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(54) **MICROCHANNEL HEAT EXCHANGER MODULE DESIGN TO REDUCE WATER ENTRAPMENT**

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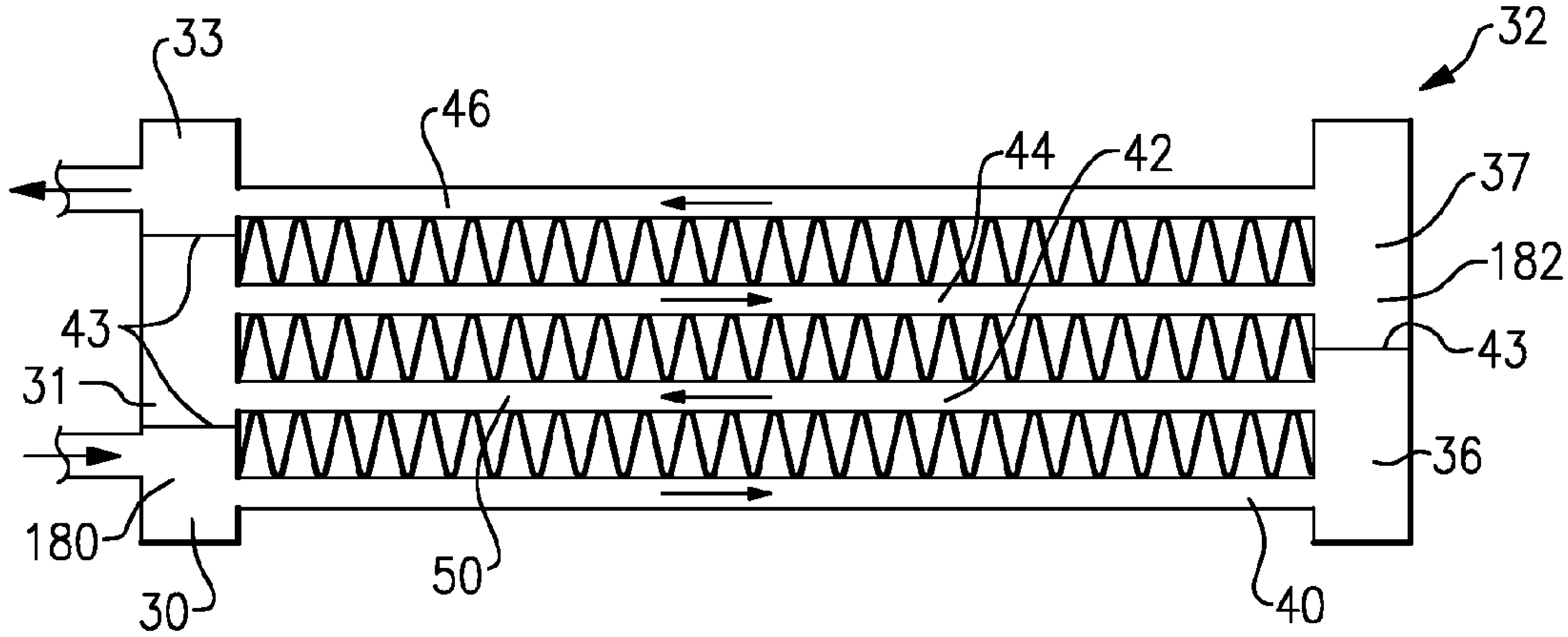
(52) **U.S. Cl.** **165/104.34**; 165/172; 165/175

(57) **ABSTRACT**

A microchannel heat exchanger has a core having at least one heat exchange tube bank having a plurality of flow channels with a small hydraulic diameter less than 5 mm. A means is provided to reduce the amount of water retained on the external surfaces of the at least one heat exchange tube bank. These means may utilize the incorporation of a particular routing of refrigerant within the heat exchanger, the operation and control of a fan associated with the heat exchanger, or the provision of structure to at least partially block liquid from reaching the heat exchanger tube bank.



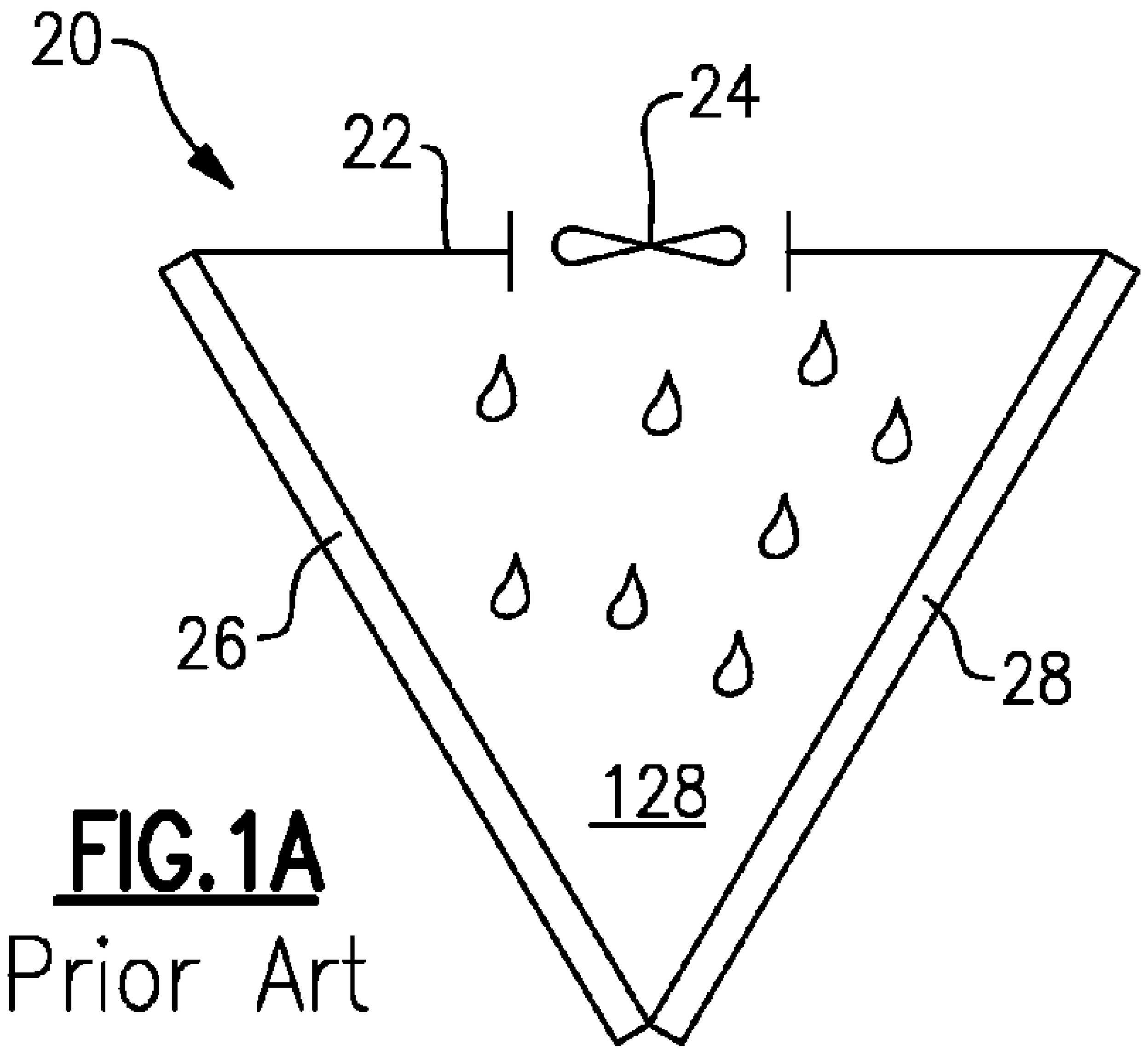


FIG.1A
Prior Art

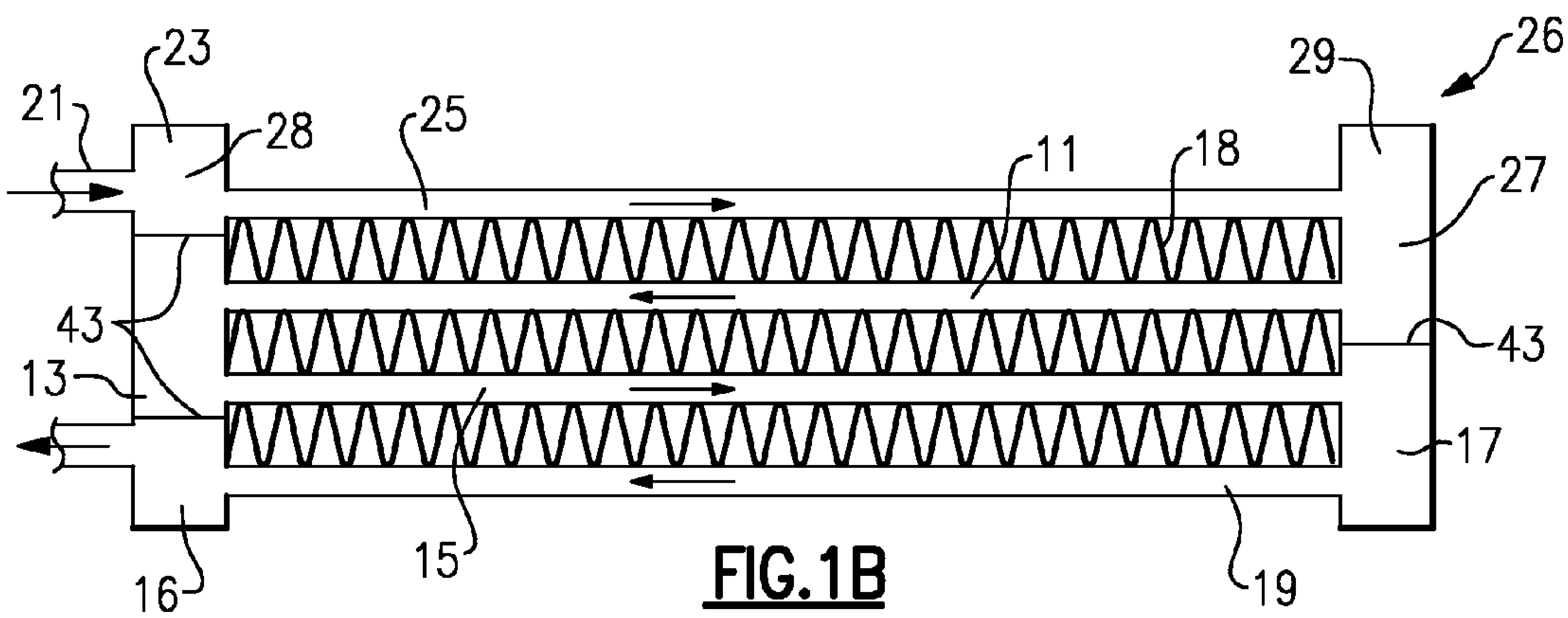


FIG.1B
Prior Art

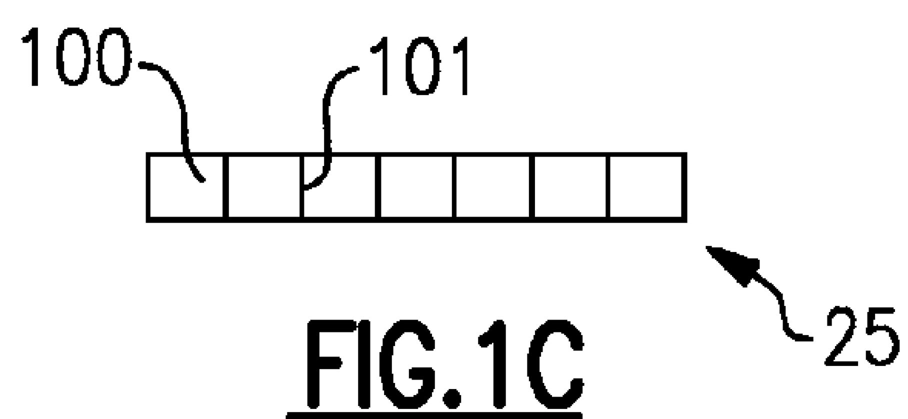


FIG.1C
Prior Art

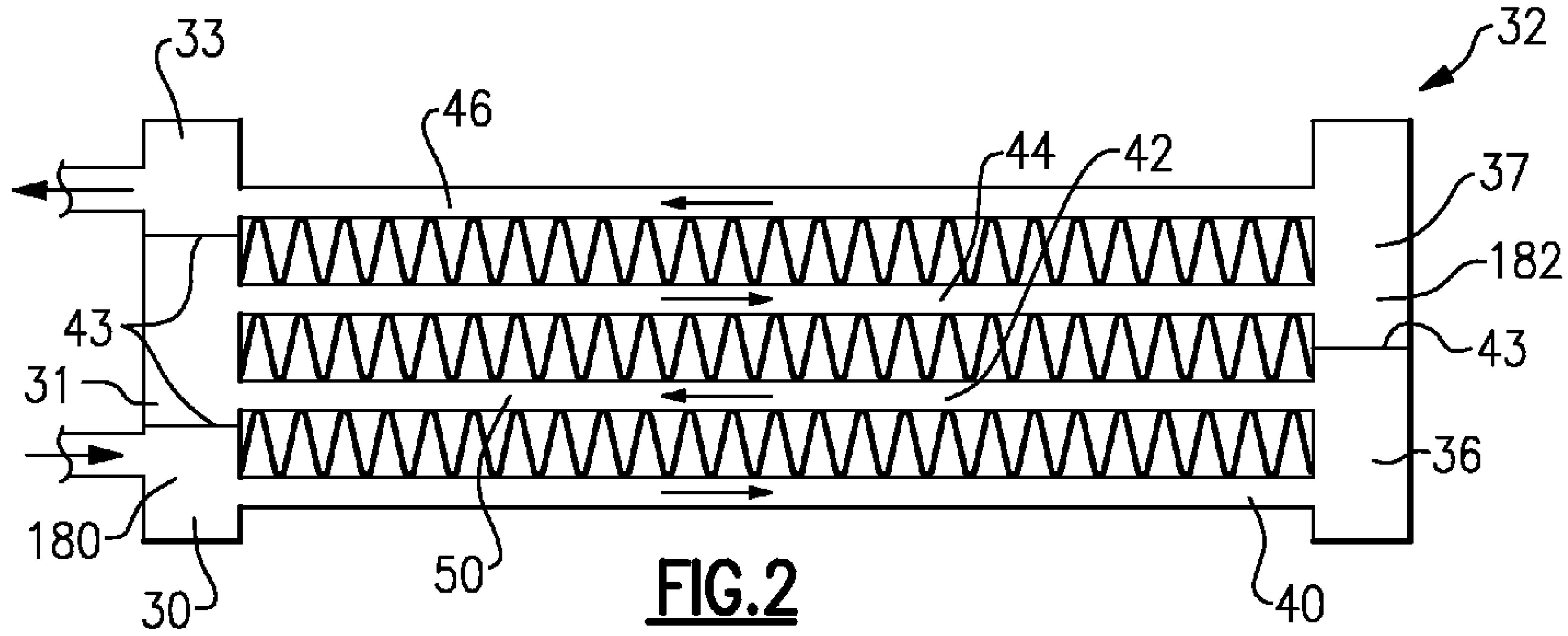


FIG.2

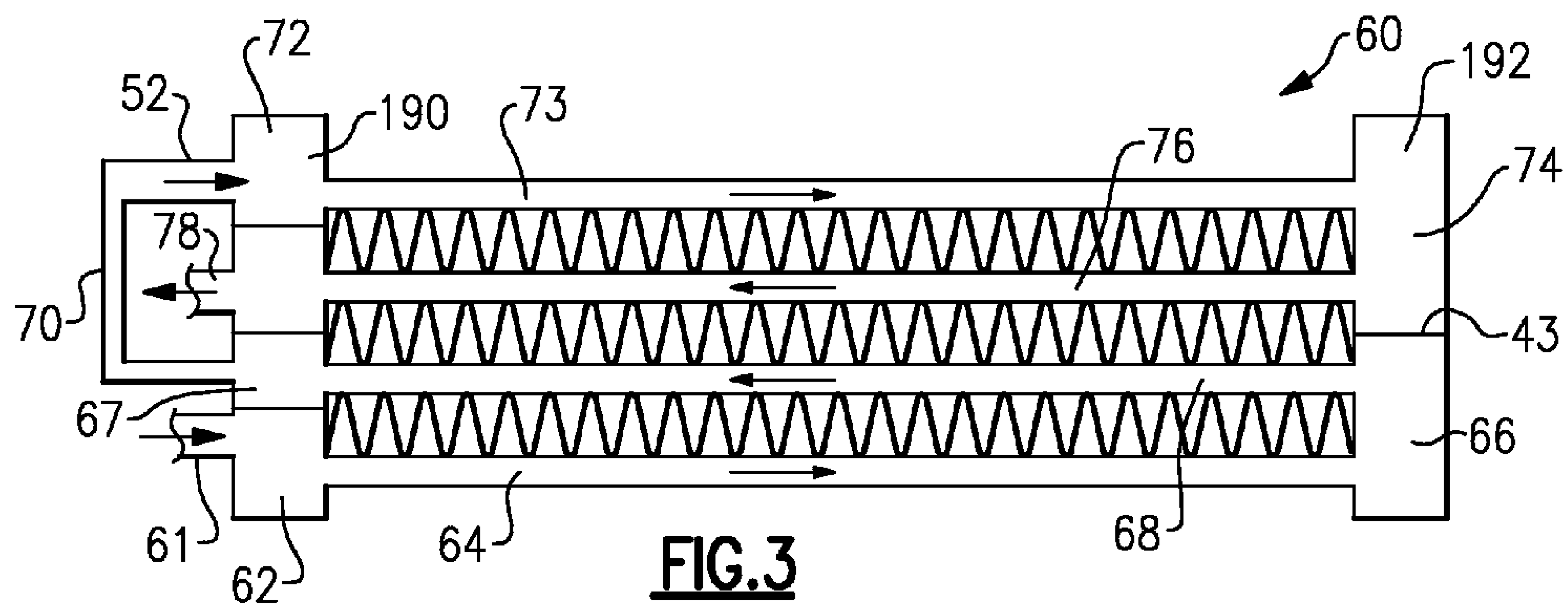


FIG.3

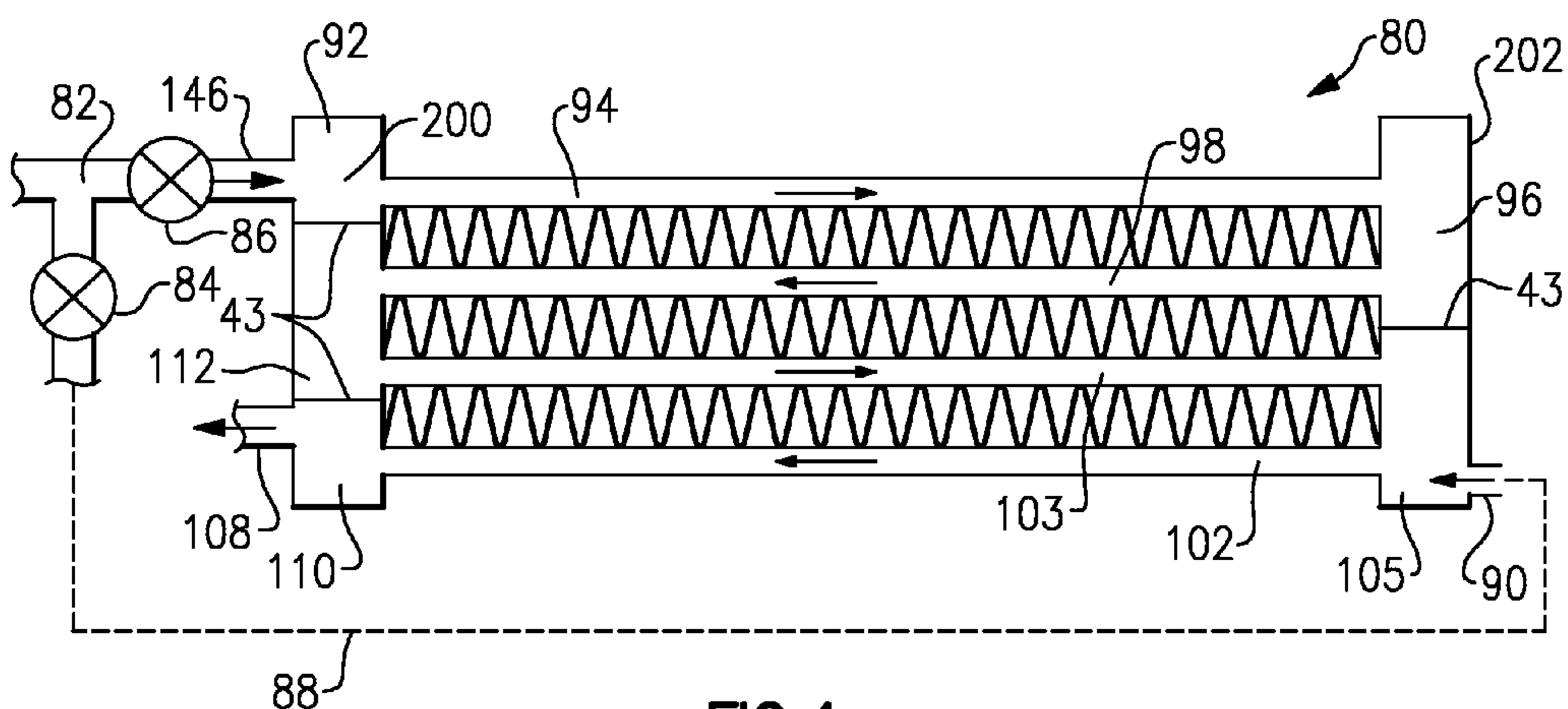


FIG.4

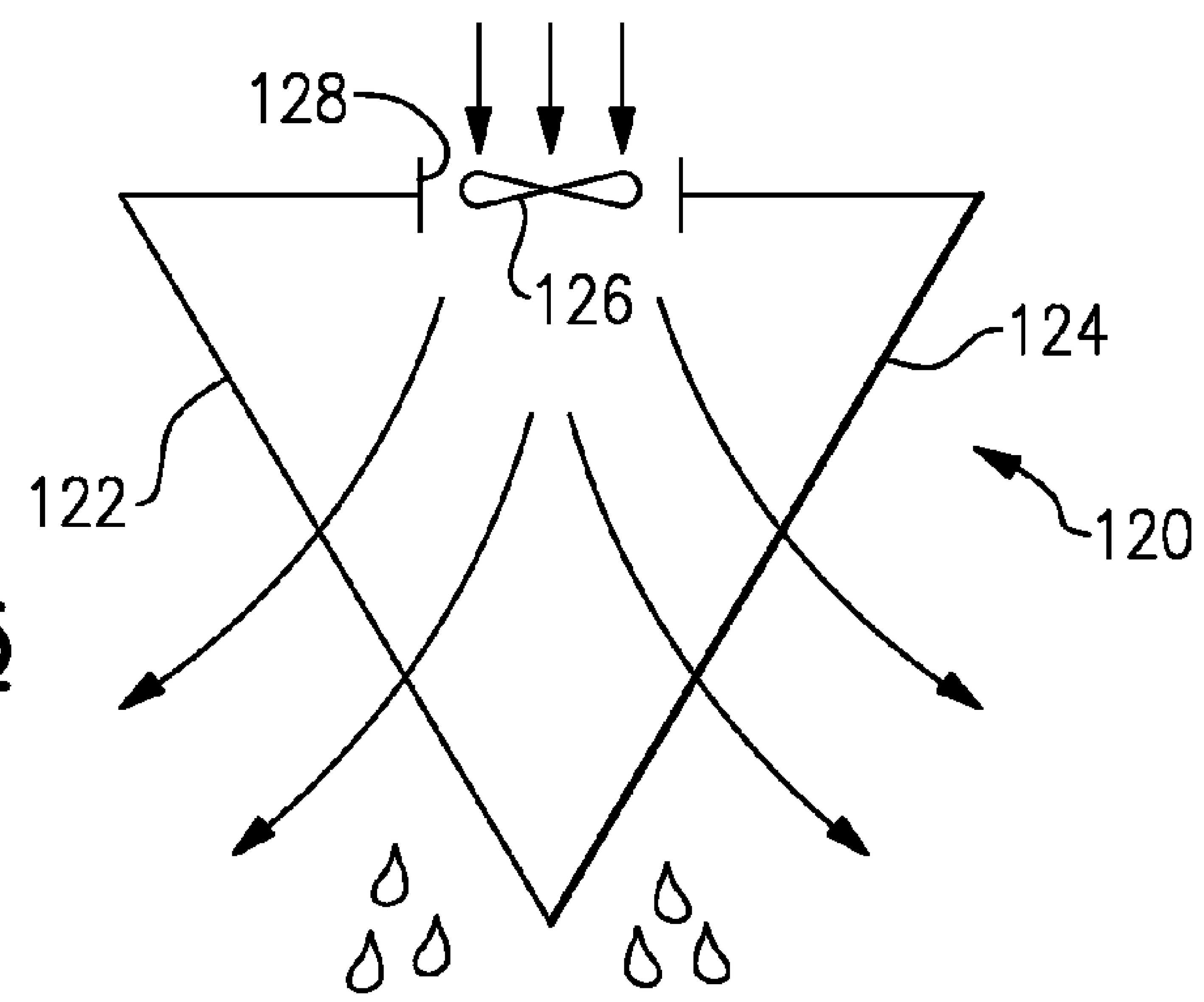


FIG.5

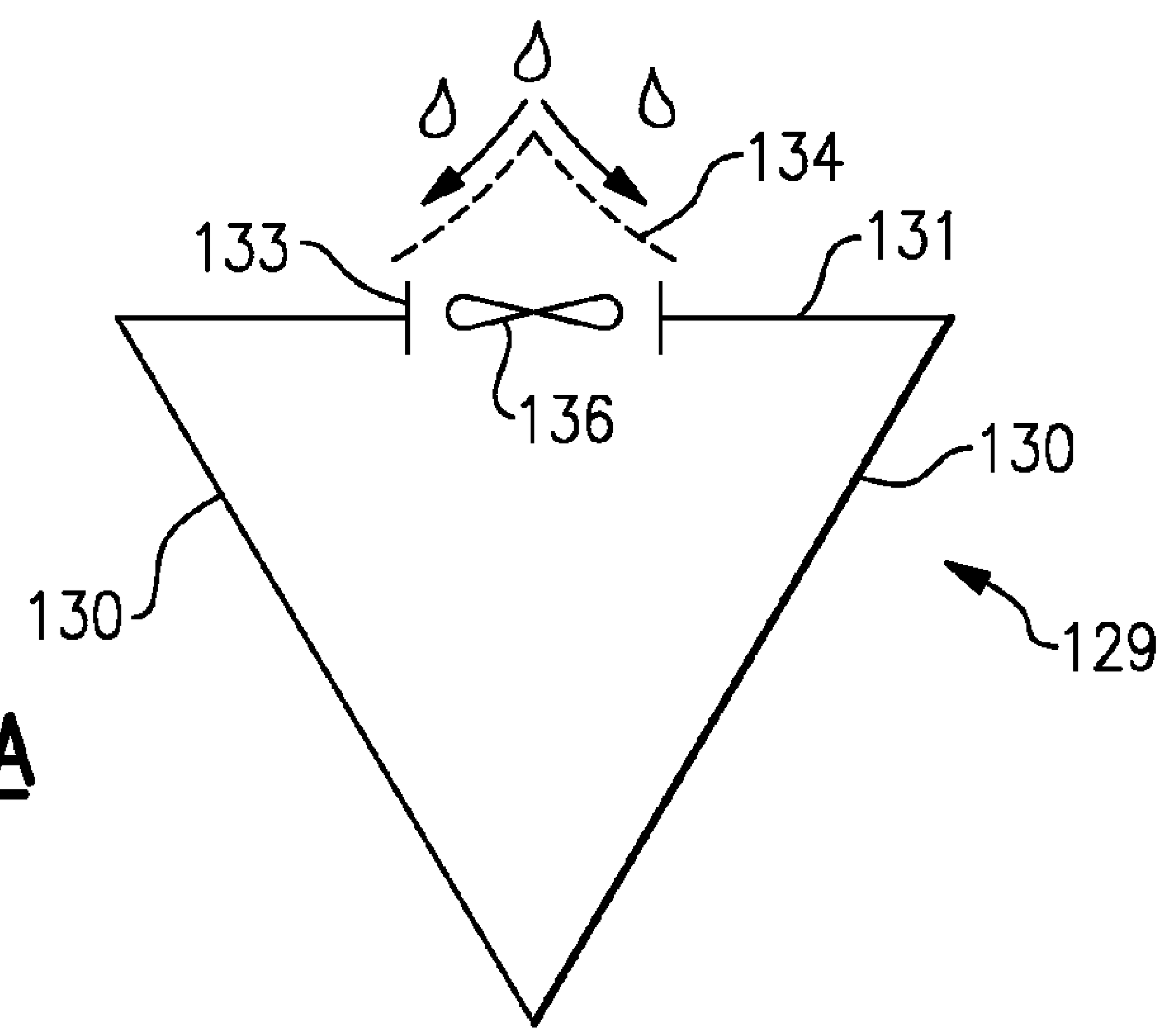


FIG.6A

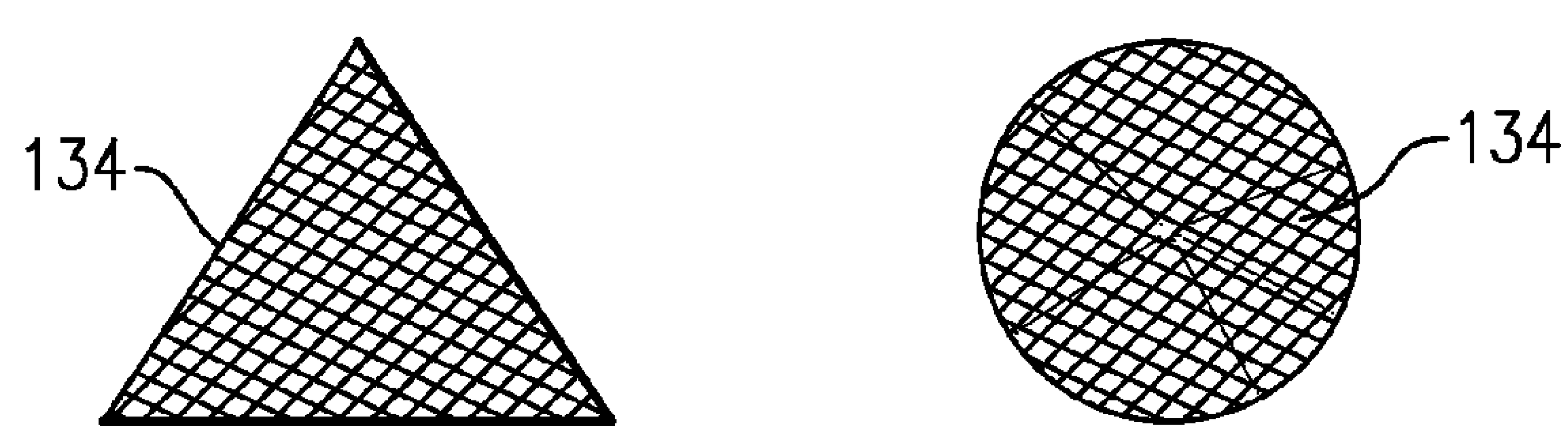


FIG.6B FIG.6C

MICROCHANNEL HEAT EXCHANGER MODULE DESIGN TO REDUCE WATER ENTRAPMENT

RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Application No. 61/095,019, which was filed Sep. 8, 2008.

BACKGROUND OF THE INVENTION

[0002] In recent years, much interest and design effort has been focused on efficient and durable operation of the heat exchangers in refrigerant systems. Sustained high effectiveness of refrigerant system heat exchangers directly translates into the augmented system performance and reduced lifetime cost. 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 indoor and outdoor heat exchangers.

[0003] These parallel flow 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 typically incorporate multiple channels and are orientated generally substantially perpendicular to a refrigerant flow direction in the inlet, intermediate and outlet manifolds that are in flow communication with the heat exchange tubes. Heat transfer enhancing fins are typically disposed in between and rigidly attached to the heat exchange tubes. The primary reasons for the employment of the parallel flow heat exchangers, which usually have all-aluminum furnace-brazed construction, are related to their superior performance, high degree of compactness, structural rigidity, reduced refrigerant charge and enhanced resistance to corrosion.

[0004] Microchannel heat exchangers provide beneficial results, at least in part, because their internal flow channels are of quite small hydraulic diameter. However, there are other challenges associated with microchannel heat exchangers. One challenge is that bare outdoor microchannel heat exchangers (as other heat exchanger types) are susceptible to atmospheric corrosion in industrial and coastal corrosive environments, due to the nature of their construction, material system and manufacturing processes.

[0005] In particular, the increased amount of water potentially retained on external heat exchanger surfaces and increased wet time, particularly in coastal corrosive environments, can present corrosion challenges.

[0006] Protective anti-corrosion coatings are known but are expensive. On the other hand, while less expensive coatings may be known, they are less effective. Therefore, it is desired to considerably reduce the amount of water retained on external surfaces of the outdoor heat exchanger (typically condenser or gas cooler), and thus significantly slow down corrosion reaction.

SUMMARY OF THE INVENTION

[0007] In a disclosed embodiment of this invention, a microchannel heat exchanger is provided with at least one heat exchange tube bank having a plurality of flow channels with a hydraulic diameter less than 5 mm, and preferably less than 2 mm, and having a means incorporated into the heat exchanger and associated sub-system or structural design to reduce the amount of water retained on the heat exchanger external surfaces.

[0008] The means may utilize the incorporation of a particular routing of refrigerant within the heat exchanger, the operation and control of a fan associated with the heat exchanger, or the provision of structure to at least partially block liquid from reaching the heat exchanger tube bank.

[0009] 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

[0010] FIG. **1**A shows a prior art arrangement of a microchannel heat exchanger.

[0011] FIG. **1**B schematically shows one example of known heat exchanger.

[0012] FIG. **1**C is a cross-sectional view through a tube bank.

[0013] FIG. **2** shows a first embodiment of the invention.

[0014] FIG. **3** shows a second embodiment of the invention.

[0015] FIG. **4** shows a third embodiment of the invention.

[0016] FIG. **5** shows yet another embodiment of the invention.

[0017] FIG. **6**A shows another embodiment of the invention.

[0018] FIG. **6**B shows a side view of a portion of the FIG. **6**A embodiment.

[0019] FIG. **6**C is a top view of a portion of the FIG. **6**A embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0020] A typical microchannel heat exchanger outdoor module **20** is illustrated in FIG. **1**A. An upper deck **22** includes a fan system **24** for moving (typically pulling) air over a pair of microchannel heat exchangers **26** and **28**. As can be appreciated, water accumulated inside outdoor module **20** will tend to collect near a lower portion **128** of this heat exchanger arrangement. Furthermore, moisture present in the atmospheric air, particularly in humid environments, will also accumulate on external heat exchanger surfaces. Due to the close-coupled construction of the microchannel heat exchanger, this moisture is retained within the heat exchanger core for prolonged periods of time. It should be noted that the outdoor module **20** shown in FIG. **1**A is exemplary, and there many design variations of the outdoor module arrangements, including (but not limited to) vertical and V-shaped as well as straight and formed heat exchangers. All these designs and constructions are within the scope and can benefit from the invention.

[0021] As shown in FIG. **1**B, the microchannel heat exchanger **26** includes an inlet **21** fluidly connected and delivering refrigerant to a top chamber **23** of an inlet/outlet manifold **28**. After leaving the top chamber **23** of the manifold **28**, refrigerant passes into a first heat exchange tube bank **25** and to a top chamber **27** of an opposed intermediate manifold **29**. From the top chamber **27** of the manifold **29**, the refrigerant returns through a second heat exchange tube bank **11** to an intermediate chamber **13** of the manifold **28**. From the intermediate chamber **13** of the manifold **28**, refrigerant passes through a third heat exchange tube bank **15** back to a bottom chamber **17** of the intermediate manifold **29**. From the bottom chamber **17** of the manifold **29**, the refrigerant passes through yet another forth heat exchange tube bank **19** to an outlet chamber **16** of the manifold **28**. As shown, divider plates **43** divide manifolds **28** and **29** into the chambers **23**, **13**, **16** and **27**, **17** respectively. In addition, fins **18** are positioned between the heat exchange tube banks **25**, **11**, **15**, and **19**. It should be noted that a four-pass heat exchanger configuration is exemplary, and different numbers of passes can be incorporated within the same heat exchanger construction. All these arrangements are within the scope of the invention.

[0022] As can be appreciated, in the condenser or gas cooler case, the hottest refrigerant (refrigerant typically leaving the compressor) is at the inlet **21** and within first heat exchange tube bank **25** of the heat exchanger **26**, namely within the top section of the microchannel heat exchanger **26**. As mentioned above, the greatest accumulation of water will be at the lower section of the microchannel heat exchanger **26**. This top-to-bottom refrigerant flow arrangement is typical for microchannel condensers, since condensing refrigerant flow naturally coincides with the direction of gravity.

[0023] As shown in FIG. **1**C, the heat exchange tubes of the tube banks include a plurality of small refrigerant channels **100** provided by separator walls **101**. These channels have hydraulic diameter less than 5 mm, and preferably less than 2 mm. The channels can be any number of shapes and the term "diameter" does not imply a circular cross-section.

[0024] In FIG. **2**, an embodiment **32** includes an inlet chamber **30** of an inlet/outlet manifold **180** at a vertically lower position leading to a heat exchange tube bank **40** passing refrigerant to a chamber **36** of an intermediate manifold **182**. From the chamber **36**, refrigerant passes through a heat exchange tube bank **42** to a chamber **31** of the inlet/outlet manifold **180**, and back through yet another heat exchange tube bank **44** to another chamber **37** of the intermediate manifold **182**. From the chamber **37**, the refrigerant passes through a heat exchange tube bank **46** to an outlet chamber **33** of the inlet/outlet manifold **180**. In the FIG. **2** embodiment, as opposed to the FIG. **1**B prior art, the inlet chamber **30** is at a bottom section of the microchannel heat exchanger **32**, providing a much hotter refrigerant to this section than would exist in the outlet chamber **33** at the heat exchanger exit.

[0025] By routing the hottest refrigerant into the inlet **30** positioned at the lower section of the microchannel heat exchanger, the hotter refrigerant will provide more heat to evaporate moisture retained on the external heat exchanger surfaces of the bottom area **128** of FIG. **1**A, where the most amount of moisture is typically accumulated. Thus, the effect of corrosion at the most susceptible lower heat exchanger tube banks will be greatly reduced.

[0026] FIG. **3** shows an embodiment **60** wherein the inlet refrigerant line **61** is also at the vertically lowermost portion leading into an inlet chamber **62** of an inlet/outlet manifold **190**. From the inlet chamber **62**, the refrigerant passes through a heat exchange tube bank **64** to a chamber **66** in an intermediate manifold **192**, a heat exchange tube bank **68**, the intermediate chamber **67** of the inlet/outlet manifold **190**, and through a branch refrigerant line **70** to another intermediate chamber **72** of the same inlet/outlet manifold **190** not adjacent to the chamber **67**, leading in turn to a heat exchange tube bank **73**. From the heat exchange tube bank **73**, the refrigerant passes through yet another intermediate chamber **74** of the intermediate manifold **192**, the heat exchange tube bank **76**, and to the outlet refrigerant line **78**. Essentially, this embodiment provides hotter refrigerant at the bottom and top heat exchanger tube bank sections **64** and **73**, which might be more exposed to the effects of corrosion than the intermediate heat exchange tube banks **68** and **76**. This may be beneficial, for instance, in situations when the top and bottom heat exchanger sections have reduced airflow and hence much lower water removal potential, in comparison to the center section. The FIG. **3** embodiment is purely exemplary, and other branch line configurations to provide intertwined refrigerant passes (in comparison to conventional staggered refrigerant passes) are also feasible and within the scope of the invention.

[0027] FIG. **4** shows an embodiment **80** wherein the refrigerant inlet line **82** is located within the top section of the microchannel heat exchanger. Refrigerant flow control devices such as valves **84** and **86** selectively route refrigerant through a tap line **88** to an injection point **90**. If the valve **86** is open and the valve **84** is closed, refrigerant will pass normally into an inlet chamber **92** of inlet/outlet manifold **200**, a heat exchange tube bank **94**, an intermediate chamber **96** of an intermediate manifold **202**, back through a heat exchange tube bank **98** to an intermediate chamber **112** of the inlet/outlet manifold **200**. From the intermediate chamber **112** refrigerant passes through a heat exchange tube bank **103** to a chamber **105** of the intermediate manifold **202**, and a heat exchange tube bank **102**. From the heat exchange tube bank **102**, the refrigerant passes through an outlet chamber **110** of the inlet/outlet manifold **200** and to an outlet refrigerant line **108**. This embodiment will operate as in the prior art of FIG. 1B. However, either periodically, or when some indication has been received that there is moisture accumulating on the external surfaces of the lower heat exchange tube bank **102**, the valve **86** may be closed or restricted and the valve **84** opened (partially or fully). Thus, at least a portion of hot refrigerant vapor from the inlet refrigerant line **82** will pass into the injection point **90**. This hot refrigerant will provide additional heat to assist in evaporation of accumulated condensate on the external surfaces of the low heat exchange tube bank **102**. The valves **84** and **86** can be ON/OFF solenoid valves or regulating valves and can be operated in a pulsation mode or in a modulation mode respectively. As was stated above, the FIG. **4** embodiment is exemplary, and other refrigerant bypass line configurations to provide a higher temperature refrigerant to the heat exchanger sections with increased amount of accumulated condensate on a periodic basis are also feasible and within the scope of the invention.

[0028] FIG. **5** shows yet another embodiment encapsulating a different way of reducing the condensate amount accumulated on external heat exchanger surfaces of an outdoor heat exchanger module **120**. In the outdoor heat exchanger module **120**, there are microchannel heat exchangers **122** and **124** and an air-moving device such as fan **126**. The fan **126** typically operates in a forward direction to pull air over the microchannel heat exchangers **122** and **124** and then through a fan orifice **128**. However, the fan **126** may be run in reverse to blow air over the heat exchangers **122** and **124**, thus also blowing the accumulated condensate off of the external surfaces of the heat exchangers **122** and **124** (since airflow and gravity directions are coincidental now). The fan **126** may be run in reverse either periodically, or, again, when some indication has been received (such as, for instance, increased airside pressure drop) regarding condensate accumulation on external surfaces of the heat exchangers **122** and **124**. Typically, axial fans provided within outdoor heat exchanger modules have sufficient airflow, while running in reverse, but other fan types can be utilized as well. If the fan **126** is a multi-speed or variable speed fan, then fan speed may be increased to reduce the condensate removal time. Further, if a multi-fan system is associated with the outdoor heat exchanger module **120**, the number of operating fans may be increased to shorten the blow-off time as well. It should be pointed out that fan reversed operation can be coincidental with refrigerant system compressor operation, so that hot refrigerant circulating throughout the refrigerant system assists in condensate removal through evaporation, or fan reversals can be executed and controlled independently.

[0029] Furthermore, to remove condensate from external surfaces of the heat exchangers **122** and **124**, during prolonged periods of shutdown in particular, fan system **126** can be turned on periodically, based on a timer or a sensor reading. Additionally, during normal operation, particularly at low ambient temperatures, a number of operational fans can be reduced (e.g. for a multi-fan system), or a speed of a variable speed fan can be reduced, to achieve lower airflow and higher temperature of the refrigerant circulating through the heat exchangers **122** and **124**, thus resulting in faster condensate evaporation and heat exchanger dryout.

[0030] FIG. **6**A shows an embodiment **129** intended to reduce the likelihood of rain water reaching the heat exchanger cores. Here, an upper deck **131** of the outdoor heat exchanger module **129** is generally solid. A fan orifice **133** receives a cap **134**. Heat exchangers **130** thus are exposed to sufficiently reduced amount of water, since the cap **134** tends to divert the rain water radially outwardly and away from the heat exchangers **130**. As shown in FIG. **6**B, the cap **134** may be generally conical but other shapes or configurations (e.g. pyramidal) are also acceptable. FIG. **6**C is a top view of the cap **134**. Furthermore, the cap **134** may be formed of a wire mesh, perforated plate or the like, with sufficient porosity not to impede airflow provided by a fan **136** and small cell size preventing water to drain through the cap **134**. On the other hand, the cap **134** may be made of solid material, and the airflow provided by the fan **136** will escape through the gap between the cap **134** and the upper deck **131**.

[0031] The refrigerant systems that utilize this invention can be used in many different applications, including, but not limited to, air conditioning systems, heat pump systems, marine container units, refrigeration truck-trailer units, and supermarket refrigeration systems. Also, although the invention is described in reference to microchannel heat exchangers and outdoor applications, such as condensers and gas coolers, it can be applicable to other heat exchanger types, such as round tube and plate fin heat exchangers, and indoor applications, such as reheat heat exchangers and evaporators. Furthermore, although the invention is described in reference to slanted heat exchanger configuration with horizontal tube orientation, it can be applied to vertical arrangements with either vertical or horizontal tube orientation.

[0032] 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:

a heat exchanger core including at least one heat exchange tube bank with heat exchange tubes in the at least one heat exchange tube bank having a plurality of internal parallel flow channels; and

a means to reduce condensate retention within the heat exchanger core.

2. The heat exchanger as set forth in claim **1**, wherein said means to reduce condensate retention within the heat exchanger core include routing of the refrigerant flowing inside said heat exchange tubes.

3. The heat exchanger as set forth in claim **2**, wherein there are a plurality of said heat exchange tube banks, and refrigerant flows in opposed parallel directions through said plurality of heat exchange tube banks from an inlet manifold, into an intermediate manifold, and from said intermediate manifold to an outlet manifold, said inlet manifold fluidly connected to a first heat exchange tube bank, with both said inlet manifold and said first heat exchange tube bank being located in a bottom section of the heat exchanger to provide a higher temperature refrigerant to the bottom section of the heat exchanger.

4. The heat exchanger as set forth in claim **3**, wherein there are more than two of said heat exchange tube banks, with said first heat exchange tube bank being a vertically lowermost of said heat exchange tube banks, and one of intermediate heat exchange tube banks being a vertically uppermost of said heat exchange tube banks.

5. The heat exchanger as set forth in claim **3**, wherein there are more than two of said heat exchange tube banks, with said heat exchange tube banks being arranged in a vertically intertwined configuration.

6. The heat exchanger as set forth in claim **5**, wherein at least one branch pipe routes refrigerant from one of said heat exchange tube banks to another of said heat exchange tube banks.

7. The heat exchanger as set forth in claim **3**, wherein a flow control device for selectively tapping at least a portion of higher temperature refrigerant from an upstream location to a downstream location to provide additional heating at the downstream location is included.

8. The heat exchanger as set forth in claim **7**, wherein said downstream location is in an intermediate manifold.

9. The heat exchanger as set forth in claim **8**, wherein said intermediate manifold communicates with a vertically lowermost one of said plurality of heat exchange tube banks.

10. The heat exchanger as set forth in claim **1**, wherein there is at least one fan associated with the heat exchanger, said at least one fan being operable to move air over said at least one heat exchange tube bank to absorb heat from refrigerant flowing inside said heat exchange tubes, said at least one fan being selectively operable in a reverse direction to move air over said at least one heat exchange tube bank to remove moisture accumulated on external heat exchanger surfaces.

11. The heat exchanger as set forth in claim **1**, wherein there is at least one fan associated with the heat exchanger, said at least one fan being operable to move air over said at least one heat exchange tube bank to absorb heat from refrigerant flowing inside said heat exchange tubes, said at least one fan is a variable speed fan and said variable speed fan is selectively and periodically operated at a reduced speed to increase temperature of refrigerant flowing through at least one heat exchange tube bank to remove moisture accumulated on external heat exchanger surfaces.

12. The heat exchanger as set forth in claim **1**, wherein there is at least one fan associated with the heat exchanger, said at least one fan being operable to pull air over said at least one heat exchange tube bank to absorb heat from refrigerant flowing inside said heat exchange tubes, said at least one fan to be periodically turned on during prolonged shutdown periods to move air over said at least one heat exchange tube bank to remove moisture accumulated on external heat exchanger surfaces.

13. The heat exchanger as set forth in claim **1**, wherein there are at least two fans associated with the heat exchanger, said at least two fans being operable to move air over said at least one heat exchange tube bank to absorb heat from refrigerant flowing inside said heat exchange tubes, and at least one fan of said at least two fans to be selectively and periodically turned off to increase temperature of refrigerant flowing through at least one heat exchange tube bank to remove moisture accumulated on external heat exchanger surfaces.

14. The heat exchanger as set forth in claim **1**, wherein there is a frame structure associated with the heat exchanger, said frame structure including a generally solid upper deck and a fan mounted to said frame structure and moving air over said at least one heat exchange tube bank through a fan orifice, and a cover for blocking moisture from entering said fan orifice.

15. The heat exchanger as set forth in claim **14**, wherein said cover includes a wire mesh material.

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