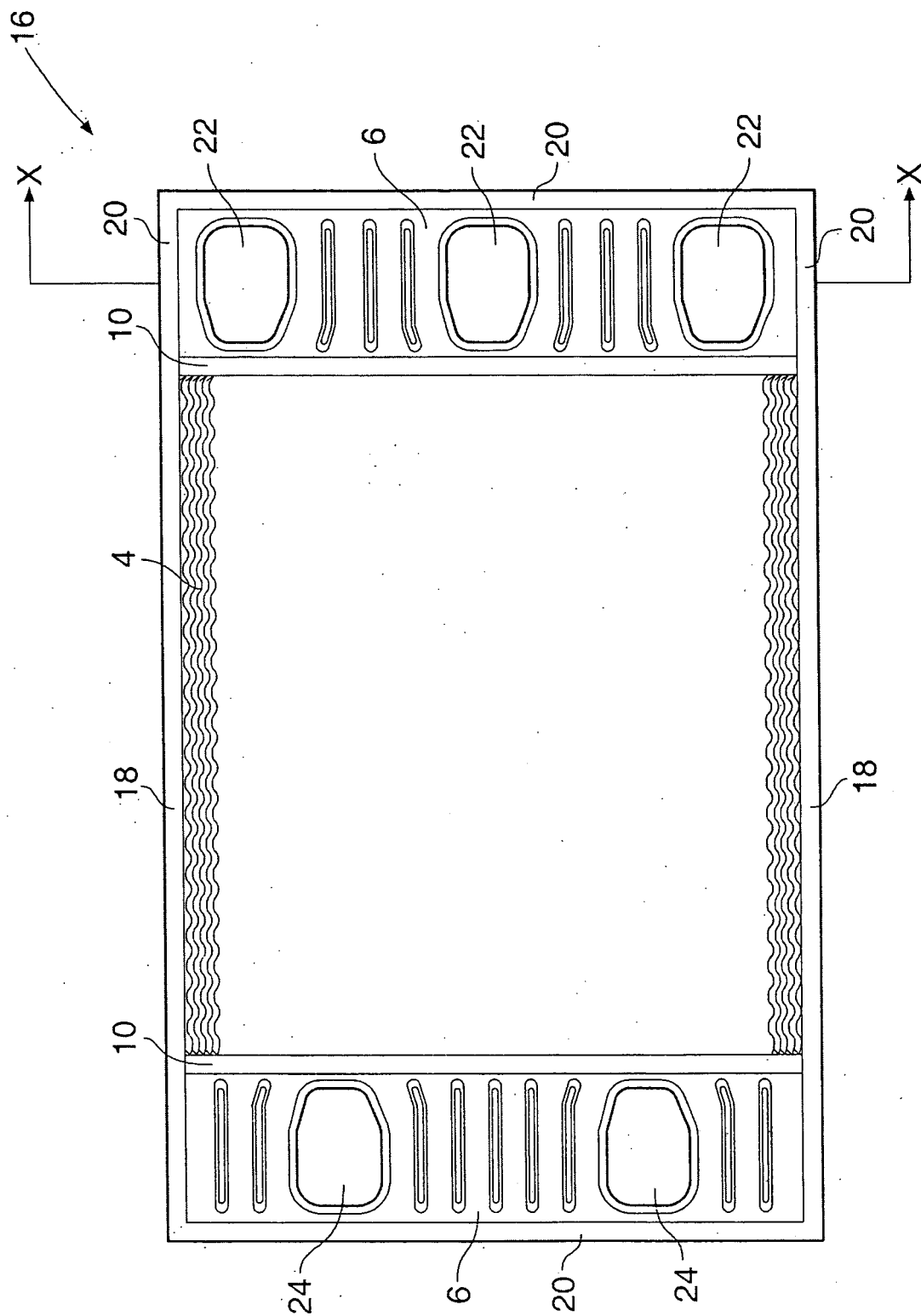


Fig. 3

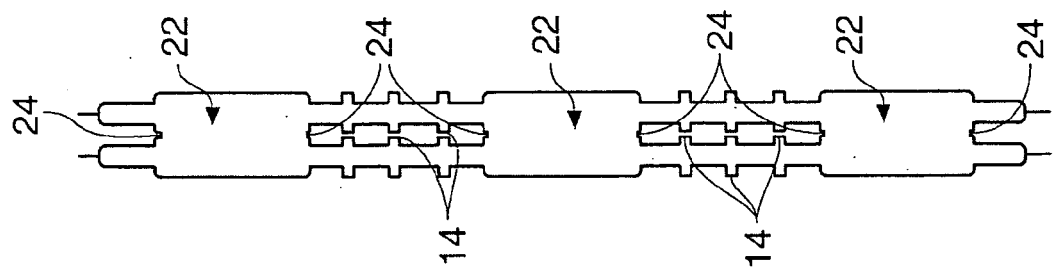


Fig. 5b

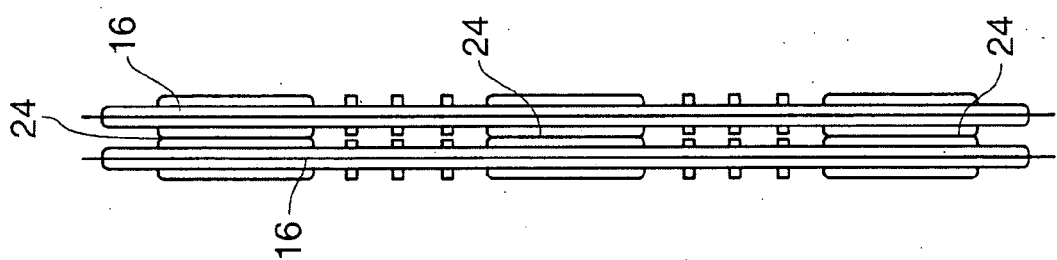


Fig. 5a

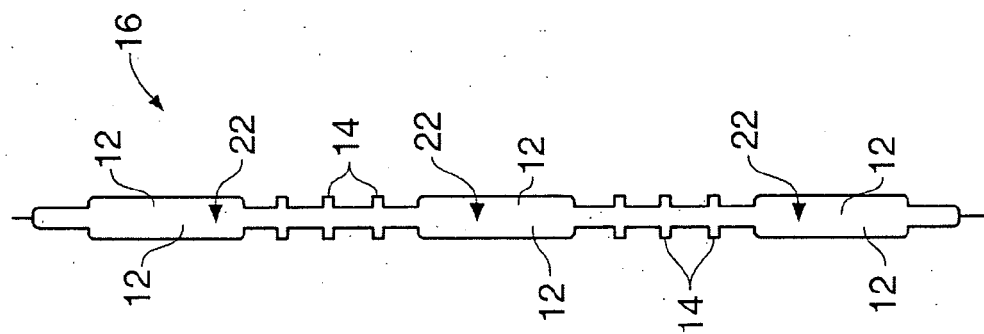


Fig. 4b

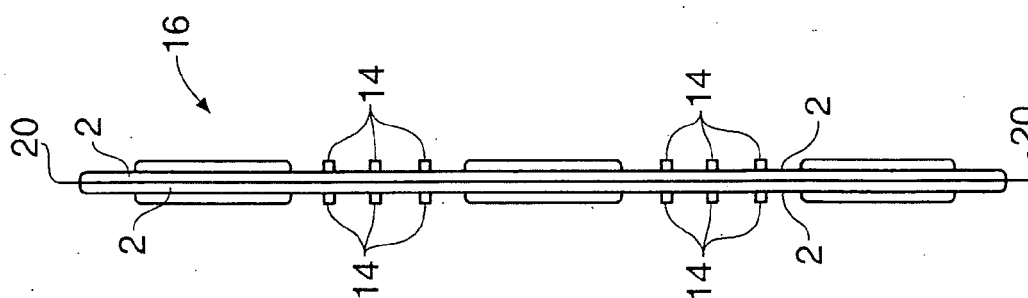


Fig. 4a

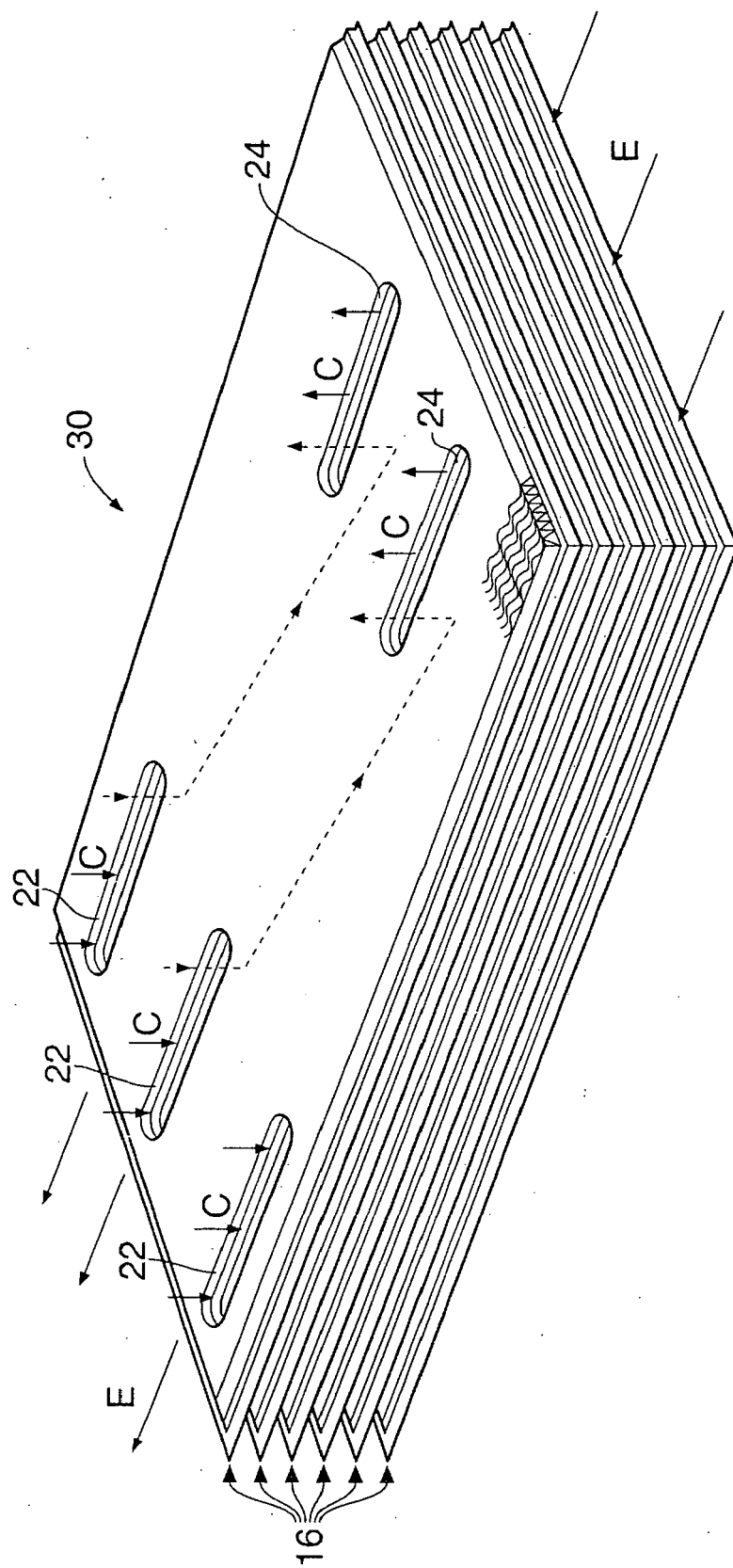


Fig. 6



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 25 5849

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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