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Nakamura et al.

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[45] **June 25, 1974**

[54] **HEAT EXCHANGER**

[75] Inventors: **Kenya Nakamura**, Okazaki; **Makoto Kuroyanagi**, Hekinan, both of Japan

[73] Assignee: **Nippondenso Co., Ltd.**, Kariya-shi, Japan

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Apr. 18, 1972 Japan 47-46233

[52] **U.S. Cl.** **165/166,** 165/157

[51] **Int. Cl.** **F28b 3/08**

[58] **Field of Search** 165/166, 167, 60, 39.51, 165/141, 155, 157, 164, 165

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Primary Examiner—Charles J. Myhre

Assistant Examiner—Theophil W. Streule, Jr.

Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

A heat exchanger for heat exchange between low-temperature and high-pressure air and high-temperature and low-pressure gas comprising a housing, a plurality of partition members disposed substantially radially in the housing for defining therebetween alternate air and gas passages for passing the air and gas in directions opposite to each other, a first corrugated fin disposed in each air passage, and a second corrugated fin disposed in each gas passage. The first fins are suitably cut out at one end thereof to communicate with an air inlet of the heat exchanger, and the second fins are suitably cut out at the end remote from the cut-out end of the first fins to communicate with a gas inlet of the heat exchanger so as to attain satisfactory heat exchange between the two fluids.

5 Claims, 9 Drawing Figures

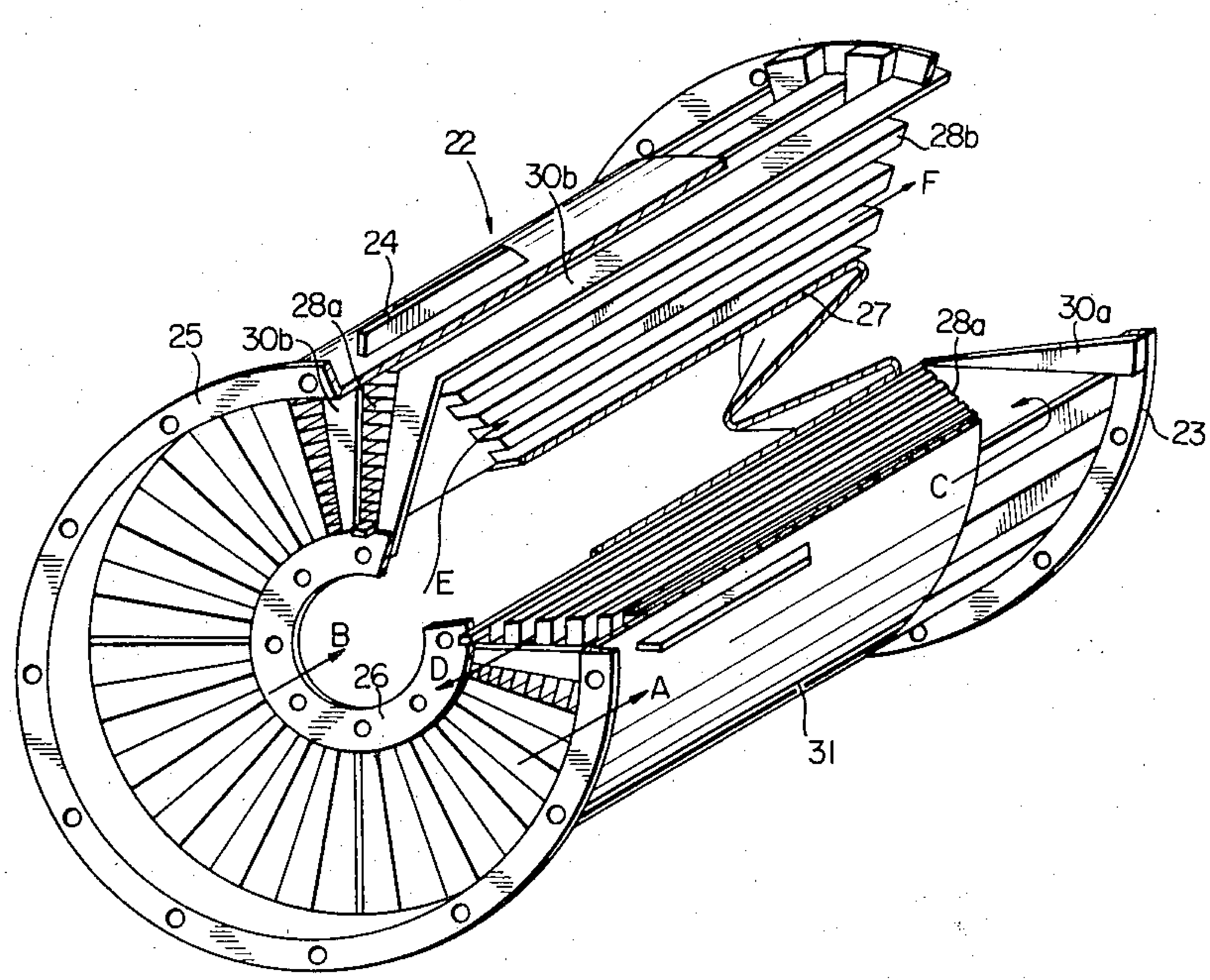

FIG. 1

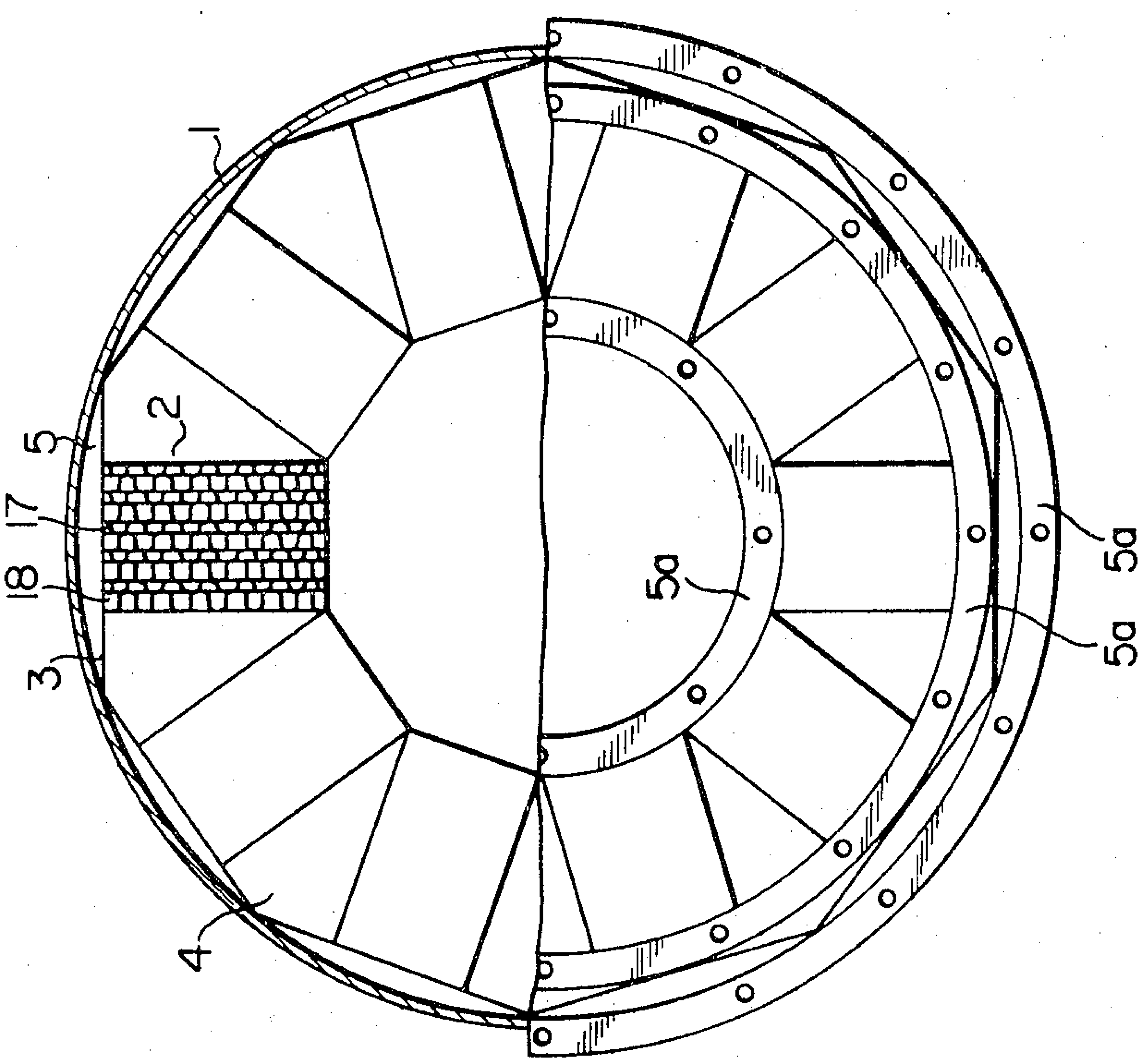

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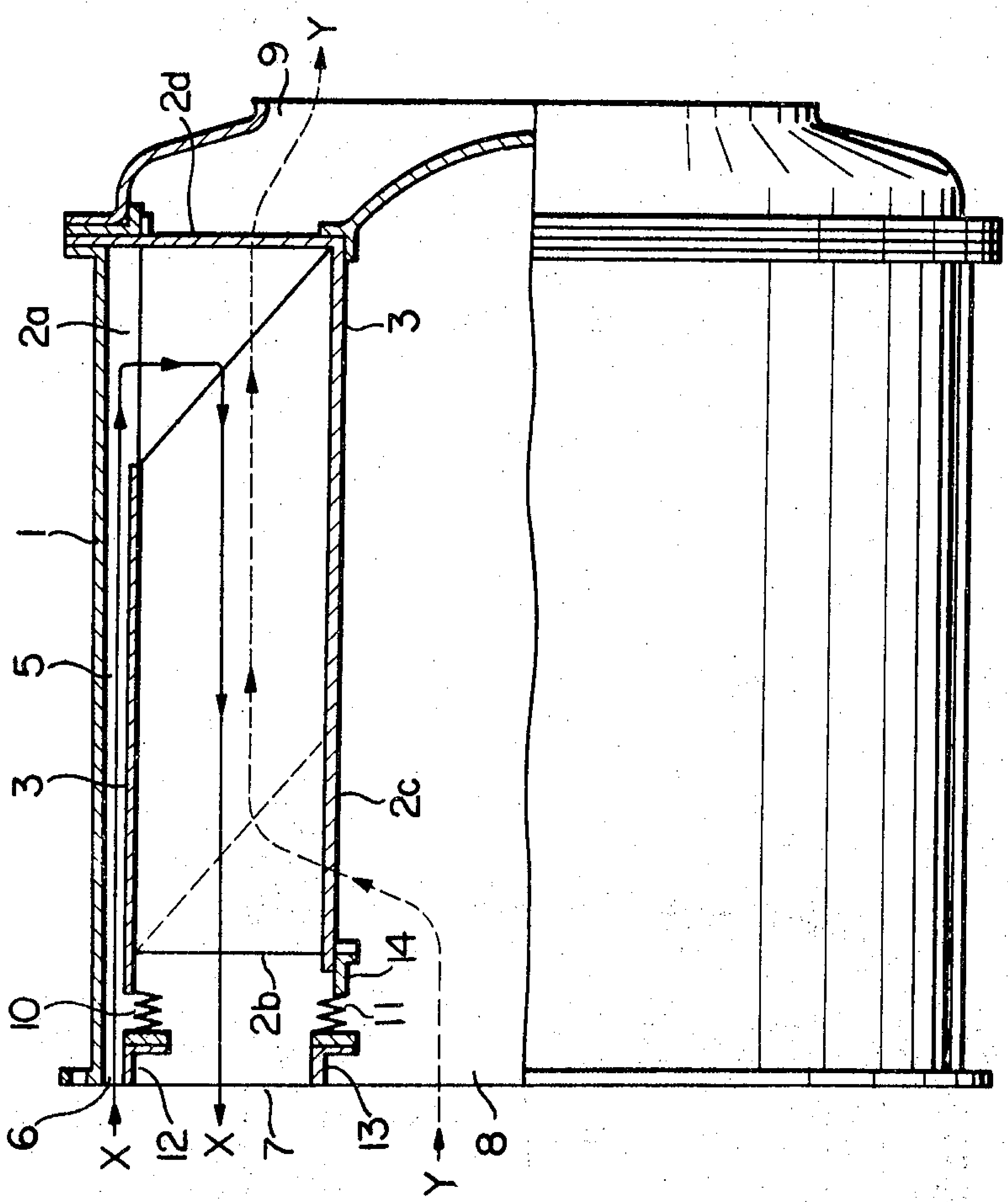
FIG. 2



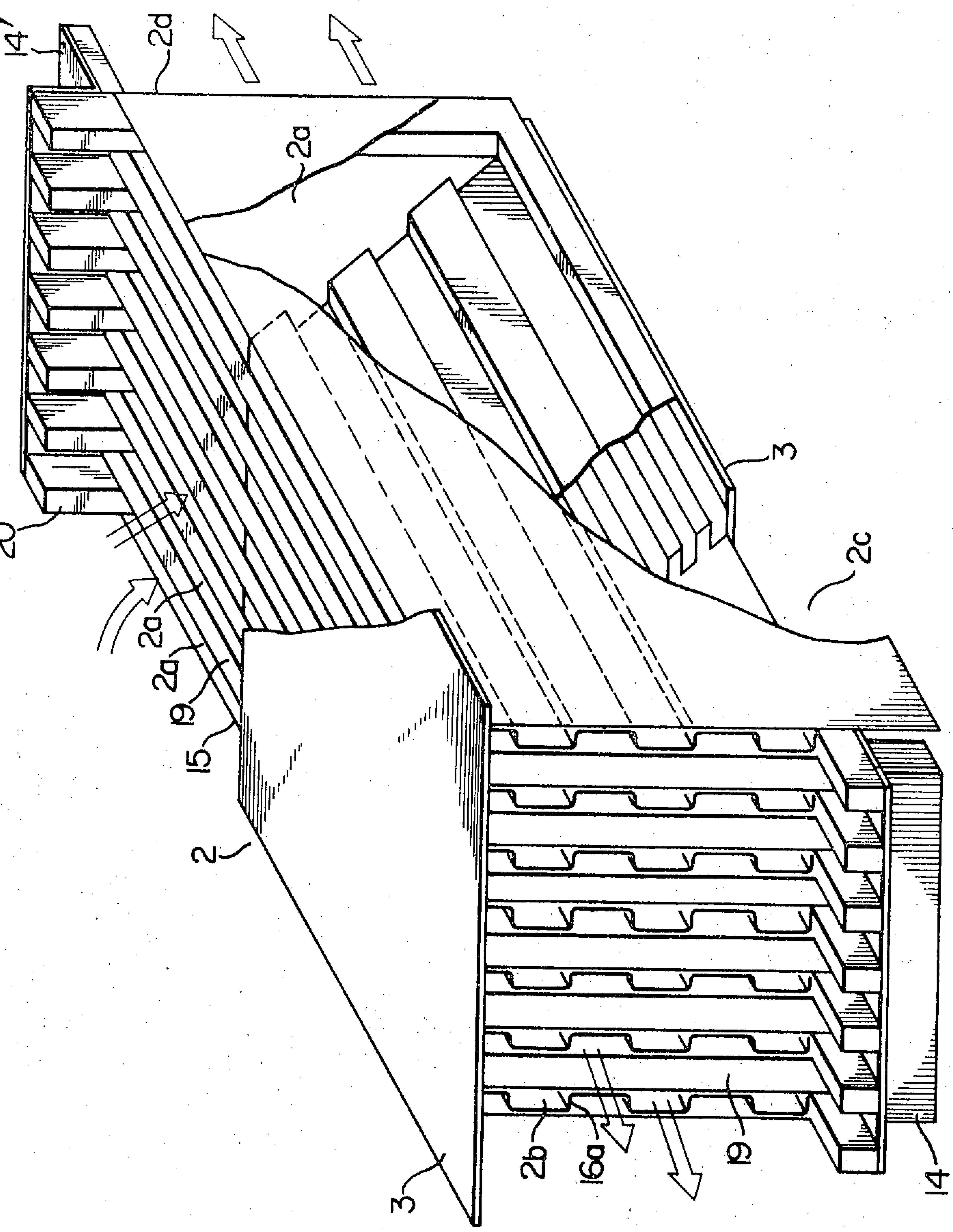


FIG. 3

FIG. 4

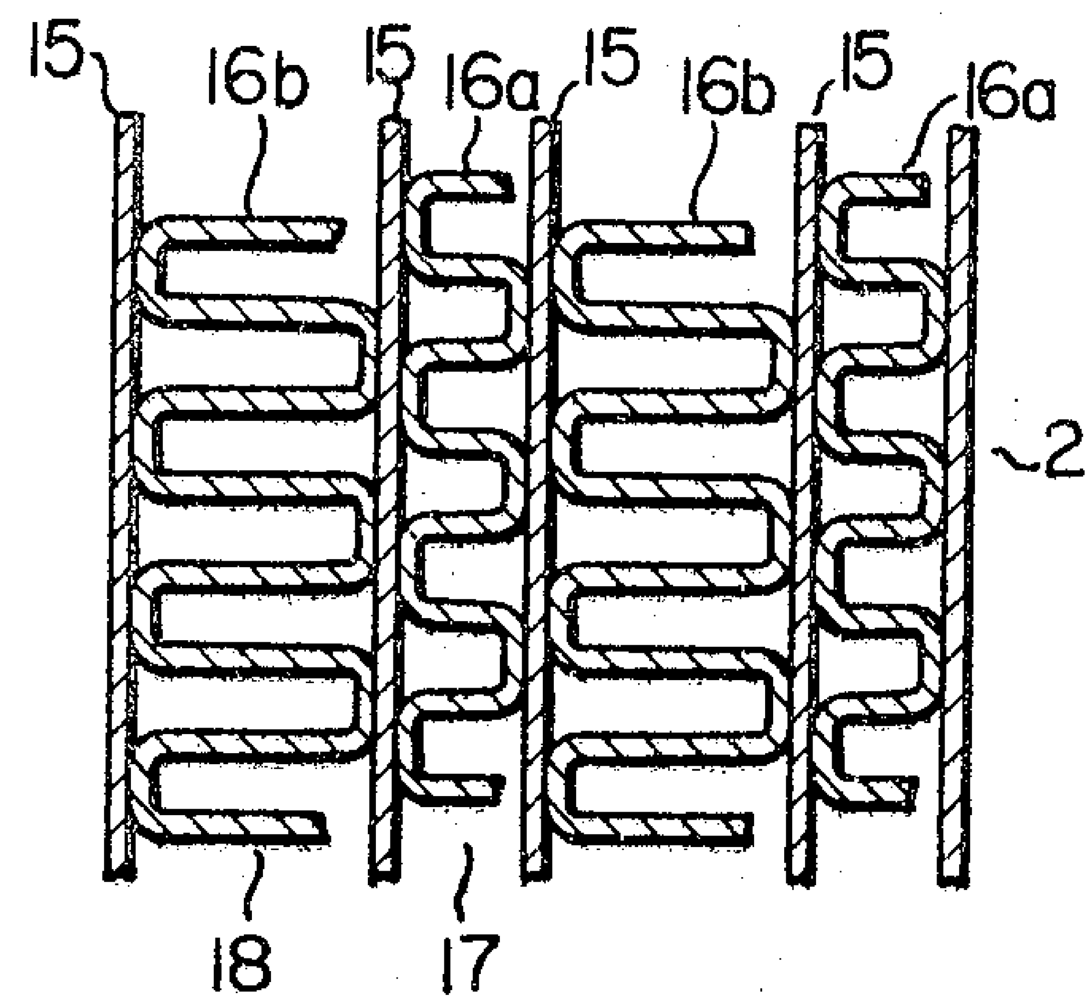


FIG. 9

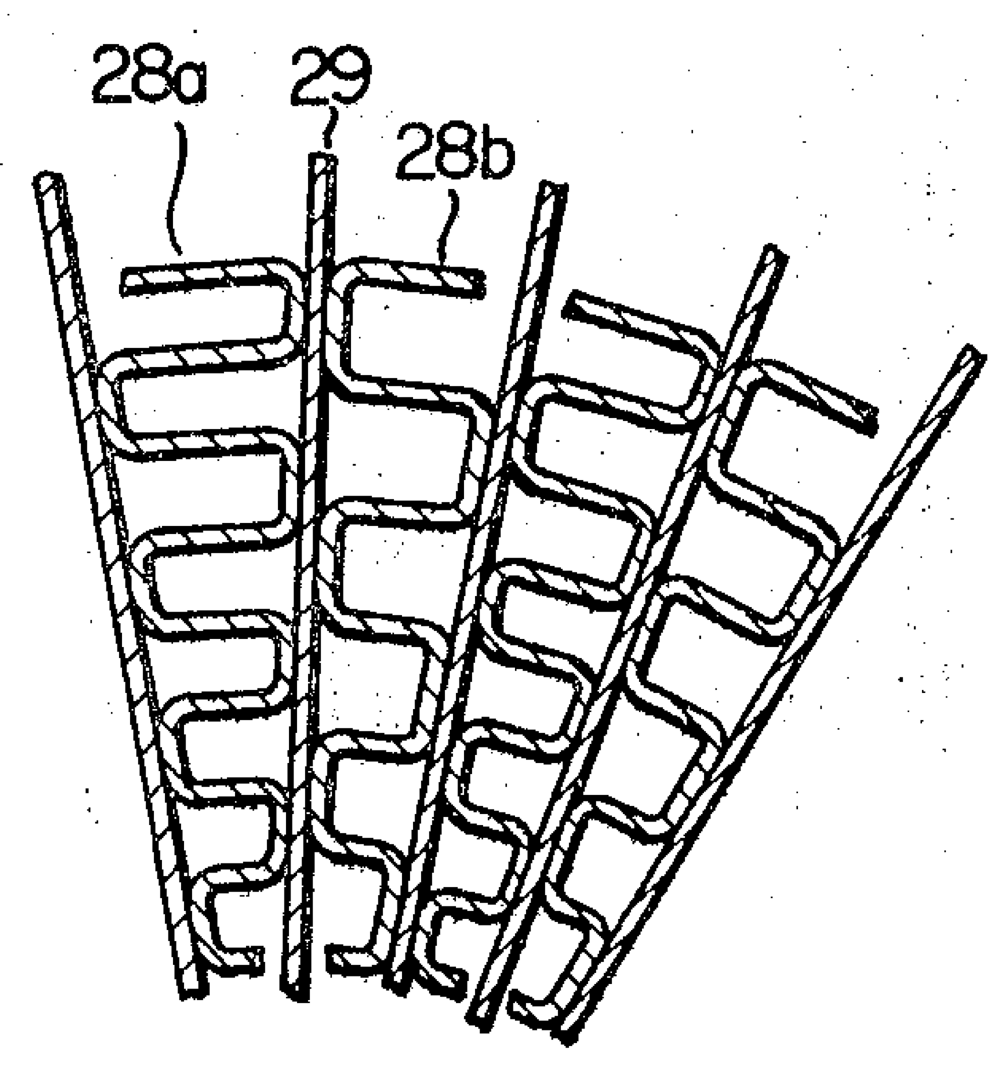


FIG. 5

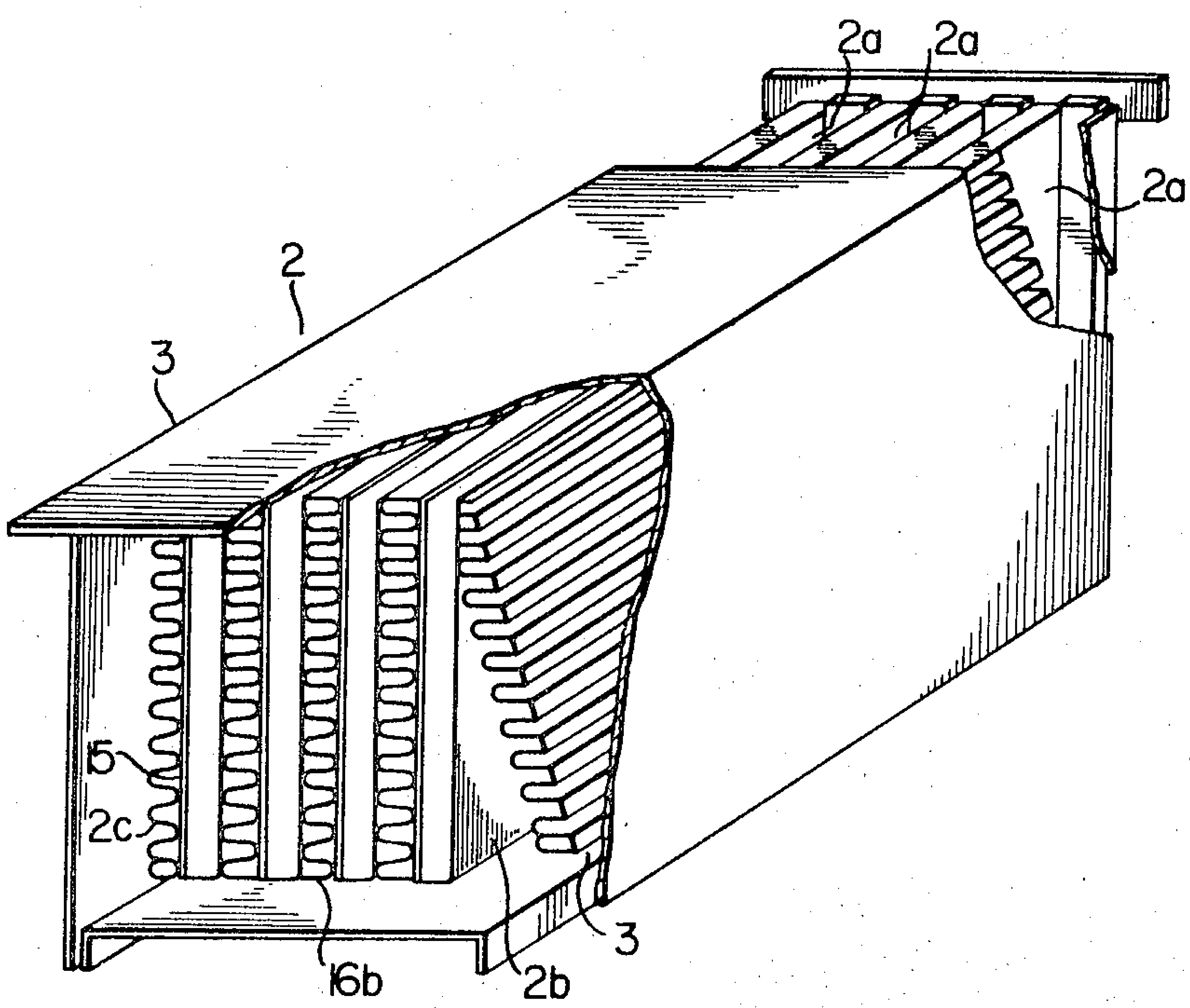


FIG. 6

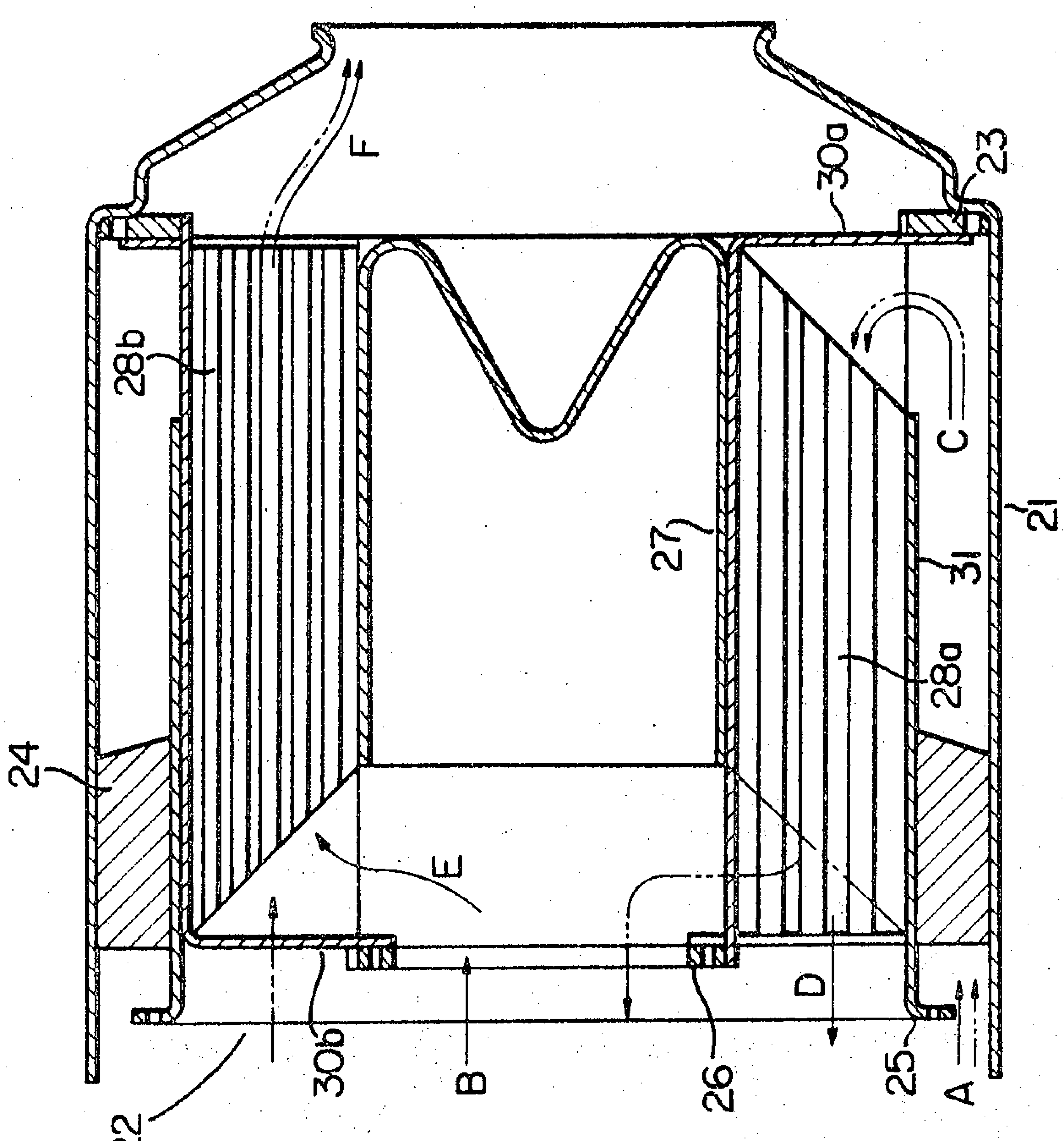
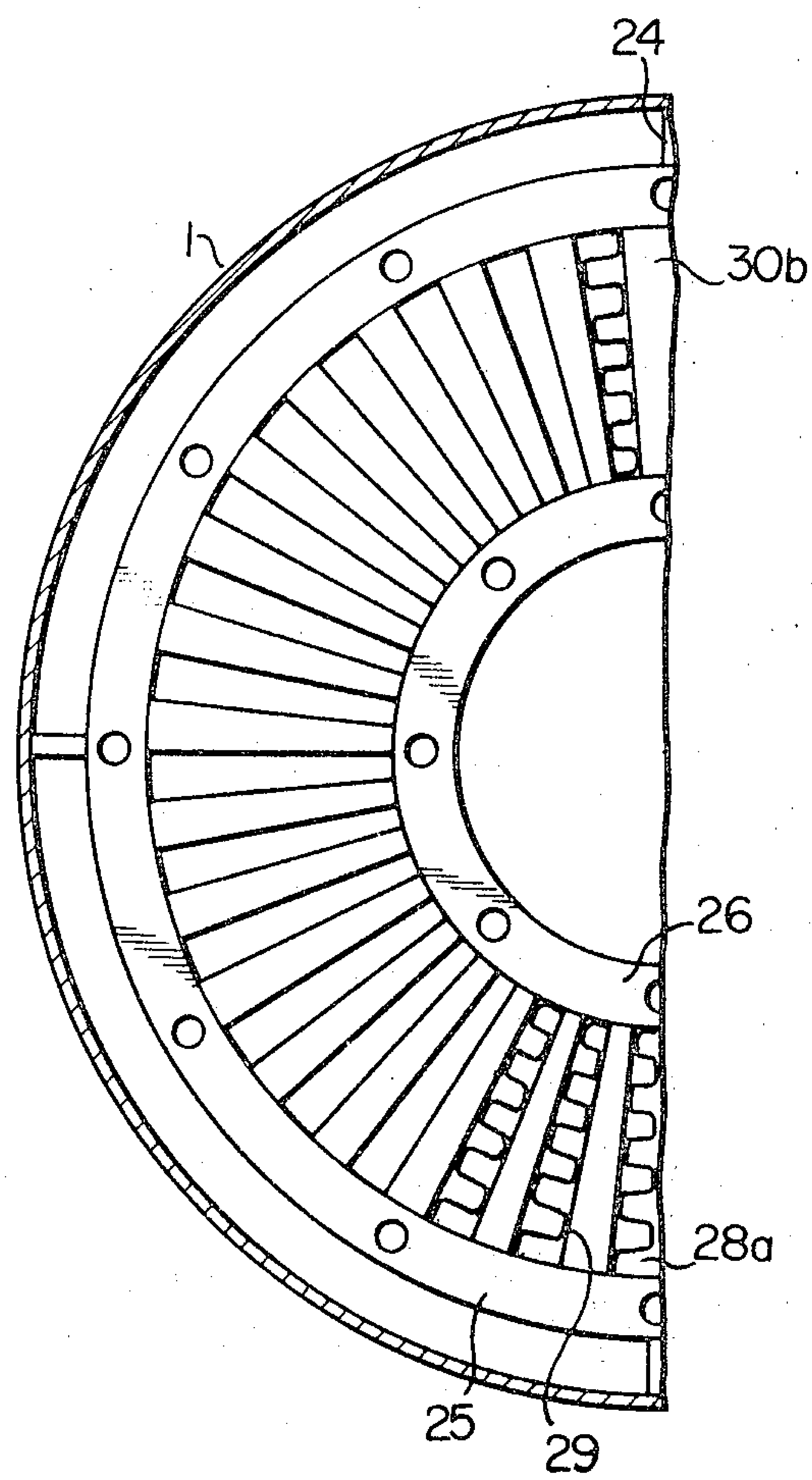


FIG. 7



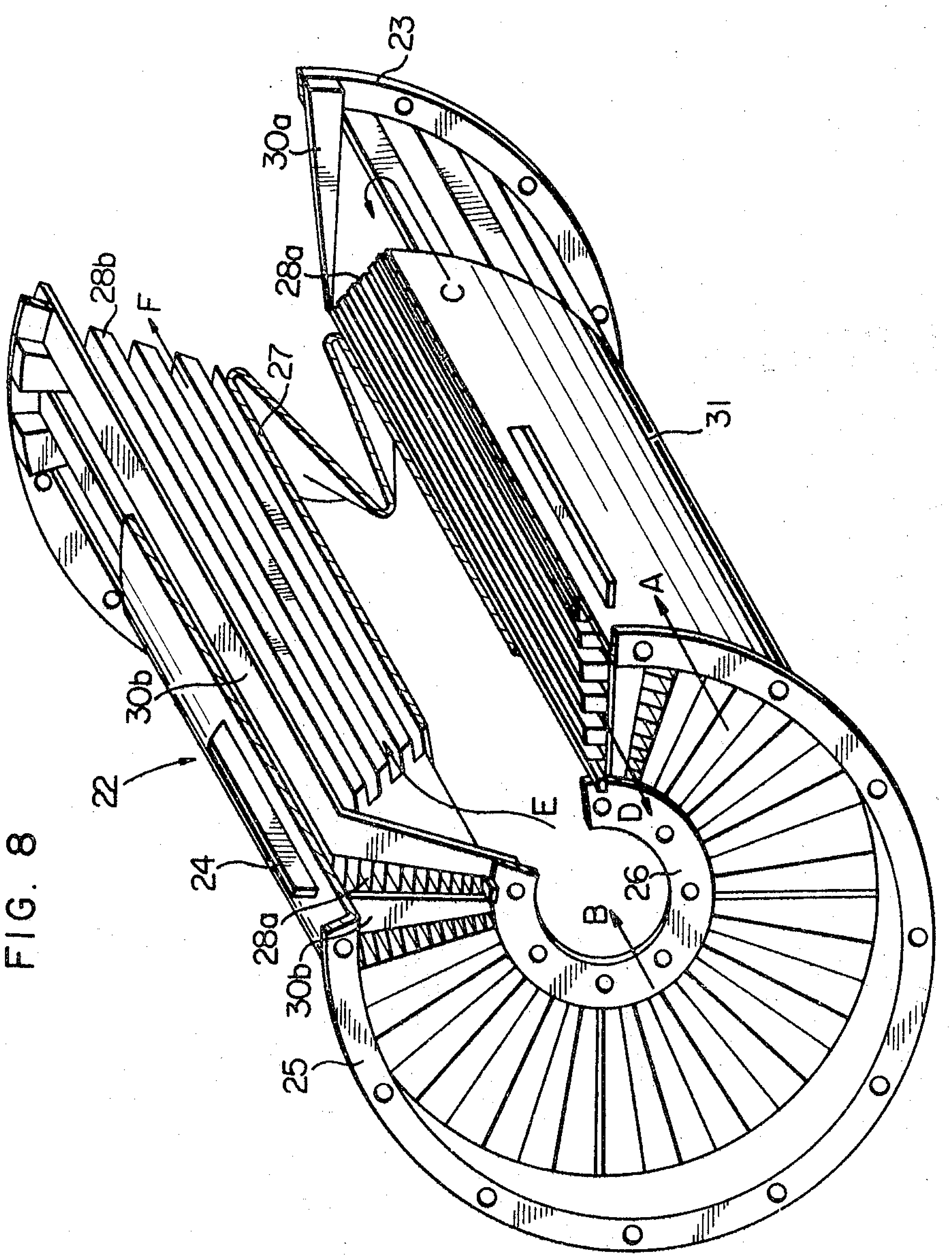


FIG. 8

HEAT EXCHANGER

This invention relates to heat exchangers, and more particularly to a heat exchanger of the kind preferably used with an engine such as a gas turbine engine for vehicles.

It is generally most important for a heat exchanger to accommodate the largest possible heat transfer area within a limited space, since the largeness of this heat transfer area is one of the greatest factors governing the performance of the heat exchanger. Recuperative heat exchangers known in the art include tube bundle tube-fin heat exchangers employing solely tubes arranged in parallel and tube-fine type heat exchangers comprising the combination of tubes and fins. Plate-fin type heat exchangers comprising the combination of fluid conduits and corrugated fins manufactured by forming flat plates in the shape are especially widely employed for the reasons that such a heat exchanger is quite small in size and has a large heat transfer area. Further, these heat exchangers are classified into the parallel flow type, cross flow type and counter flow type depending on the directions of fluids placed in heat exchange relation. However, the conventional heat exchangers of the tube bundle type and tube-fin type have been defective in that there is a great restriction in the inner and outer effective heat transfer areas and the selection of working fluids is also subject to a limitation. Further, these heat exchangers have been defective in that a high heat exchange efficiency cannot be expected due to the fact that the working fluids must be inevitably passed in parallel flow or cross flow relation. The counterflow type heat exchanger in which working fluids are passed through adjoining conduits in counterflow relation has also been defective in that a complex arrangement is required for separating the different fluids from each other so that the fluids flowing into and out of the adjoining conduits may not be mixed with each other. This type of heat exchanger has further been defective in that it is quite bulky due to the inclusion of many unnecessary dead spaces in the heat transfer zones and a very complex process and a long period of time are required for the manufacture.

With a view to obviate such prior art defects, it is an object of the present invention to provide a novel and improved heat exchanger which comprises a cylindrical housing, a plurality of core units disposed radially within said housing, each said core unit including a plurality of partition members arranged in parallel for defining therebetween alternate passages for passing a first fluid and a second fluid in directions opposite to each other, a first corrugated fin disposed in each of said first fluid passages, and a second corrugated fin disposed in each of said second fluid passages, and a plurality of first fluid admitting space portions defined between the inner wall of said housing and said core units for communication with said first fluid passages in said core units. The heat exchanger having the features set forth in the above is quite small in size and the effective heat transfer area can be adjusted as desired by suitably selecting the number of the first and second fluid passages and the number of the core units.

Another object of the present invention is to provide a heat exchanger of the above character in which at least one of said first and second fins is provided with a cut-out at one or either end thereof so as to pass the first and second fluids in the directions opposite to each other.

A further object of the present invention is to provide a heat exchanger comprising a cylindrical housing, a heat exchange unit disposed within said housing, a plurality of partition members disposed radially in said heat exchange unit for defining alternate passages for a first fluid and a second fluid, a first corrugated fin disposed in each of said first fluid passages, and a second corrugated fin disposed in each of said second fluid passages, at least one of said first and second fins being provided with a cut-out at one or either end thereof so as to pass these two different fluids through said alternate passages in directions opposite to each other. The heat exchanger having the features set forth in the above possesses a large heat transfer area and is quite small in size due to the fact that unnecessary dead spaces are substantially eliminated.

The above and other objects, features and advantages of the present invention will be apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a partly sectional side elevation view showing the structure of an embodiment of the present invention;

FIG. 2 is a partly sectional front elevation of the heat exchanger shown in FIG. 1;

FIG. 3 is a partly cut-away, enlarged perspective view showing the structure of one of the core units in the heat exchanger shown in FIG. 1;

FIG. 4 is an enlarged section of parts of the air and gas passages in the core unit shown in FIG. 3;

FIG. 5 is a partly cut-away perspective view showing a modification of the core unit shown in FIG. 3;

FIG. 6 is a longitudinal section showing the structure of another embodiment of the present invention;

FIG. 7 is a side elevation of the left-hand half of the heat exchanger shown in FIG. 6;

FIG. 8 is a partly sectional perspective view showing the structure of the heat change unit in the heat exchanger shown in FIG. 6; and

FIG. 9 is an enlarged sectional view of parts of the heat exchanger shown in FIG. 6.

An embodiment of the present invention will be described with reference to FIGS. 1 to 4.

Referring to FIGS. 1 and 2, a cylindrical housing 1 forms an outer shell of a heat exchanger. A plurality of core units 2 are disposed radially within the housing 1 for the heat exchange between air at a low temperature and high pressure and gas at a high temperature and low pressure. A plurality of radially spaced members 3 connect the radially arranged core units 2 with one another in such a manner that a space 4 is defined between any two adjacent core units 2. An arcuate space portion 5 is defined between the inner wall of the housing 1 and each of the radially outer connecting members 3 for admitting low-temperature and high-pressure air into each core unit 2. Each of these spaces 4 is closed gas-tight by the core units 2 disposed on opposite sides thereof and by the associated core unit connecting members 3. The heat exchanger is provided with a plurality of flange portions 5*a* for mounting on an apparatus such as a gas turbine engine. The low-temperature and high-pressure air is supplied from a compressor (not shown) to be fed through an air inlet 6 of the heat exchanger into each arcuate air admitting space portion 5, thence into air inlet portions 2*a* of each core unit 2. The low-temperature and high-pressure air is turned into high-temperature and high-pressure air through the heat exchange with the high-temperature and low-pressure gas while passing through each core unit 2 and such air is discharged through air outlet portions *2b* of each core unit 2, thence through an air outlet 7 of the heat exchanger to be supplied to a combustor (not shown). The high-temperature and low-pressure gas is supplied through a gas inlet **8** of the heat exchanger into gas inlet portions *2c* of each core unit 2 to be subjected to heat exchange with the low-temperature and high-pressure air while passing through the core unit **2**, and the low-temperature and low-pressure gas produced by the heat exchange is discharged through gas outlet portions *2d* of each core unit **2**, thence through a gas outlet **9** of the heat exchanger to the exterior. The direction of flow of the air in each core unit 2 is opposite to the direction of flow of the gas. Freely expansible sealing means **10** and **11** are disposed between the radially outer connecting member 3 and a passage forming member 12 and between another passage forming member 13 and a seal supporting member **14** respectively for each core unit **2.**

Referring to FIGS. 3 and 4 showing in detail the structure of each core unit **2,** a plurality of rectangular partition members **15** of, for example, stainless steel are arranged in parallel to define therebetween alternate air and gas passages **17** and **18.** A first fin **16***a* in corrugated form consisting of a series of rectangular portions is disposed in each air passage **17** and a second fin **16***b* in corrugated form consisting of a series of rectangular portions is disposed in each gas passage **18** as shown. The first fins **16***a* disposed in the air passages **17** defined between the associated partition members **15** are cut out in the form of a triangle at one end thereof to provide the air inlet portions *2a* and are not cut to remain in the original rectangular shape at the other end thereof to provide the air outlet portions *2b*. Similarly, the second fins **16***b* disposed in the gas passages **18** defined between the associated partition members **15** are cut out in the form of a triangle at the end remote from the cut-out end of the first fins **16***a* to provide the gas inlet portions *2c* and are not cut out to remain in the original rectangular shape at the other end thereof to provide the gas outlet portions *2d*. An L-shaped gas sealing member **19** is interposed gas-tight at its upstanding and horizontal portions between the corresponding opposite surface portions of each pair of the partition members **15** defining the gas passage **18** therebetween. Similarly, an L-shaped air sealing member **20** is interposed air-tight at its upstanding and horizontal portions between the corresponding opposite surface portions of each pair of the partition members **15** defining the air passage **17** therebetween. These sealing members **19** and **20** are alternately disposed in a confronting relationship as shown. The seal supporting member **14** of, for example, L-like cross section is fixed gas-tight at a position at which the horizontally extending portions of the air sealing members **20** intersect the upstanding portions of the gas sealing members **19.** Another supporting member **14'** is fixedly disposed gas-tight at a position at which the upstanding portions of the air sealing members **20** intersect the horizontally extending portions of the gas sealing members **19.** The core unit connecting members **3** are secured gas-tight to the upper and lower ends of the partition members **15** in such a manner as to provide the air and gas inlet portions **2a** and **2c** of the core unit **2.**

In operation, referring to FIG. **2,** air at a low temperature and high pressure supplied from the compressor (not shown) passes through the air inlet **6** of the heat exchanger into each arcuate space portion **5,** and after changing the direction of flow by 180°, the air flows into the air inlet portions **2a** of each core unit **2** to pass through the air passages **17** in the core unit **2.** Thus, the air flows in a direction X — X shown by the solid line. On the other hand, gas at high temperature and low pressure flows through the gas inlet **8** of the heat exchanger into the gas inlet portions *2c* of each core unit **2** to pass through the gas passages **18** in the core unit **2** in a direction Y — Y shown by the dotted line. Thus, the low-temperature and high-pressure air passing through the air passages **17** having the first fins **16***a* therein is brought into a satisfactory heat exchange relation with the high-temperature and low-pressure gas which passes through the gas passages **18** having the second fins **16***b* therein in a direction opposite to the flowing direction of the low-temperature and high-pressure air, with the result that the low-temperature and high-pressure air turns into high-temperature and high-pressure air and the high-temperature and low-pressure gas turns into low-temperature and low-pressure gas. Then, the high-temperature and high-pressure air passes through the air outlet portions *2b* of each core unit **2** to be supplied to the combustor (not shown) from the air outlet **7** of the heat exchanger while the low-temperature and low-pressure gas passes through the gas outlet portions *2d* of each core unit **2** to be discharged to the exterior from the gas outlet **9** of the heat exchanger.

In the embodiment above described, the first and second fins **16***a* and **16***b* in each core unit **2** are cut out in a triangular form at one end thereof to provide the air inlet portions *2a* and gas inlet portions *2c* respectively. Referring to FIG. **5** showing a modification of the core unit **2** shown in FIG. **3**, the first fins **16***a* disposed in the air passages **17** are cut out in a triangular form at opposite ends thereof as shown, while the second fins **16***b* disposed in the gas passages **18** are not cut out and have a rectangular shape. The first and second fins **16***a* and **16***b* are alternately fixed between the partition members **15** defining the air and gas passages **17** and **18** so that the cut-out ends of the first fins **16***a* provide the air inlet and outlet portions *2a* and *2b*, while the rectangular ends of the second fins **16***b* provide the gas inlet and outlet portions *2c* and *2d* in each core unit **2.** Further, although the closed space portions **4** are provided between the core units **2** in the embodiment above described, these space portions **4** may be eliminated and additional core units **2** may be disposed in these spaces so as to increase the effective heat transfer area.

It will be understood from the above description that, in the first embodiment of the heat exchanger according to the present invention, a plurality of partition members are parallelly disposed to define therebetween a plurality of alternate air and gas passages for passing air and gas in directions opposite to each other and are combined with heat transfer fins to constitute a core unit, a plurality of such core units being disposed radially within a cylindrical housing, and the air passages in each core unit communicate with an air admitting space portion defined between the inner wall of the cylindrical housing and the core unit. The structure above described is advantageous in that the heat exchanger is small in size, has a large effective heat transfer area and can be very simply manufactured due to the fact that the air admitting space portion can be formed by mere disposition of each core unit in the radial portion within the cylindrical housing, thereby eliminating the need for provision of any especial air supply conduit for supplying air into the air passages of the core unit. Further, by virtue of the fact that the core units disposed within the housing are independent of each other, leakage of air and gas can be easily detected and leaking parts can be repaired during the steps of manufacture and assembling. Thus, heat exchanger is from any air or gas leakage and the gas and air passages can be easily cleaned. The present invention is further advantageous in that the effective heat transfer area of the heat exchanger can be easily adjusted by suitably increasing or decreasing the number of the core units and also by increasing or decreasing the heat transfer area of the partition members and fins. Furthermore, by virtue of the fact that air and gas pass through the alternate air and gas passages in directions opposite to each other, satisfactory heat exchange between the air and the gas can be attained. Moreover, any especial means are not required for causing flow of the air and gas in the opposite directions and the heat exchanger has a simplified structure. Further, the heat exchanger has a satisfactory mechanical strength due to the fact that the core units are housed within the cylindrical housing.

Another embodiment of the present invention will be described with reference to FIGS. 6 to 9. Referring to FIG. 6, a heat exchange unit 22 is housed within a cylindrical housing 21. The heat exchange unit 22 is provided with an annular portion or ring 23 which is bolted to the cylindrical housing 21 for fixing the heat exchange unit 22 to the housing 21. The heat exchange unit 22 is supported within the housing 21 by a plurality of stays 24 welded to the heat exchange unit 22. The heat exchange unit 22 and housing 21 are mounted to the body of an apparatus such as a gas turbine engine (not shown) by a flange portion 25 and a ring 26. The heat exchange unit 22 includes an inner casing 27 which is closed at one end thereof. A plurality of first fins 28*a*, second fins 28*b* and partition members 29 are alternately radially disposed around the inner casing 27. The first and second fins 28*a* and 28*b* are corrugated and have a width which is gradually enlarged from the inner toward the outer end. The assembly consisting of these fins 28*a*, 28*b* and partition members 29 is in the form of a thick-walled cylinder. As seen in FIGS. 6 and 8, the first fins 28*a* are cut out at one or right-hand end thereof, while the second fins 28*b* are cut out at the left-hand end remote from the cut-out end of the first fins 28*a*, and these first and second fins 28*a* and 28*b* are alternately arranged with the partition members 29 interposed therebetween. A first L-shaped sealing member 30*a* is in sealing engagement with the radially inner end edges and right-hand end edges of the partition members 29 disposed on opposite sides of each of the first fins 28*a* as seen in FIGS. 6 to 8. Similarly, a second L-shaped sealing member 30*b* is in sealing engagement with the radially outer end edges and left-hand end edges of the partition members 29 disposed on opposite sides of each of the second fins 28*b*. Further, these first and second sealing members 30*a* and 30*b* intersect at the opposite ends thereof and the rings 23 and 26 are welded to these intersecting portions to serve as a sealing means for these intersecting portions. An outer casing 31 is secured as by soldering to the second L-shaped sealing members 30*b*, and the flange portion 25 is formed at the left-hand end of the outer casing 31 as seen in FIGS. 6 to 8. The right-hand end of the outer casing 31 registers with the starting position of the cut-out at the right-hand end of the first fins 28*a*, and the left-hand end of the inner casing 27 registers with the starting portion of the cut-out at the left-hand end of the second fins 28*b* as best shown in FIG. 6.

In operation, air at a low temperature and high pressure is supplied from a compressor (not shown) to pass through the space between the housing 21 and the outer casing 31 in a direction as shown by the arrow A. On the other hand, combustion gas at a high temperature and low pressure is supplied through the opening of the ring 26 in a direction as shown by the arrow B. The low-temperature and high-pressure air flows then in a direction as shown by the arrow C to enter the triangular spaces defined by the cut-out ends of the first fins 28*a*, partition members 29 and first L-shaped sealing members 30*a*, thence into the air passages defined between the partition members 29 and containing the first fins 28*a* therein to be discharged through the space between the ring 26 and the outer casing 31 in a direction as shown by the arrow D. On the other hand, the high-temperature and low-pressure combustion gas flows in a direction as shown by the arrow E to enter the triangular spaces defined by the cut-out ends of the second fins 28*b*, partition members 29 and second L-shaped sealing members 30*b*, thence into the gas passages defined between the partition members 29 and containing the second fins 28*b* therein to be discharged through the space between the ring 23 and the inner casing 27 in a direction as shown by the arrow F. In the heat exchanger, heat exchange between the low-temperature and high-pressure air and the high-temperature and low-pressure combustion gas occurs through the medium of the first and second fins 28*a*, 28*b* and partition members 29. As a result, the air supplied in the low-temperature and high-pressure state is turned into high-temperature and high-pressure air and such air is fed in the direction of the arrow D to be supplied into the combustor in the gas turbine engine (not shown) for combustion, while the combustion gas supplied in the high-temperature and low-pressure state is turned into low-temperature and low-pressure gas and such gas is discharged to the exterior in the direction of the arrow F.

In the second embodiment of the present invention, the first fins 28*a* and second fins 28*b* are cut out at their right-hand and left-hand ends in the manner shown in FIG. 6 so as to provide the air and combustion gas inlet portions respectively. However, the first fins 28*a* may be cut out at the left-hand end thereof as shown by the two-dot chain line in FIG. 6 in addition to the cut-out at the right-hand end thereof, while the second fins 28*b* may not be cut out at either end thereof, and the shape of the first and second L-shaped sealing members 30*a* and 30*b* may be slightly modified. In such a modification, the air and combustion gas flow in respective directions as shown by the two-dot chain lines and satisfactory heat exchange between the air and the combustion gas can be similarly effectively attained.

What is claimed is:

1. A heat exchanger comprising a cylindrical housing, a plurality of partition members disposed within

said housing for defining alternate passages for a first fluid and a second fluid, first corrugated fins are each disposed in each of said first fluid passages, second corrugated fins are each disposed in each of said second fluid passages, at least one of said first and second fins being formed with oblique cut out portions at at least one end thereof so as to provide inlet portions for introducing said two fluids into said alternate passages in directions opposite to each other.

2. A heat exchanger comprising a cylindrical housing, a plurality of core units disposed radially within said housing, each of said core units having a square cross section and including a plurality of partition members arranged substantially parallel to one another for defining therebetween alternate passages for passing first and second fluids in opposite directions, first corrugated fins one each disposed in each of said first fluid passages, second corrugated fins one each disposed in each of said second fluid passages, one of said first and second corrugated fins being formed with oblique cut out portions at their radially outer ends so as to provide inlet portions to introduce said first or second fluid into said first or second fluid passages, a plurality of fluid admitting space portions defined between the inner wall of said housing and radially outer surfaces of said core units for communication with said first or second fluid passages in said core units through said cut out portions, and a cylindrical space defined by the radially inner surfaces of said core units at a center portion in said housing for communication with the other of said first and second fluid passages.

3. A heat exchanger as defined in claim **2,** wherein oblique cut out portions are formed also at the radially inner ends of the corrugated fins disposed in the other of said first and second fluid passages, said cut out portions of the corrugated fins disposed in one of said first

and second fluid passages being opened to said fluid admitting space portions, said cut out portions of the corrugated fins disposed in the other of said passages being opened to said cylindrical space.

4. A heat exchanger comprising a cylindrical housing, a heat exchanger unit disposed within said housing, said heat exchanger unit including a plurality of partition members disposed radially for defining alternate passages for a first fluid and a second fluid, first corrugated fins each having a wedge-shaped cross section and being disposed in each of said first fluid passages, second corrugated fins each having a wedge-shaped cross section and being disposed in each of said second fluid passage, one of said first and second fins being formed with oblique cut out portions at their radially outer ends so as to provide inlet portions to introduce said first or second fluid into said first or second fluid passages, respectively, a plurality of fluid admitting space portions defined between the inner wall of said housing and the outer periphery of said heat exchanger unit for communication with said first or second fluid passages in said heat exchanger unit through said cut out portions, and a cylindrical space defined by the inner periphery of said heat exchanger unit at a center portion in said housing for communication with the other of said first and second fluid passages.

5. A heat exchanger as defined in claim **4,** wherein oblique cut out portions are formed also at the radially inner ends of the corrugated fins disposed in the other of said first and second fluid passages, said cut out portions of the corrugated fins disposed in one of said first and second fluid passages being opened to said fluid admitting portion, said cut out portions of the corrugated fins disposed in the other of said passages being opened to said cylindrical space.

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