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(54) **INTEGRATED MULTI-CIRCUIT MICROCHANNEL HEAT EXCHANGER**

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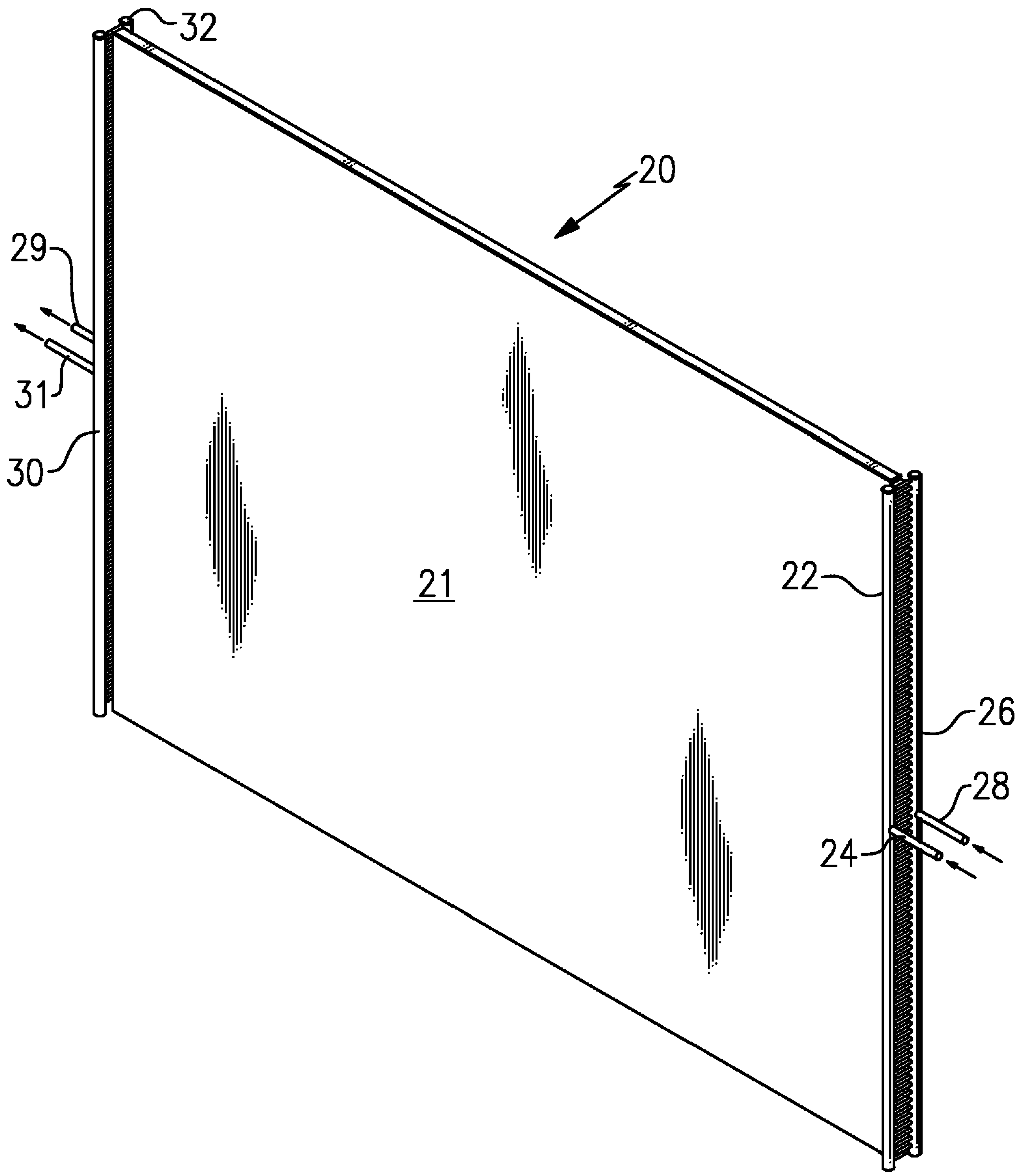
(52) **U.S. Cl.** **165/173**

(57) **ABSTRACT**

A microchannel heat exchanger has at least two manifolds, with the at least two manifolds communicating with a respective one of a first and second plurality of heat exchange tube banks. The first and second plurality of heat exchange tube banks are intertwined within a single microchannel heat exchanger core.



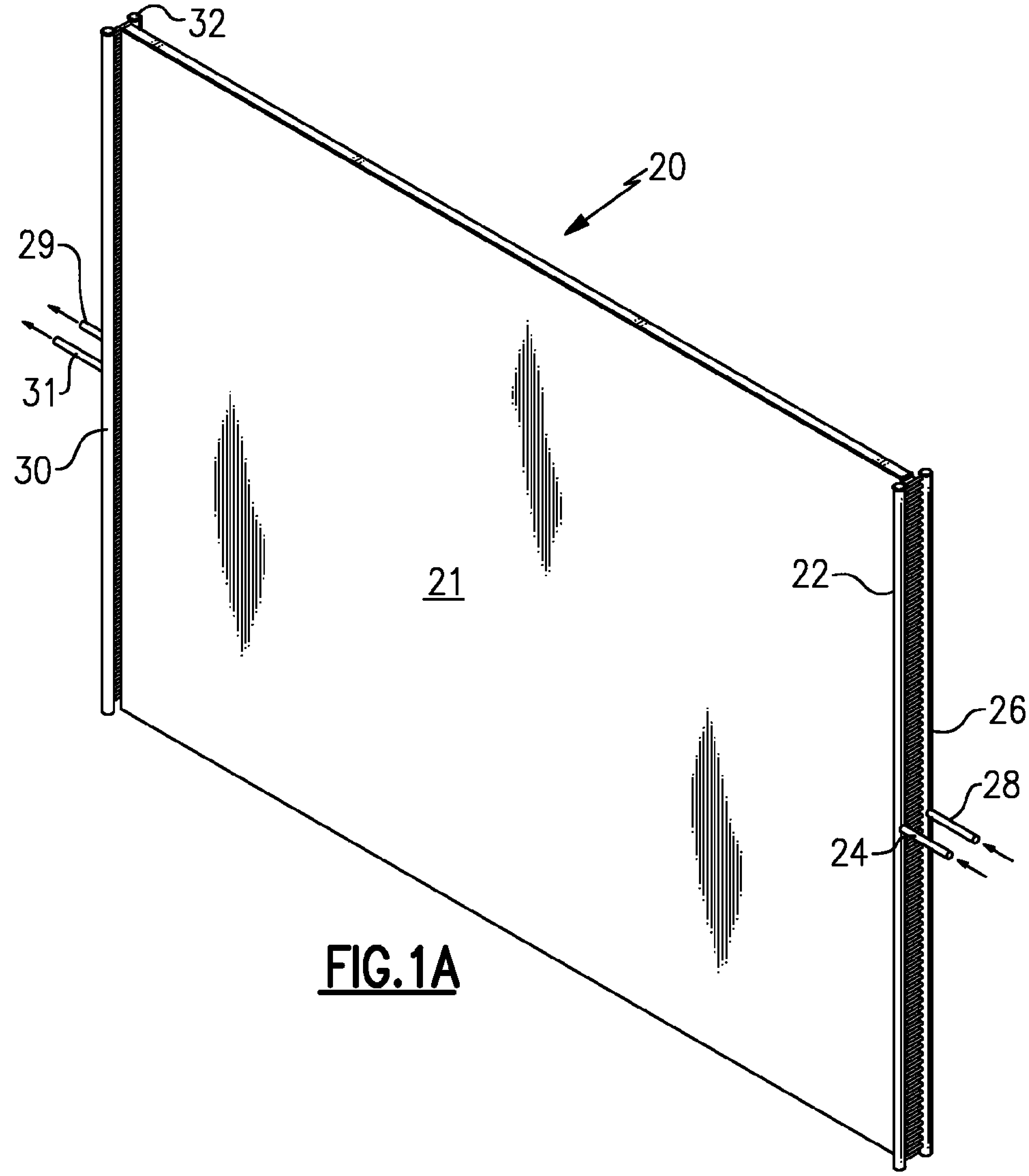


FIG.1A

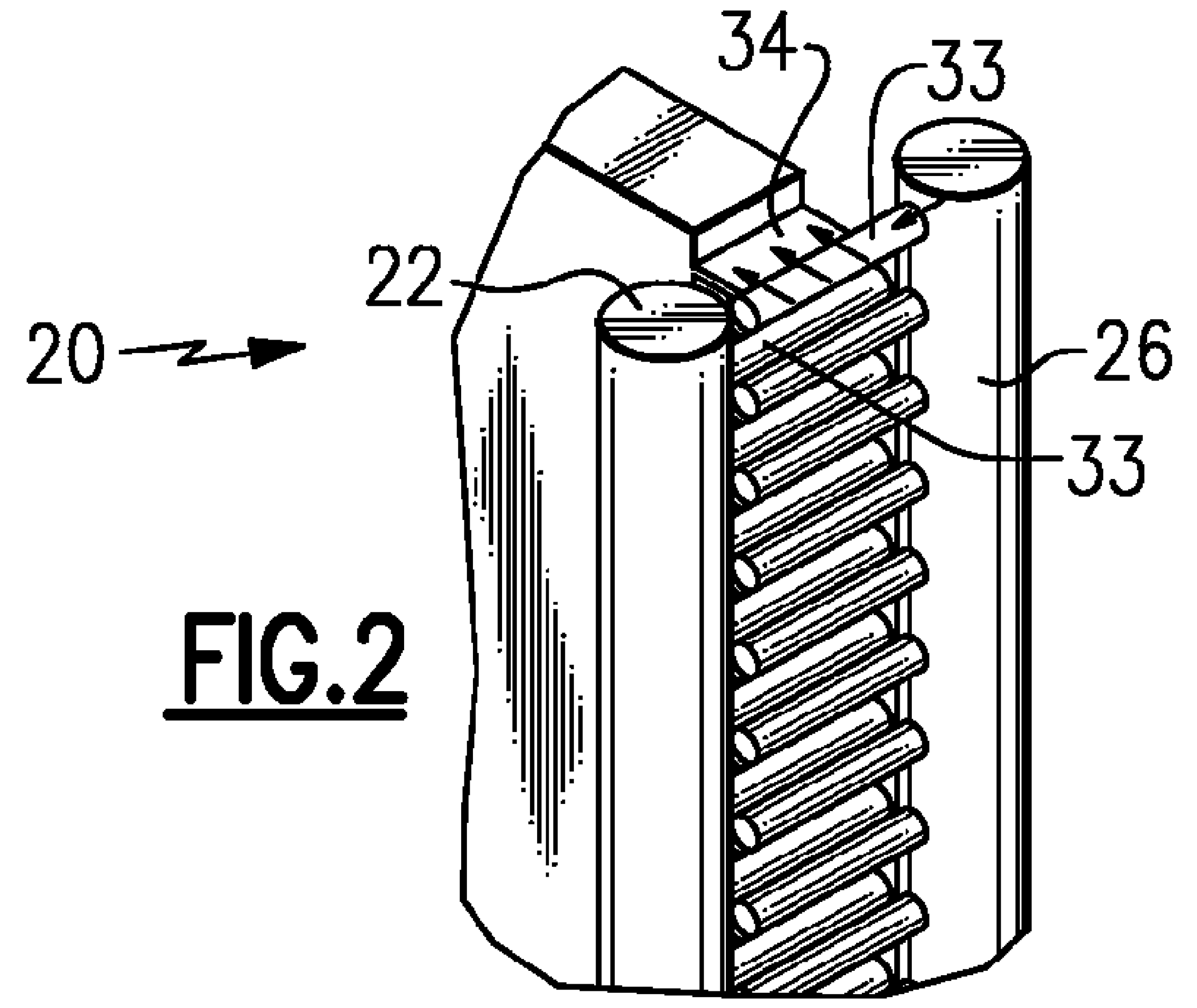


FIG.2

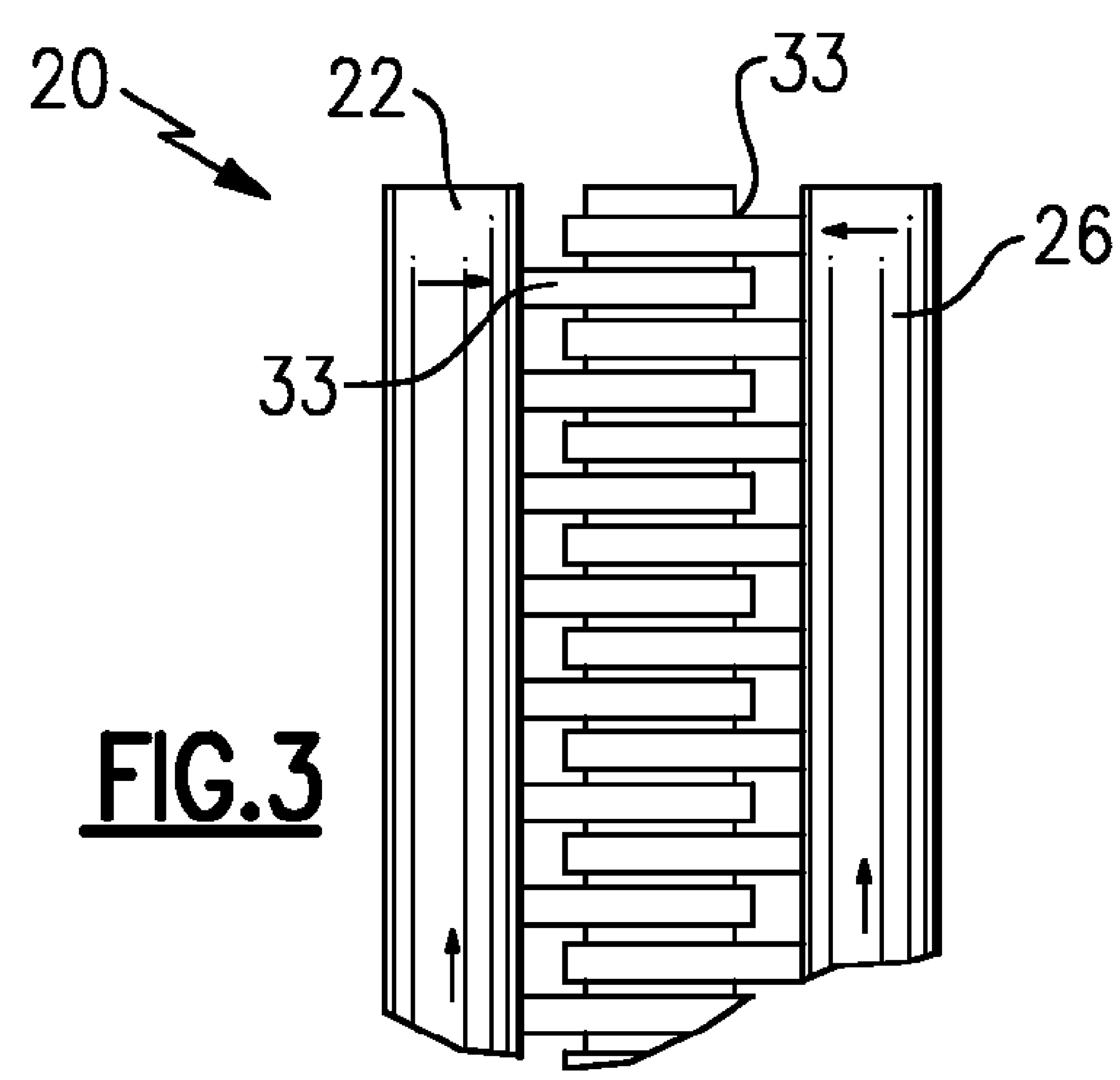


FIG.3

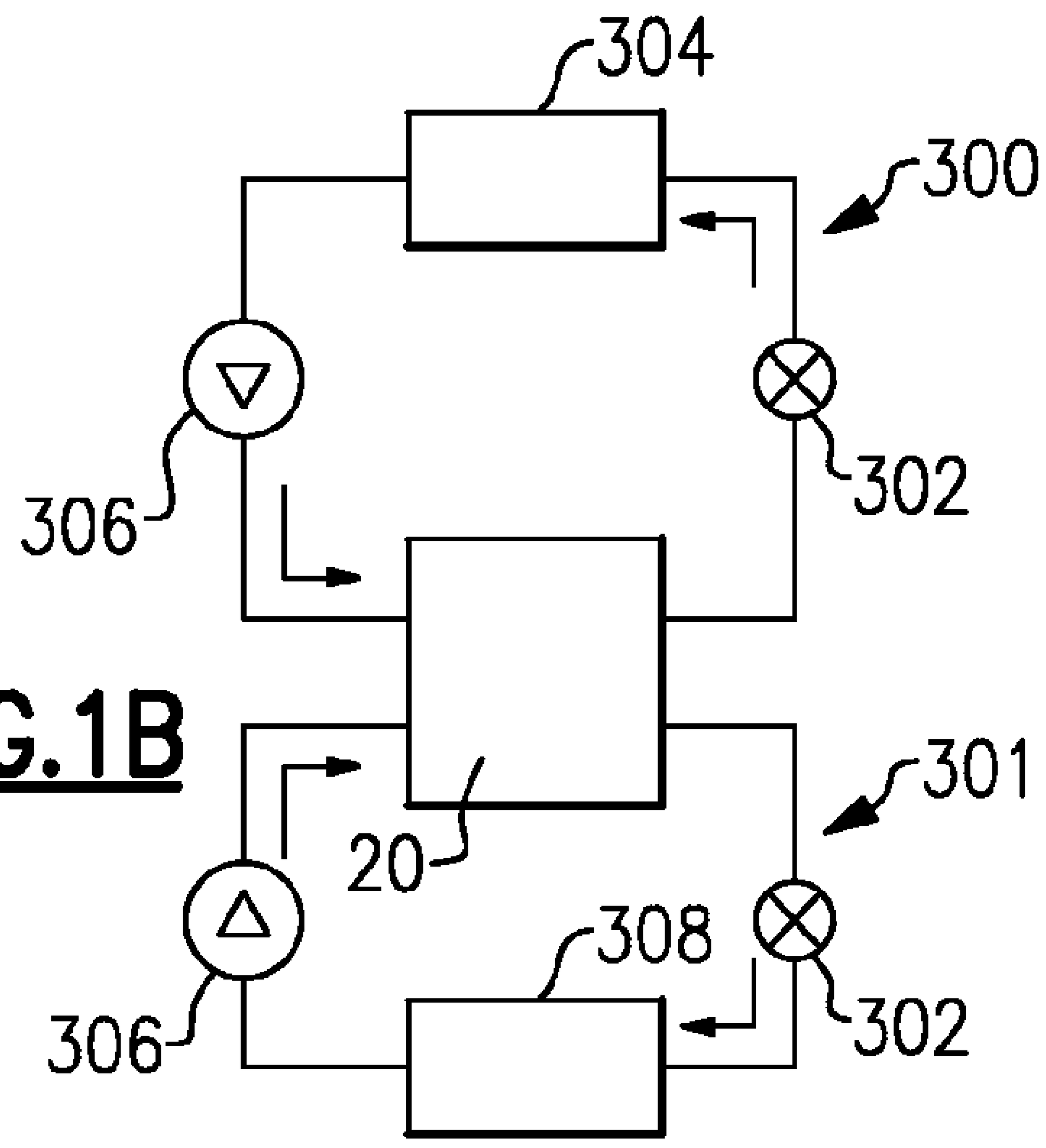


FIG.1B

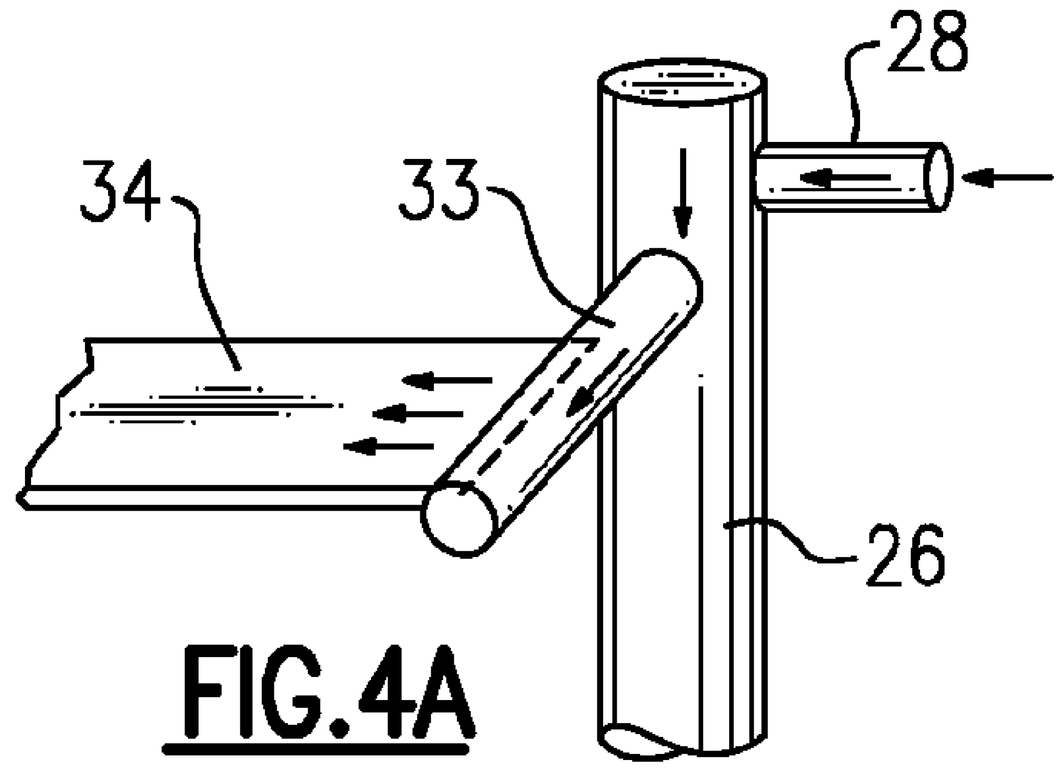


FIG.4A

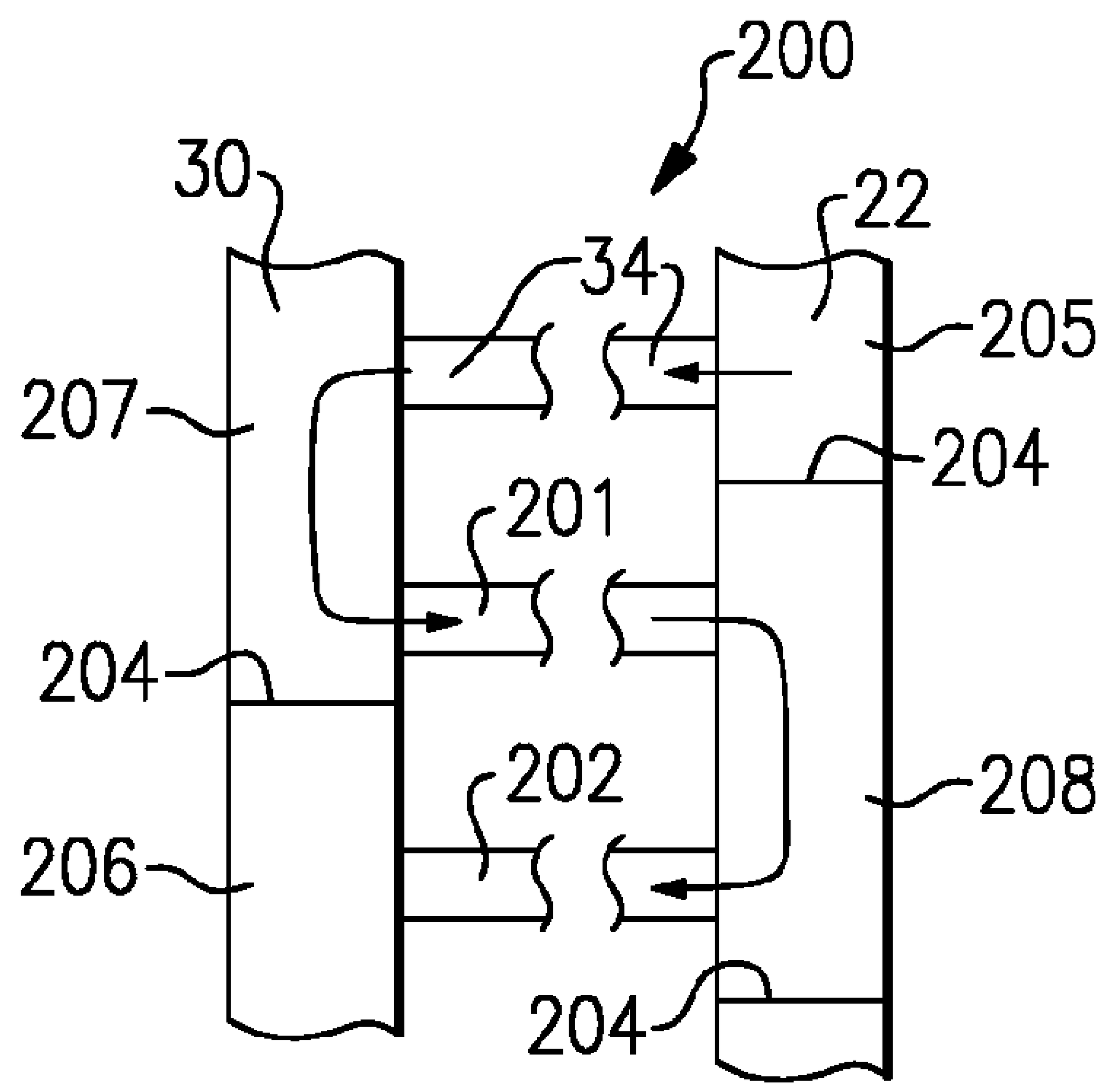


FIG.4B

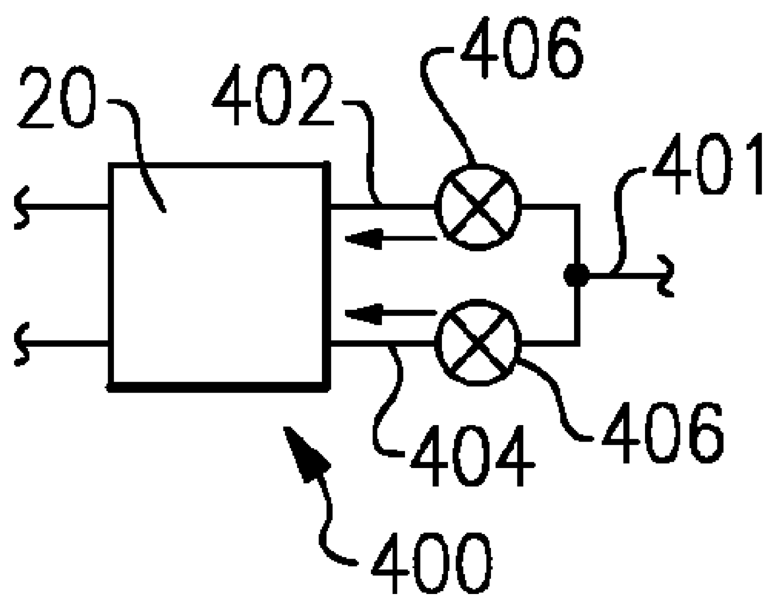


FIG.1C

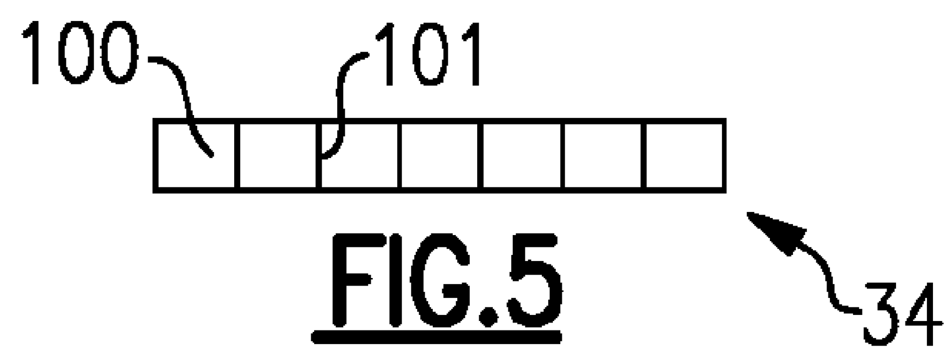


FIG.5

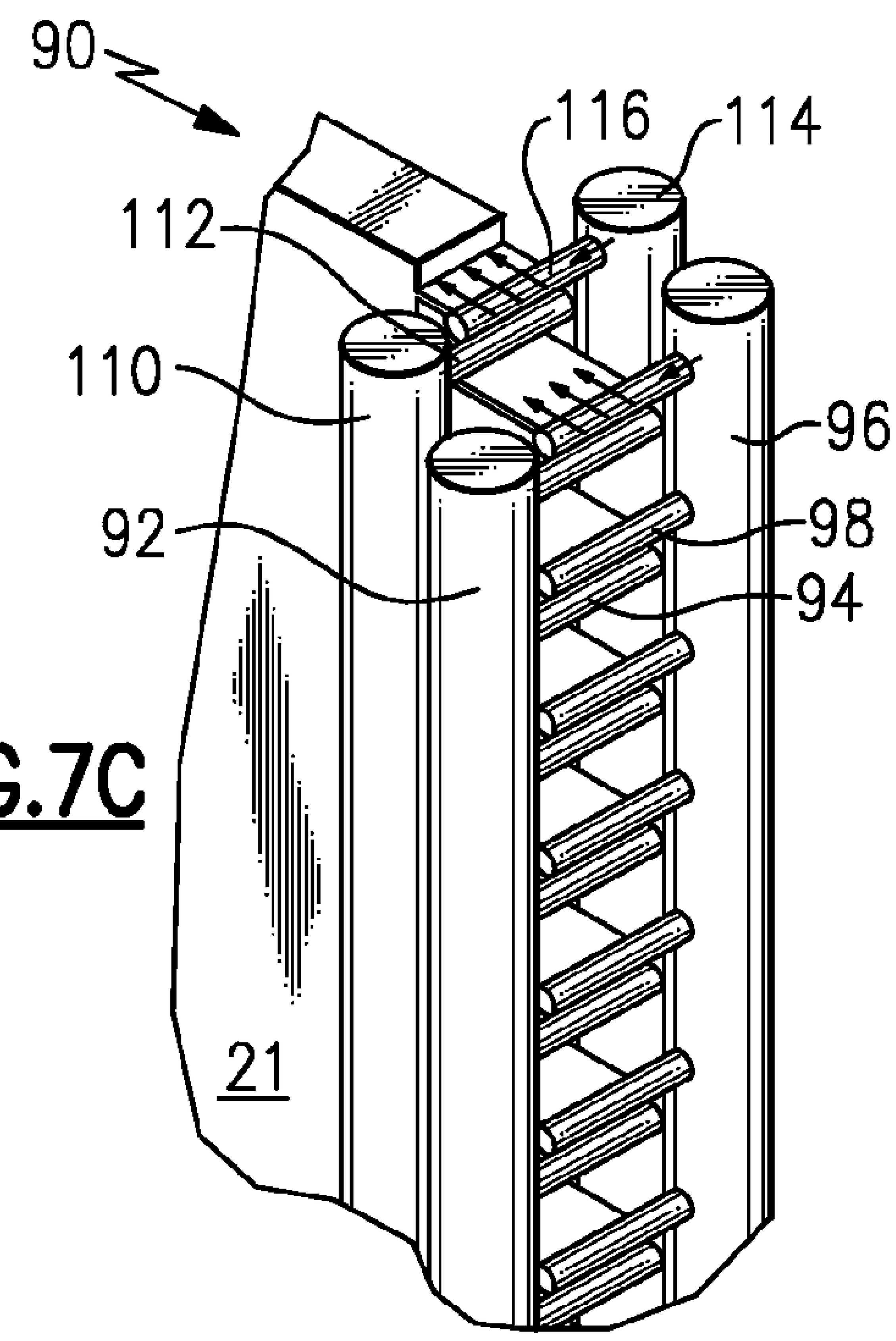


FIG.7C

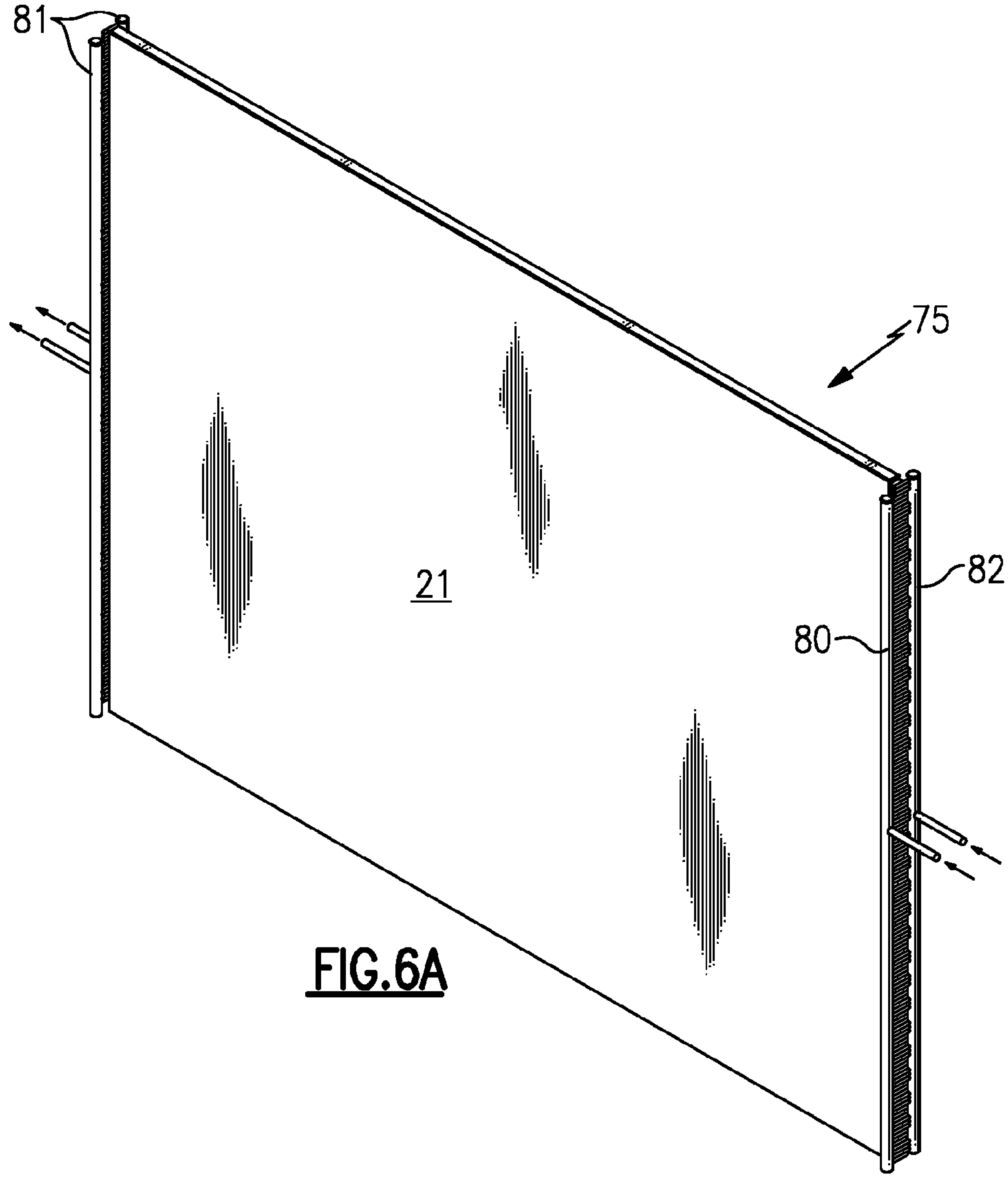


FIG.6A

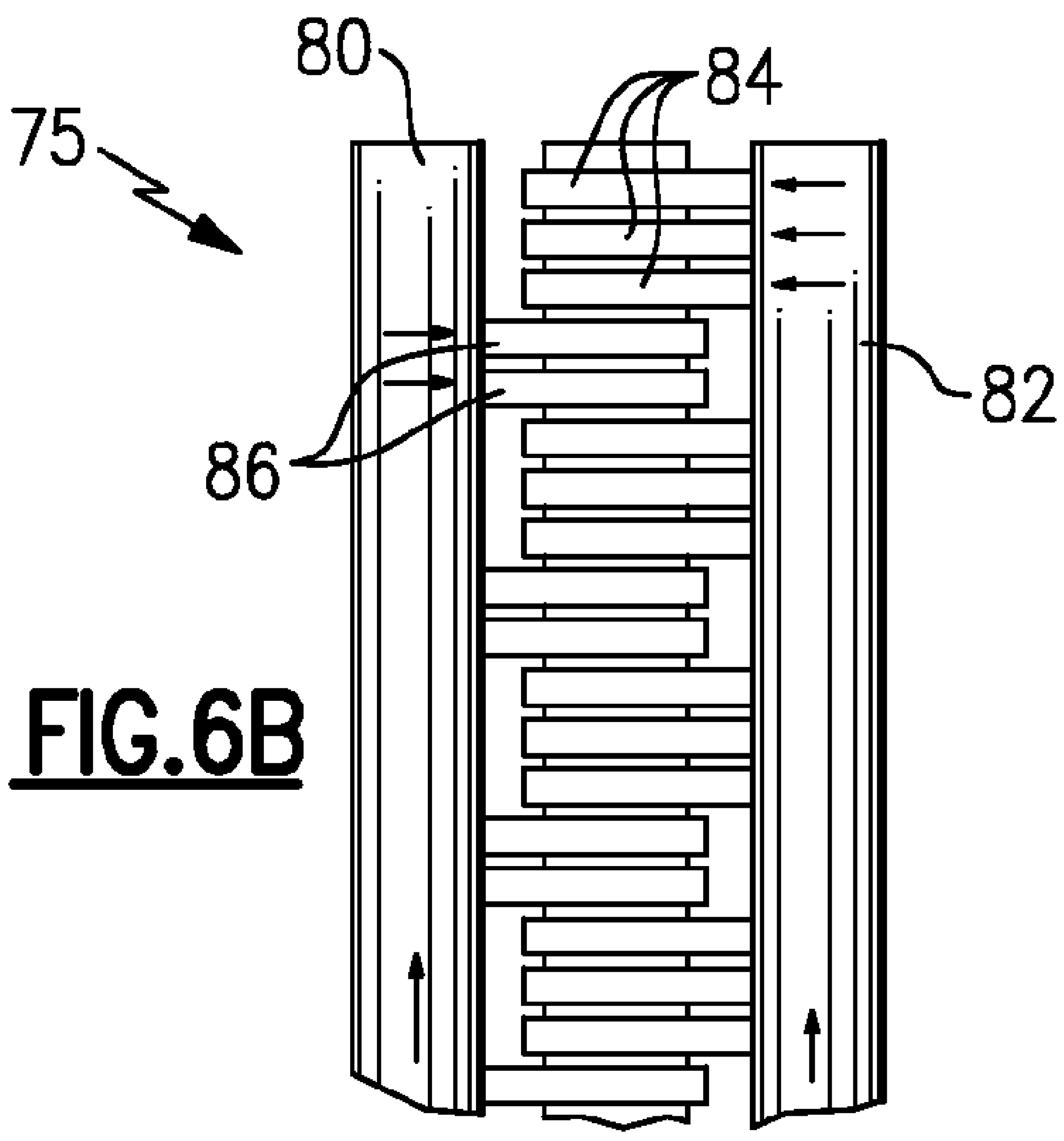


FIG.6B

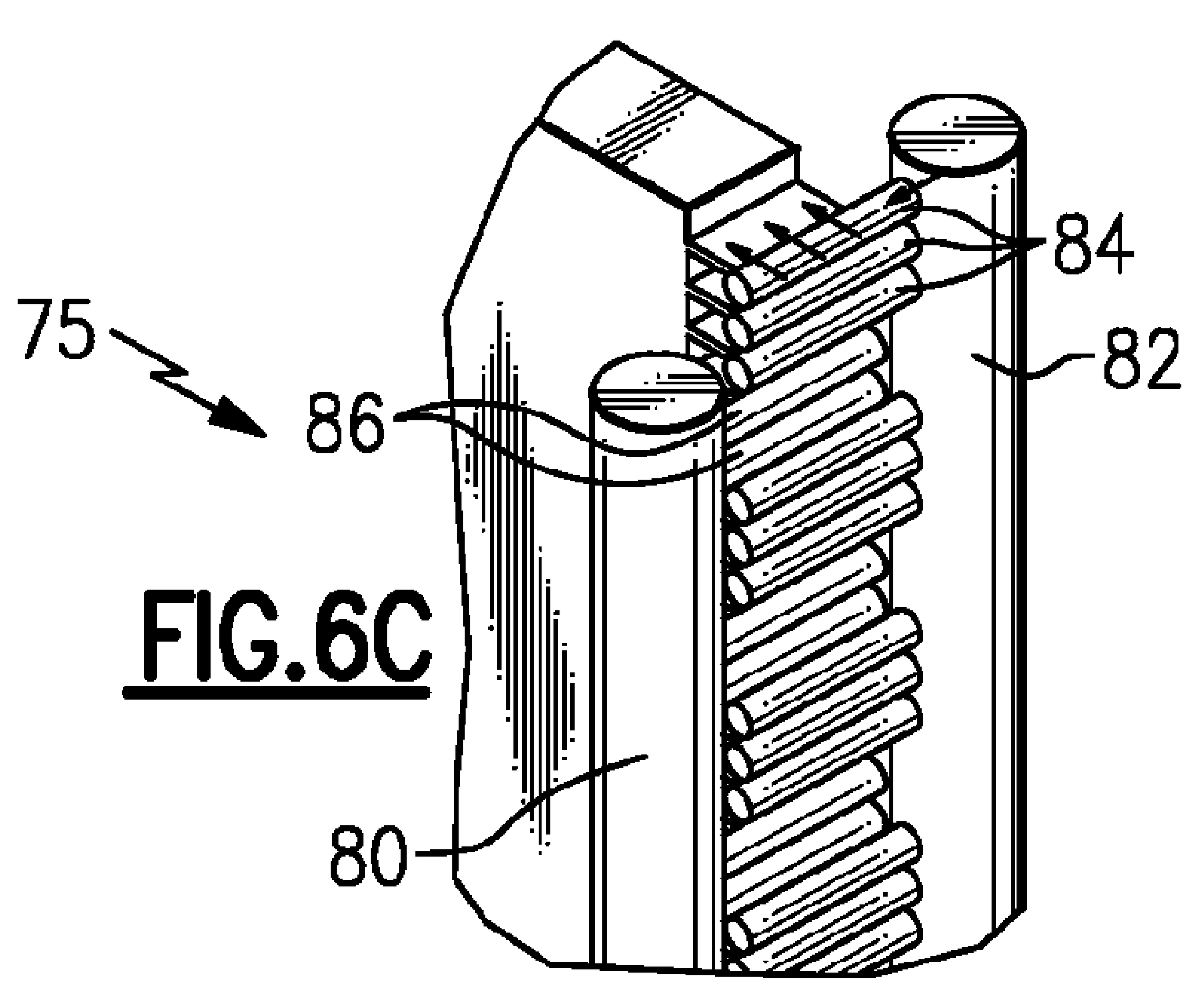


FIG.6C

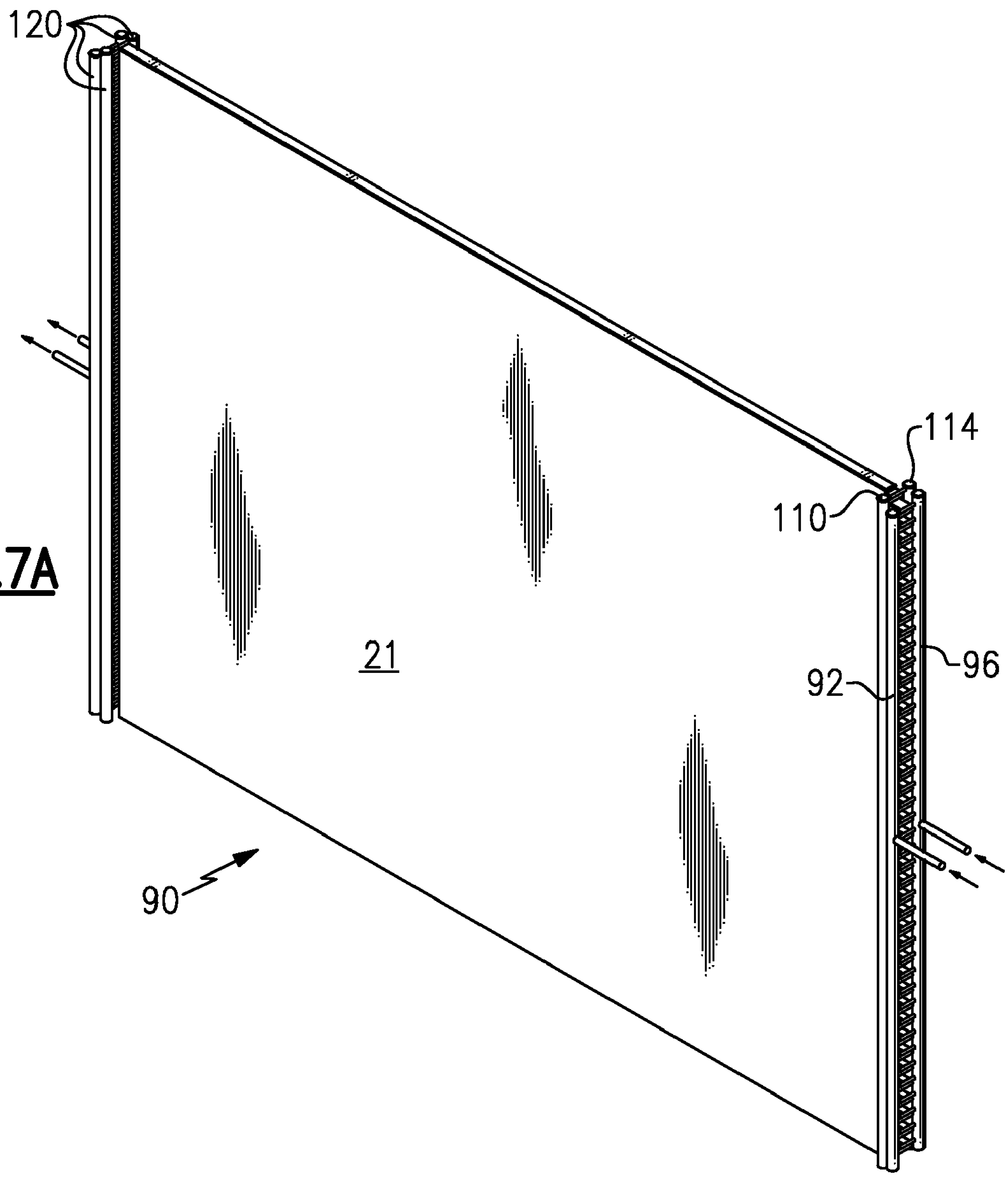


FIG.7A

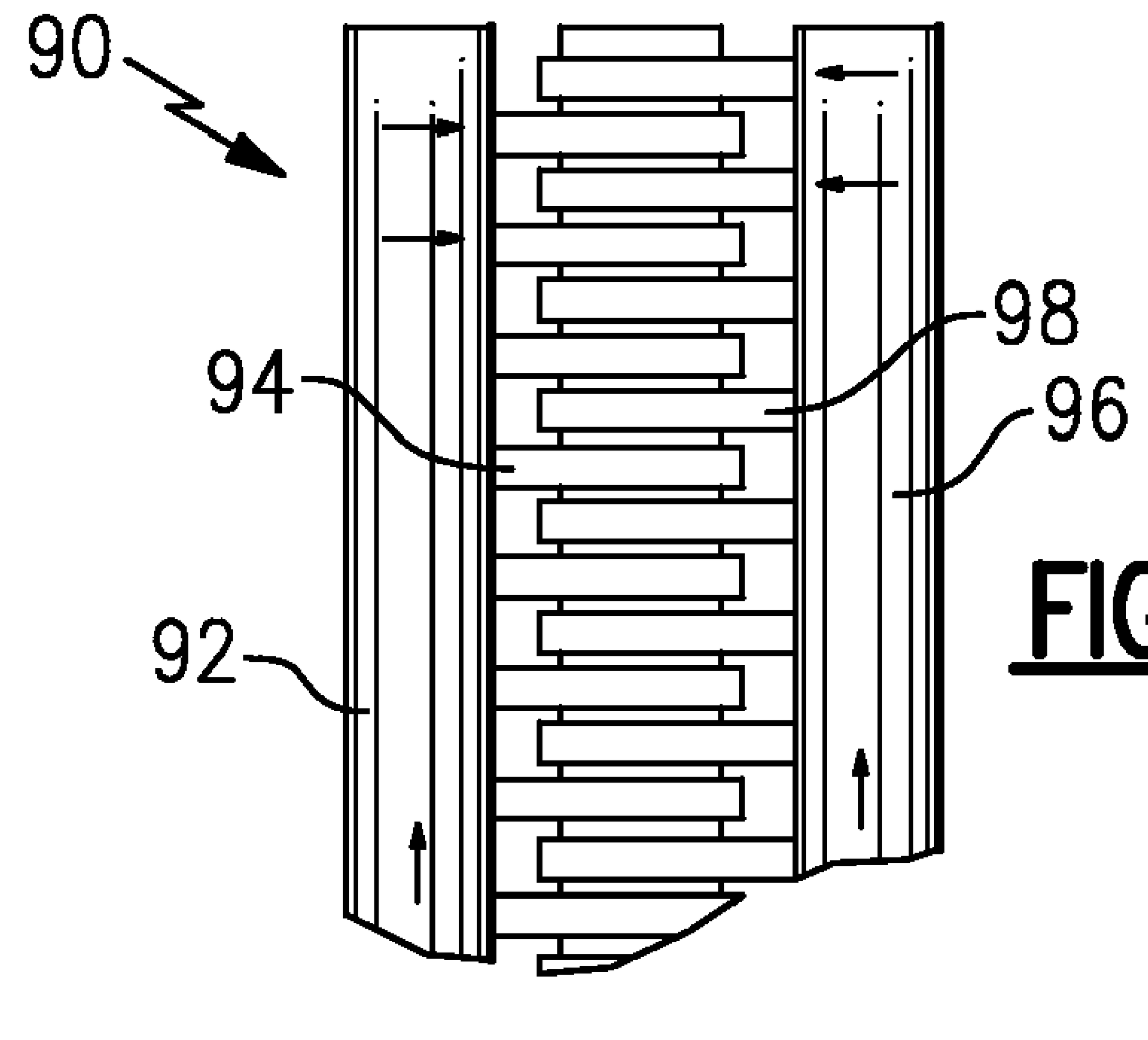


FIG.7B

INTEGRATED MULTI-CIRCUIT MICROCHANNEL HEAT EXCHANGER

RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional patent application No. 61/080780, which was filed Jul. 15, 2008.

BACKGROUND OF THE INVENTION

[0002] In recent years, much interest and design effort has been focused on the efficient operation of the heat exchangers (and condensers, gas coolers and evaporators in particular) of refrigerant systems. One relatively recent advancement in heat exchanger technology is the development and application of parallel flow, or so-called microchannel or minichannel, heat exchangers (these two terms will be used interchangeably throughout the text), as the condensers, gas coolers and evaporators.

[0003] These heat exchangers are provided with a plurality of parallel heat exchange tubes, typically of a non-round shape, among which refrigerant is distributed and flown in a parallel manner. The heat exchange tubes are orientated generally substantially perpendicular to a refrigerant flow direction in inlet, intermediate and outlet manifolds that are in flow communication with the heat exchange tubes. The heat exchange tubes typically have a multi-channel construction, with refrigerant distributed within these multiple channels in a parallel manner. Heat transfer fins may be inter-disposed and rigidly attached to the heat exchange tubes. The primary reasons for the employment of the parallel flow heat exchangers, which usually have aluminum furnace-brazed construction, are related to their superior performance, high degree of compactness, structural rigidity, lower weight, lower refrigerant charge and enhanced resistance to corrosion.

[0004] At times, there may be reasons to have multiple distinct refrigerant circuits within a single heat exchanger core and construction in a refrigerant system. As one example, a dual circuit refrigerant system having two completely separate refrigerant independent circuits with separate compressors and heat exchangers, etc. can be provided to achieve capacity control and efficiency improvement. In other applications, it may be desirable to route the total refrigerant flow only through a portion of the heat exchanger, while utilizing the entire heat exchanger frontal area. Furthermore, it may be desirable to implement multiple independent refrigerant paths of a single refrigerant circuit through the heat exchanger core to improve the heat exchanger effectiveness.

[0005] To date, the provision of the multiple distinct refrigerant circuits utilizing total frontal or cross-sectional area of the heat exchanger has required distinct heat exchangers, at least when a microchannel heat exchanger is used. More traditional heat exchangers, such as a round tube and plate fin heat exchangers, can be formed to be of a multi-circuit intertwined configuration utilizing the total frontal area of the heat exchanger, however, microchannel heat exchangers have not been easily tailored to include such multiple circuit configurations.

SUMMARY OF THE INVENTION

[0006] A microchannel heat exchanger includes two separate manifolds leading into a plurality of separate microchannel tube banks. In embodiments, the separate tube banks extend parallel to each other along a first direction through one dimension of a heat exchange area. The banks from the at least two manifolds are interspersed along a second direction which is perpendicular to the first direction.

[0007] These and other features of the present invention can be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1**A is a 3D view of an inventive heat exchanger.

[0009] FIG. **1**B shows a first schematic that might utilize the inventive heat exchanger.

[0010] FIG. **1**C shows a second schematic that might utilize the inventive heat exchanger.

[0011] FIG. **2** shows an enlarged manifold section of the FIG. **1**A heat exchanger.

[0012] FIG. **3** is an end view of FIG. **2**.

[0013] FIG. **4**A shows detail of the manifold section of the inventive heat exchanger.

[0014] FIG. **4**B shows an alternate feature of the inventive heat exchanger.

[0015] FIG. **5** is a cross-sectional view of a heat exchange tube.

[0016] FIG. **6**A shows a 3D view of another embodiment of the inventive heat exchanger.

[0017] FIG. **6**B is an end view of the FIG. **6**A embodiment.

[0018] FIG. **6**C shows an enlarged manifold section of the FIG. **6**A heat exchanger.

[0019] FIG. **7**A shows a 3D view of another embodiment of the inventive heat exchanger.

[0020] FIG. **7**B is an end view of the FIG. **7**A embodiment.

[0021] FIG. **7**C shows an enlarged manifold section of the FIG. **7**A heat exchanger.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0022] FIG. **1** shows a microchannel heat exchanger **20** having a heat exchanger frontal or cross-sectional surface area **21**. An inlet pipe **24** supplies refrigerant into a first inlet manifold **22**, and an inlet pipe **28** supplies refrigerant into a second inlet manifold **26**. The two inlet pipes **24** and **28** can be connected to completely separate independent refrigerant circuits, or can be connected to a common refrigerant source of a single refrigerant circuit. Outlet manifolds **30** and **32** lead to outlet pipes **29** and **31**, communicating the refrigerant downstream to independent refrigerant circuits or to a single refrigerant circuit respectively. Although references to a refrigerant and to a refrigerant system are made throughout the text, any suitable heat transfer fluid, such as, for instance, water, ethylene glycol, propylene glycol or oil, and an associated system, can be utilized instead. Furthermore, although microchannel heat exchangers of the invention are schematically shown in a single-pass configuration (see for instance FIG. **1**A), any number of passes can be implemented in a similar manner, and all such multi-pass microchannel heat exchangers (see FIG. **4**B) are within the scope of the invention.

[0023] When the inlet pipes **24** and **28** and the outlet pipes **29** and **31** communicate refrigerant to separate independent refrigerant circuits of a refrigerant system, capacity control and efficiency improvement are achieved at part-load operation, as the entire frontal surface area **21** is utilized in heat transfer interaction with the air flowing across heat exchanger external surfaces, while only one of the refrigerant circuits is operating. When the inlet pipes **24** and **28** and the outlet pipes

29 and 31 communicate refrigerant to a single refrigerant circuit of a refrigerant system, at certain conditions, it may be desired to flow refrigerant only through a portion of the heat exchanger 20, while still utilizing the entire heat exchanger frontal area 21 for better performance. Such conditions may arise, for instance, for the purposes of head pressure control or maintaining minimum refrigerant velocity for proper oil circulation throughout a refrigerant system and return to the compressor. Furthermore, it may be desirable to implement multiple independent refrigerant paths of a single refrigerant circuit through the heat exchanger core to improve refrigerant distribution and the heat exchanger effectiveness. As known, refrigerant distribution is particularly important for two-phase refrigerant flows, such as a refrigerant flow entering an evaporator.

[0024] FIG. 1B shows a basic exemplary multi-circuit refrigerant system that might utilize the inventive heat exchanger 20. In this multi-circuit refrigerant system, there are two entirely separate independent refrigerant circuits 300 and 301, each incorporating its own expansion device 302, separate evaporator heat exchangers 304 and 308, and separate compressors 306. As can be appreciated, for both circuits, the refrigerant is routed through the single heat exchanger 20. The FIG. 1B is quite simplified, and the flow through the heat exchanger 20 can be better appreciated from a review of FIG. 1A. However, the power of this system configuration to provide the multiple refrigerant circuits, while still requiring only a single heat exchange 20 with fully utilized frontal area 21, especially for part-load conditions when only some of the refrigerant circuits are operational, is apparent. The system may be a heat pump or an air conditioner, and the heat exchanger 20 may be the indoor heat exchanger or the outdoor heat exchanger. In addition, the heat exchanger 20 can be utilized for other applications such as a reheat function, as an example, if appropriate refrigerant circuitry is provided.

[0025] FIG. 1C shows yet another application of the inventive heat exchanger 20. In this application, a single refrigerant line 401 leads to branch refrigerant lines 402 and 404, connecting to the refrigerant manifolds associated with the inventive heat exchanger 20. Refrigerant flow control devices such as valves 406 control refrigerant flow to the branch refrigerant lines 402 and 404, and then to the heat exchanger 20. In this manner, the total volume of refrigerant passing through the heat exchanger 20, refrigerant velocity and heat transfer area utilization for the heat exchanger 20 can be controlled. The various reasons for providing such control are known in the art, but the use of a microchannel heat exchanger providing intertwined refrigerant circuits within a single heat exchanger structure is inventive.

[0026] FIG. 2 shows a detail of the inlet manifolds 22 and 26. The outlet manifolds 30 and 32 are constructed and connected to the heat exchanger core in a similar manner. As can be appreciated, connecting tubes 33 from each manifold 22 and 26 alternatively lead to separate independent banks of heat exchange tubes 34 extending perpendicular to the plane of the frontal heat exchange surface area 21 along a first direction. Each manifold has plural connecting tubes 33 connected to plural refrigerant heat exchange tubes 34. As can be appreciated from this figure, the heat exchange tube banks 34 connected to the two manifolds 22 and 26 have an alternating pattern along a second direction along the manifold axis, which is generally perpendicular to the first direction. For instance, in some applications, the first direction is a horizontal direction and the second direction is a vertical direction; in other applications the first direction is a vertical direction and the second direction is a horizontal direction.

[0027] FIG. 3 shows the end view of the heat exchanger 20 and its manifolds 22 and 26 leading to the connecting tubes 33. Notably, while the manifolds are shown extending generally vertically, with the heat exchange tube banks extending generally horizontally, the manifolds can extend generally horizontally with the heat exchange tube banks extending generally vertically.

[0028] The heat exchanger 20 typically includes external heat transfer fins, like a standard microchannel heat exchanger construction, but they have been omitted to simplify the understanding of the drawings.

[0029] FIG. 4A shows a detail of the inlet pipe 28 leading into the inlet manifold 26, into the connecting tube 33, and into the bank of heat exchange tubes 34. As known, the heat exchange tube 34 for a microchannel heat exchanger typically has a plurality of parallel refrigerant channels 100 separated by dividing walls 101, as shown in FIG. 5. The parallel refrigerant channels 100 each preferably have a hydraulic diameter that is less than 5 mm, and may be less than 3 mm. Notably, the term "hydraulic diameter" does not imply that the channels are circular in cross-section.

[0030] FIG. 4B shows an alternative heat exchanger pass arrangement 200. This is a multi-pass heat exchanger construction, wherein the manifolds 22 and 30 are actually subdivided into multiple manifold chambers and incorporate inlet and outlet manifold chambers 205 and 206 as well as intermediate manifold chambers 207 and 208 respectively. As an example, refrigerant flows through the heat exchange tube bank 34 extending from the inlet manifold chamber 205 of the manifold 22 toward the intermediate manifold chamber 207 of the manifold 30, but then reverses flow direction through another heat exchange tube bank 201 to reach the intermediate manifold chamber 208 of the manifold 22, and then reverses direction once again to flow through yet another heat exchange tube bank 202 to reach the outlet chamber 206 of the manifold 30. Divider plates 204 subdivide each of the manifolds 22 and 30 into the manifold chambers 205 and 208 and manifold chambers 207 and 208 respectively. Within this embodiment, heat exchange tube banks of the other refrigerant circuit would be intertwined with the heat exchange tube banks 34, 201 and 202. FIG. 4B is a very simplified view. As can be appreciated, connecting refrigerant tubes 33 extending laterally from the manifolds 22 and 30 would typically be utilized within this embodiment, but are omitted in the FIG. 4B for simplicity.

[0031] FIGS. 6A and 6B show another embodiment 75 wherein an inlet manifold 82 has three adjacent connecting tubes 84, and hence three adjacent heat exchange tubes, and an inlet manifold 80 has only two adjacent connecting tubes 86, and hence only two adjacent heat exchange tubes. As before, the alternating pattern repeats itself along the manifold axis. In this manner, the relative size of the heat exchanger portion connected to each inlet manifold can be controlled. Of course, ratios other than 3:2 can be utilized. This unequal circuit split may become advantages, for instance, when refrigerant circuits and associated compression systems are of a different size and capacity, allowing for different stages of capacity modulation and unloading. It has to be understood that a single connecting refrigerant tube 84 or 86 of a larger diameter, that leads to adjacent heat exchange tubes, can be utilized instead.

[0032] FIG. 6C is a perspective 3D view showing a detail of the manifold structure. The power of the inventive system is apparent, in that it provides high flexibility control over capacity modulation by utilizing the distinct number of heat exchange tube banks of a variable size. As is apparent, refrigerant will flow into each of the manifolds **80** and **82**, into the respective connecting refrigerant tubes **86** and **84**, and then into the associated heat exchange tube banks. This embodiment can utilize the multi-pass alternative as shown in FIG. **4**B, or can be utilized in a single-pass configuration.

[0033] FIGS. **7**A and **7**B show the power and flexibility of the inventive concept wherein an embodiment **90** has an inlet manifold **92** with associated connecting refrigerant tubes **94**, an inlet manifold **96** with associated connecting refrigerant tubes **98**, an inlet manifold **110** with associated connecting refrigerant tubes **112**, and an inlet manifold **114** with associated connecting refrigerant tubes **116**. More than four independent refrigerant circuits flowing through the heat exchanger **90** can be utilized.

[0034] FIG. **7**C is a perspective 3D view showing the detail of the manifold arrangement of the FIG. **7**A. Additional manifolds can be interfit into available space around the heat exchanger structure as shown in FIG. **7**C. As illustrated, the inlet manifolds **96** and **114** are located on one side of the core heat transfer area **21**, while the manifolds **92** and **110** are positioned on an opposed side of the core heat transfer area **21**. As before, refrigerant flowing through the several inlet manifolds passes into respective connecting refrigerant tubes, and into respective heat exchange tube banks. Again, multipass configurations such as shown in FIG. **4**B can also be utilized within this embodiment.

[0035] The connecting refrigerant tubes **33** may have different cross-sectional areas, including (but not limited to) round, oval, rectangular, and square cross-sections. All these connecting refrigerant tube configurations are within the scope of the invention. Furthermore, in some design arrangements, the connecting refrigerant tubes **33** may not be required, when the heat exchange tubes **34** are bent in an alternating pattern such that they fit directly into different inlet and outlet manifolds positioned as exhibited in multiple Figures illustrating the invention. Such design arrangements, although feasible, may not be desirable from manufacturability and reliability perspectives. Lastly, inlet and outlet manifolds may be positioned at the same end of the heat exchanger core **21**, depending on the refrigerant pass arrangement within the heat exchanger core.

[0036] The inventive heat exchanger can be utilized within all types of refrigerant systems, such as air conditioning systems, refrigeration systems and heat pump systems, as well as within other auxiliary systems, such as, for instance, water cooling or heating systems, process gas/air cooling or heating systems, and oil cooling or heating systems. Moreover, the inventive heat exchanger can be utilized as an evaporator, condenser, gas cooler, reheat heat exchanger or any other heat exchanger within commercial and residential air conditioning and heat pump systems, marine container units, refrigeration truck-trailer units, merchandisers, bottle coolers, supermarket refrigeration systems, etc.

[0037] Although an embodiment of this invention has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.

What is claimed is:

1. A microchannel heat exchanger comprising:

at least two manifolds, with said at least two manifolds communicating with a respective one of a first and second plurality of heat exchange tubes; and

said first and second plurality of heat exchange tubes providing microchannel heat exchangers within a single heat exchanger core.

2. The microchannel heat exchanger as set forth in claim **1**, wherein the microchannel heat exchanger has a heat transfer surface area with said at least two manifolds each communicating to a separate one of said first and second plurality of heat transfer tubes, which extend through said heat transfer surface area along a first direction, with said first and second plurality of heat transfer tubes being generally parallel to each other, and said heat transfer area having a second direction that is generally perpendicular to said first direction, and heat exchange tubes from said first and second plurality of tubes being intertwined along said second direction.

3. The microchannel heat exchanger as set forth in claim **2**, wherein said at least two manifolds are spaced on opposed sides of said heat transfer surface area.

4. The microchannel heat exchanger as set forth in claim **1**, wherein said at least two manifolds are connected to said plurality of heat transfer tubes by connecting refrigerant tubes that extend from said at least two manifolds to be connected to said heat exchange tubes in the plane perpendicular to said heat transfer surface area.

5. The microchannel heat exchanger as set forth in claim **1**, wherein there are at least four of said manifolds, with each of said manifolds communicating with separate heat exchange tubes.

6. The microchannel heat exchanger as set forth in claim **5**, wherein there is at least one of said at least four manifolds positioned on each of two lateral sides of said heat transfer surface area.

7. The microchannel heat exchanger as set forth in claim **1**, wherein said at least two manifolds are one of inlet manifolds and outlet manifolds.

8. The microchannel heat exchanger as set forth in claim **1**, wherein each of said plurality of heat transfer tubes has a plurality of separate refrigerant channels extending into a plane of said heat transfer area, and wherein said plurality of refrigerant channels of said heat exchange tubes has a hydraulic diameter less than 5 mm, and preferably less than 3 mm.

9. The microchannel heat exchanger as set forth in claim **1**, wherein each of said connecting refrigerant tubes is connected to several heat transfer tubes.

10. The microchannel heat exchanger as set forth in claim **1**, wherein said heat exchange tubes are bent or formed to fit into said at least two manifolds.

11. The microchannel heat exchanger as set forth in claim **1**, wherein said first and second plurality of heat exchange tubes include different numbers of heat exchange tubes.

12. The microchannel heat exchanger as set forth in claim **1**, wherein there is a single refrigerant pass from an inlet manifold to an outlet manifold.

13. The microchannel heat exchanger as set forth in claim **1**, wherein there are multiple passes between an inlet manifold and an outlet manifold, with each of said inlet and outlet manifolds being subdivided to provide intermediate manifold chambers.

14. The microchannel heat exchanger as set forth in claim **1**, wherein said at least two manifolds are connected to separate independent refrigerant circuits of a refrigerant system.

15. The microchannel heat exchanger as set forth in claim **1**, wherein said at least two manifolds are connected to a single refrigerant circuit of a refrigerant system.

* * * * *