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Graham et al.

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(54) **HEAT AND MASS EXCHANGER FIN INSERTS**

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F28F 1/20 (2006.01)

(52) **U.S. Cl.**
CPC ***F28F 13/06*** (2013.01); ***F28F 1/20*** (2013.01); *F28F 2215/12* (2013.01); *F28F 2255/12* (2013.01)

(58) **Field of Classification Search**
CPC F28D 3/02; F28D 3/04; F28F 2215/12; F28F 3/025; F28F 13/06; F28F 2240/00
See application file for complete search history.

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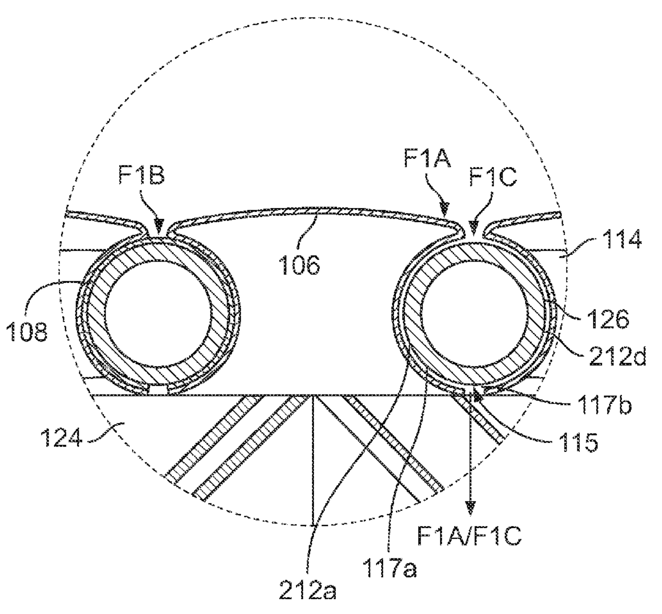
(74) *Attorney, Agent, or Firm* — DUANE MORRIS LLP; Gregory M. Lefkowitz; Joaquin Hernandez

(57) **ABSTRACT**

The disclosure relates to fin inserts for heat and mass exchangers and corresponding methods. For instance, in some examples, a fin insert to a heat and mass exchanger includes a generally rigid, longitudinally-extending member that includes a top portion and side portions. The side portions may be disposed on opposite sides of the top portion, and may include a concave shape facing away from one another. The side portions may further are each be positioned around a portion of a respective heat transfer tube.

20 Claims, 7 Drawing Sheets



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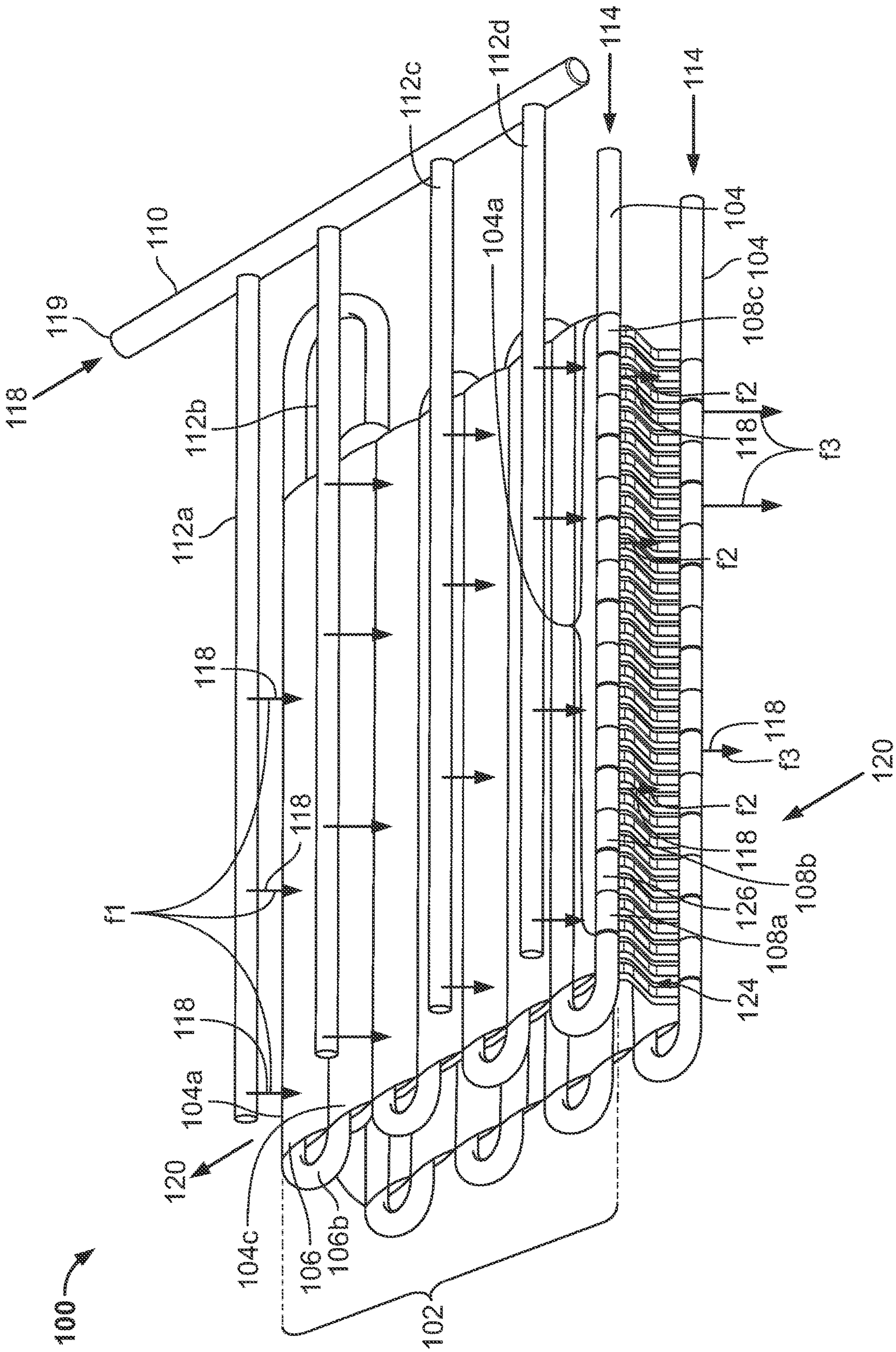
100
102
104
104a
104c
106
106b
108a
108b
108c
110
112a
112b
112c
112d
114
118
119
120
124
126
f1
f2
f3

FIG. 1

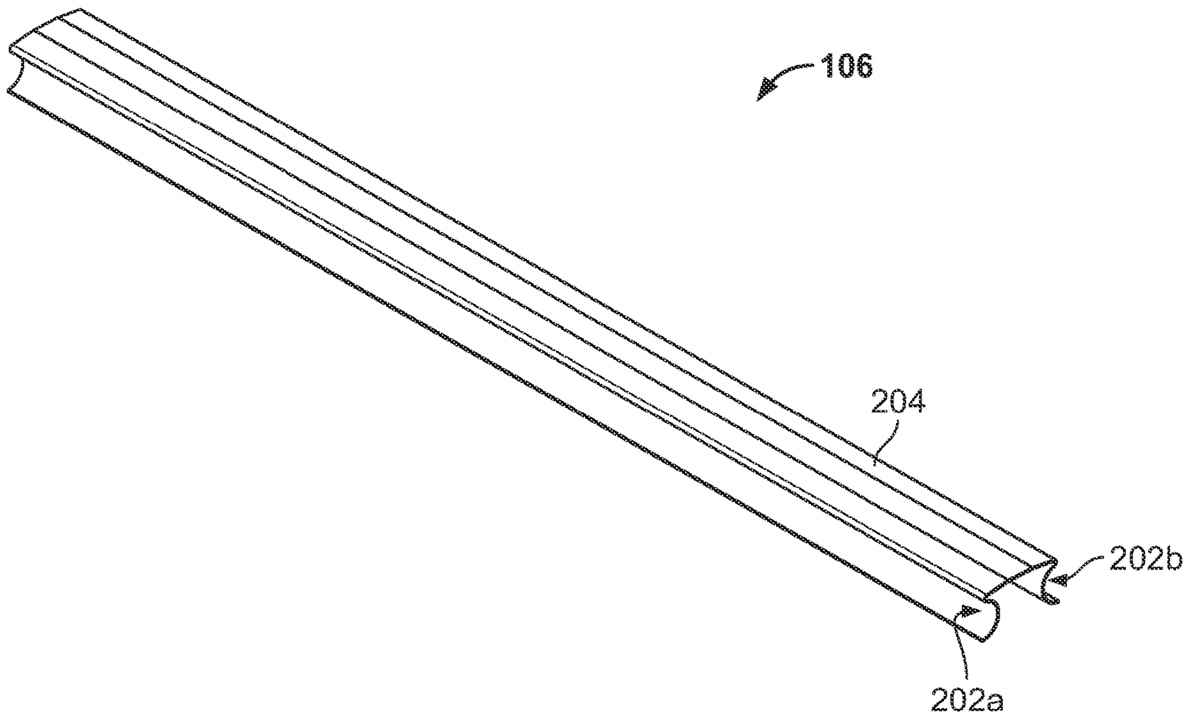
106
204
202b
202a

FIG. 2A

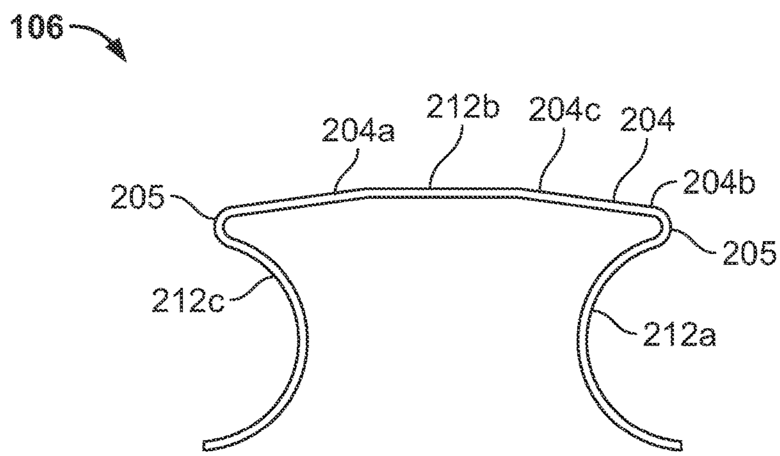
106
204a
212b
204c
204
204b
205
205
212c
212a

FIG. 2B

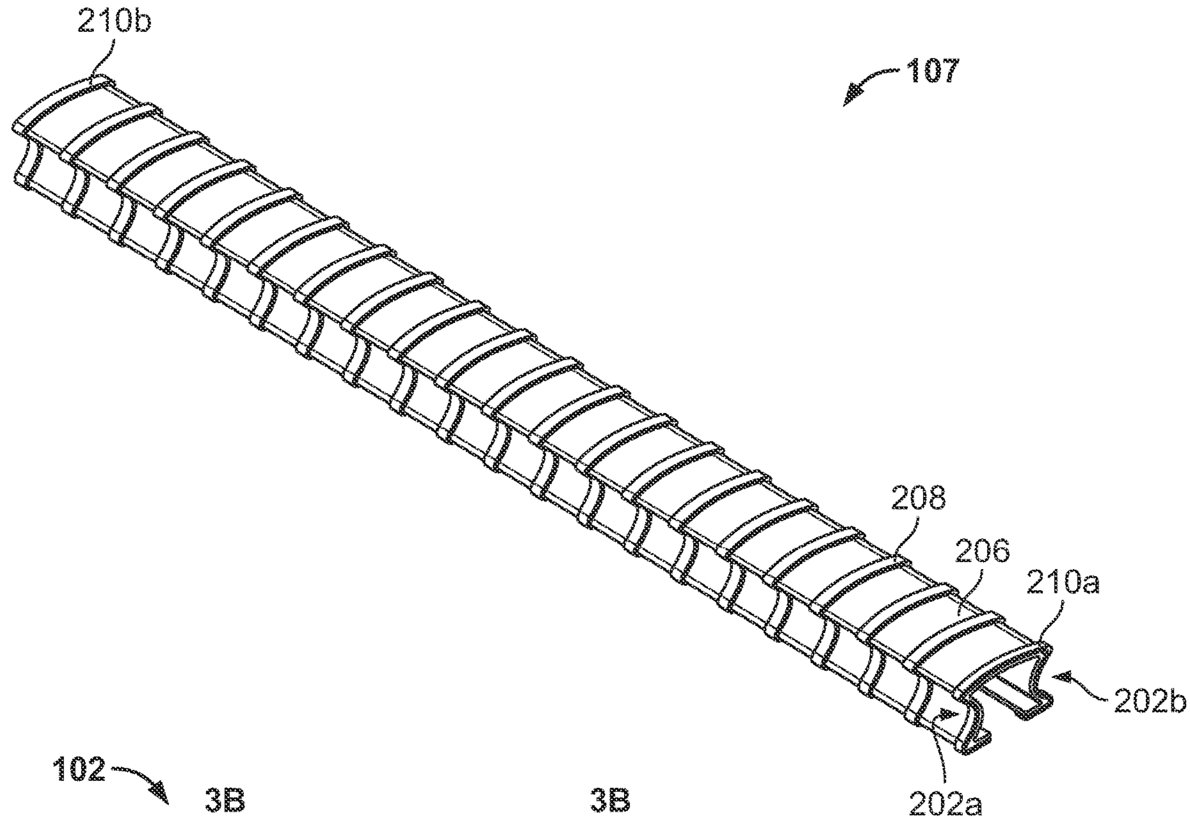

FIG. 2C

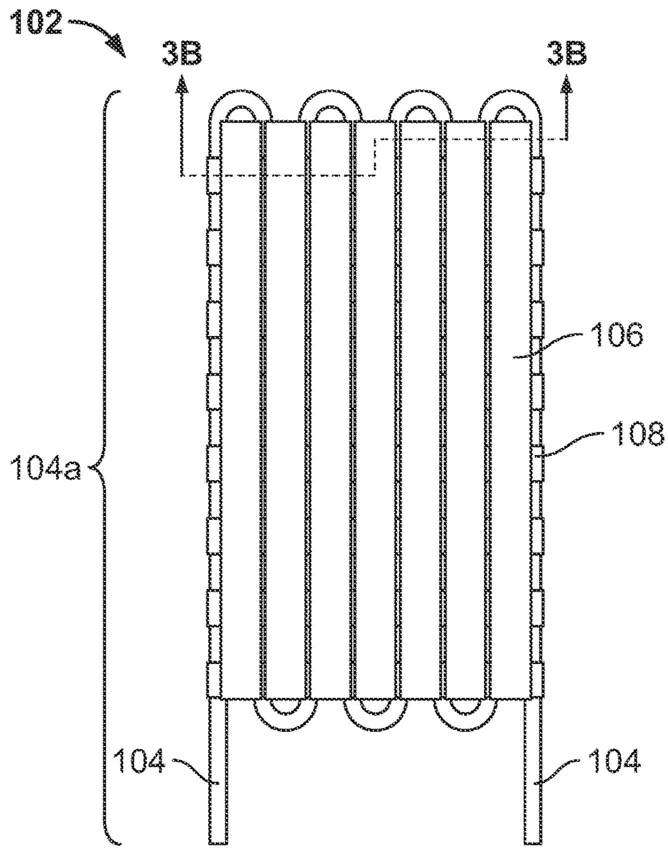

FIG. 3A

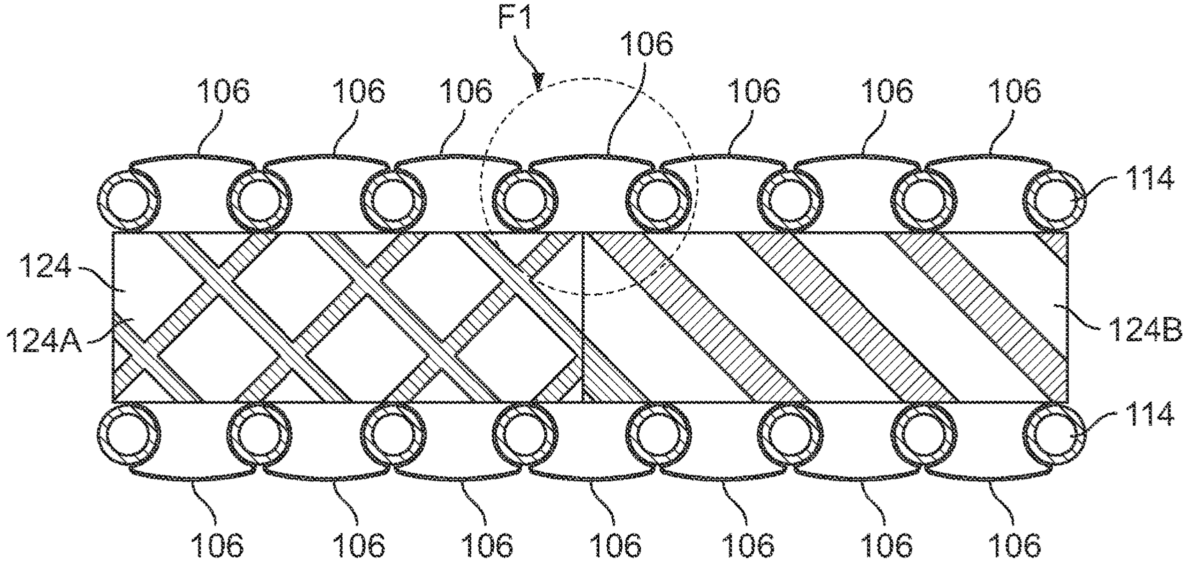
F1
106
106
106
106
106
106
106
106
114
124
124A
124B
114
106
106
106
106
106
106
106

FIG. 3B

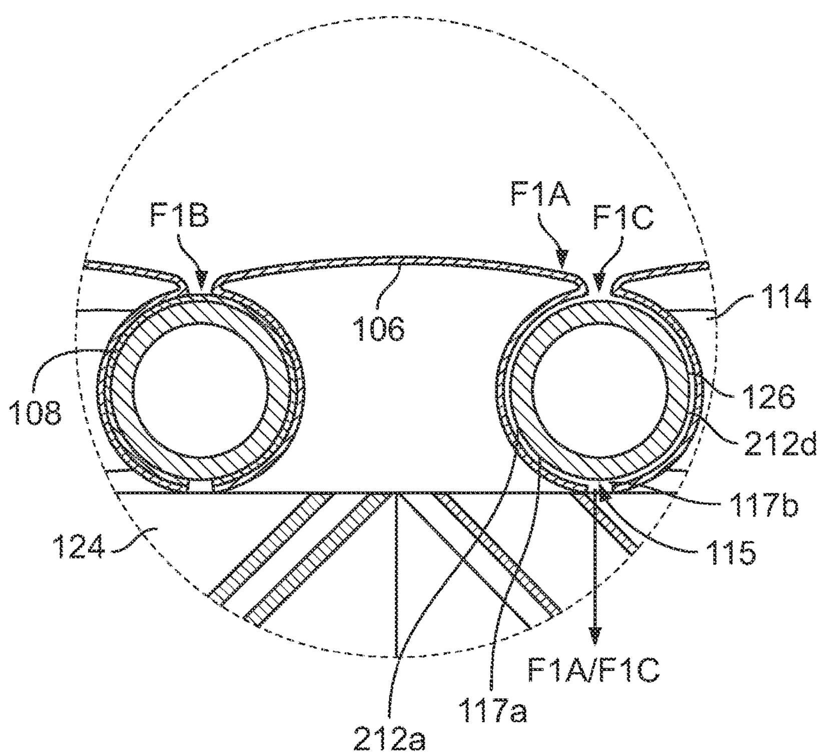
F1B
F1A
F1C
114
106
108
126
212d
117b
124
115
F1A/F1C
117a
212a

FIG. 3C

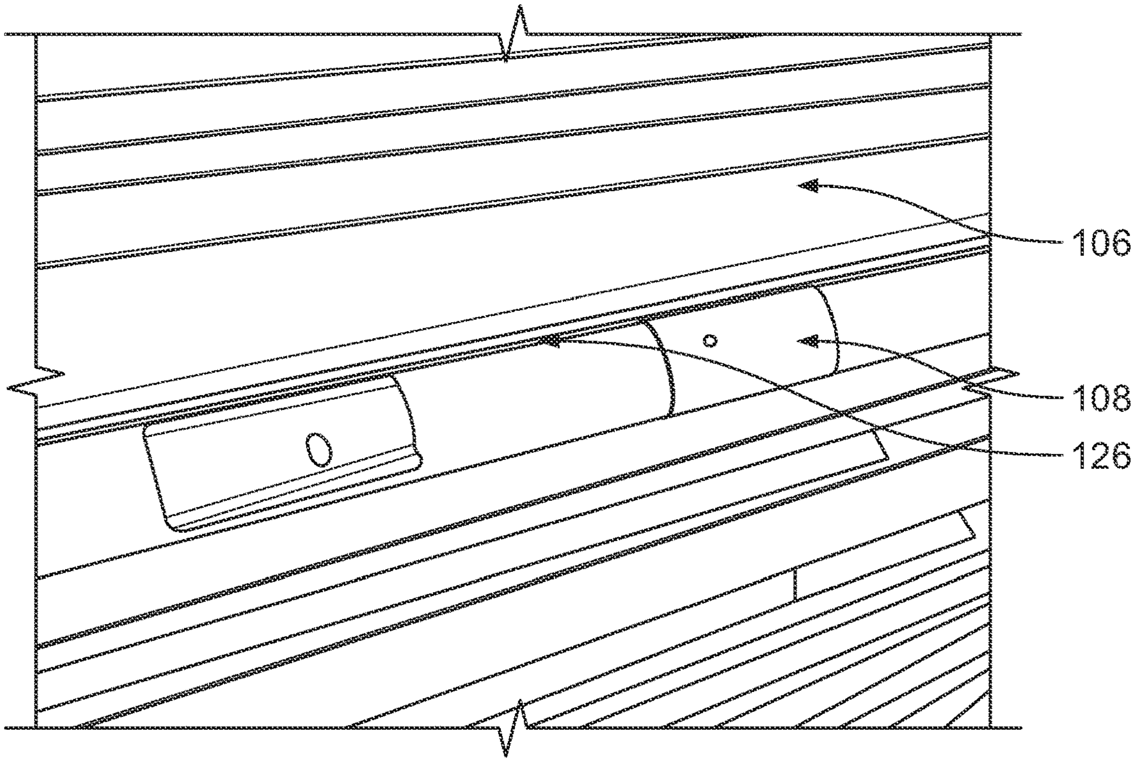

FIG. 3D

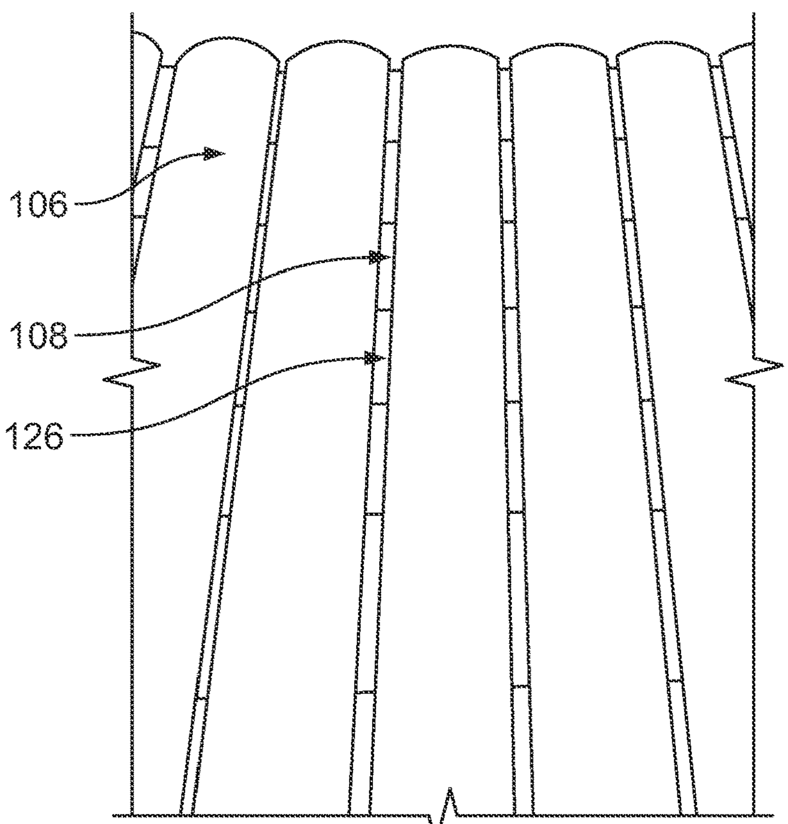

FIG. 3E

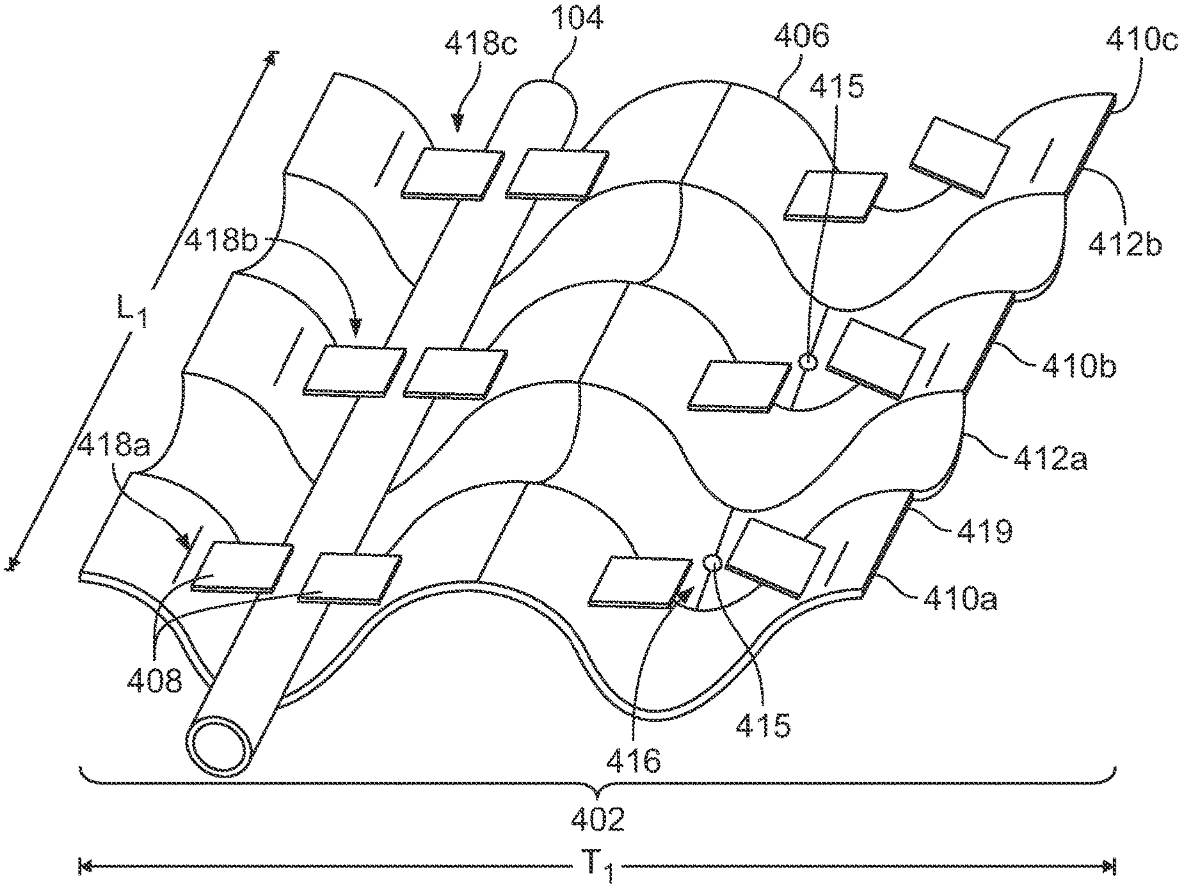
104
418c
406
415
410c
412b
418b
L1
410b
418a
412a
419
410a
408
415
416
402
T1

FIG. 4A

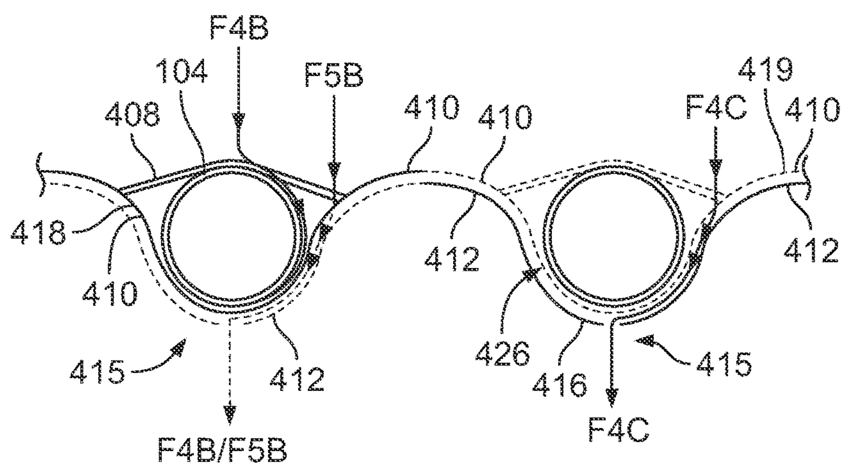
F4B
104
F5B
408
410
410
419
F4C
410
418
410
412
412
415
412
426
416
415
F4B/F5B
F4C

FIG. 4B

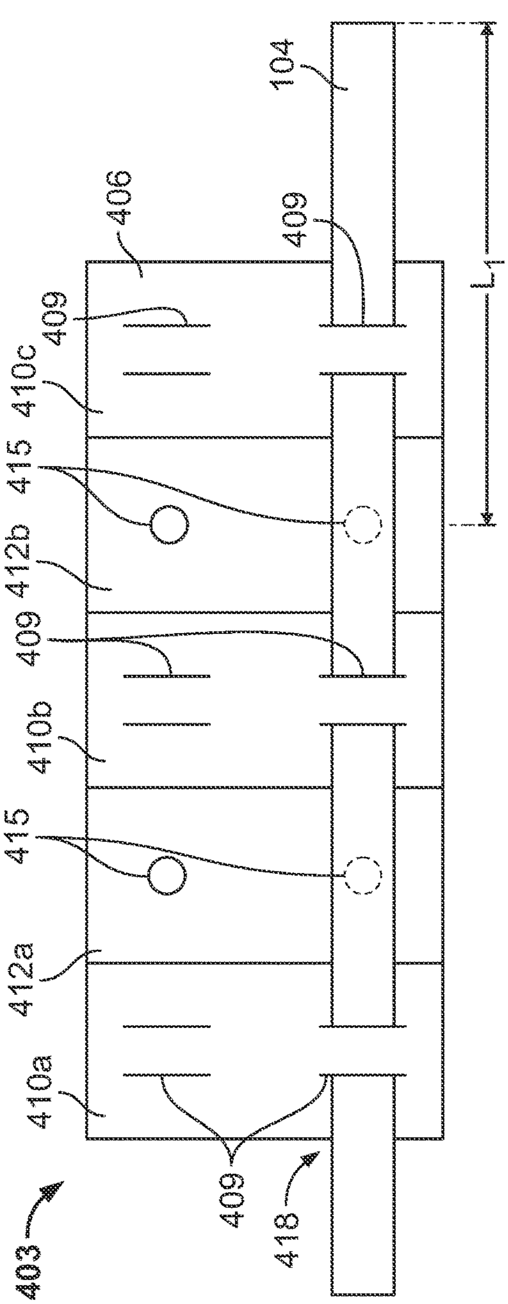

FIG. 4C

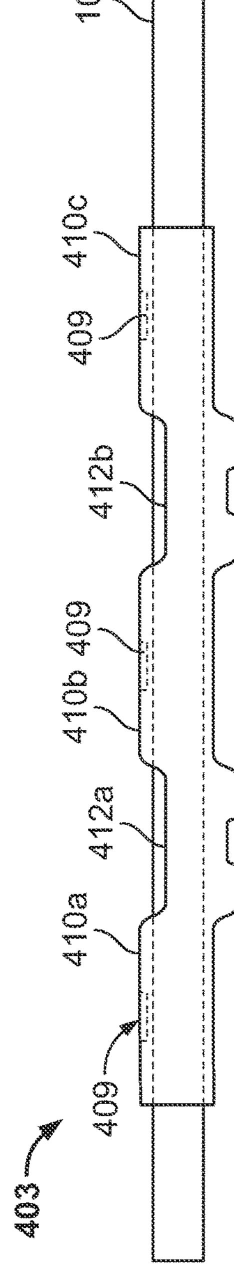

FIG. 4D

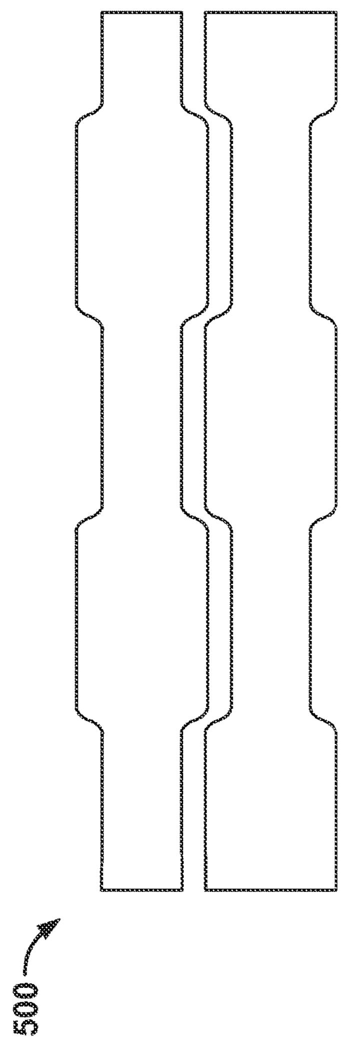

FIG. 5

HEAT AND MASS EXCHANGER FIN INSERTS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Patent Application No. 63/197,053, filed Jun. 4, 2021, and entitled "HEAT AND MASS EXCHANGER FIN INSERTS," which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

The disclosure relates generally to heat and mass exchangers, and more particularly, to fin inserts for heat and mass exchangers.

BACKGROUND

Heating ventilation and cooling (HVAC) systems generally cool ambient or room temperature air using a vapor compression refrigeration cycle. Less frequently, HVAC systems will include a liquid desiccant to dehumidify the air during the cooling process. In such liquid desiccant systems, many different approaches have been employed for dehumidification, cooling, as well as, for regeneration of the liquid desiccant.

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings are illustrative of particular embodiments of the present disclosure and therefore do not limit the scope of the present disclosure. The drawings are not to scale and are intended for use in conjunction with the explanations in the following detailed description.

FIG. **1** illustrates an example heat and mass exchanger.

FIG. **2**A illustrates a perspective view of an example fin insert.

FIG. **2**B illustrates a sectional view of the fin insert of FIG. **2**A.

FIG. **2**C illustrates a perspective view of another example fin insert.

FIG. **3**A illustrates a top view of an example heat transfer assembly depicted in FIG. **1**.

FIG. **3**B illustrates a cross-sectional view of the heat transfer assembly depicted in FIG. **3**A.

FIG. **3**C illustrates an enlarged view of detail B highlighted in the cross-sectional view of the heat transfer assembly depicted in FIG. **3**B.

FIG. **3**D is a side perspective view of the fin insert and heat transfer tube depicted in FIG. **3**A.

FIG. **3**E is another top view of the fin insert and heat transfer tube depicted in FIG. **3**A.

FIG. **4**A illustrates a perspective view of another example heat transfer assembly.

FIG. **4**B illustrates a cross-sectional view of the example heat transfer assembly of FIG. **4**A.

FIG. **4**C illustrates a top view of another example heat transfer assembly.

FIG. **4**D illustrates a side view of the example heat transfer assembly of FIG. **4**C.

FIG. **5** illustrates a side view of example beading rollers.

DETAILED DESCRIPTION

The following discussion omits or only briefly describes conventional features of heat and mass exchangers that are apparent to those skilled in the art. It is noted that various embodiments are described in detail with reference to the drawings, in which like reference numerals represent like parts and assemblies throughout the several views. Reference to various embodiments does not limit the scope of the claims attached hereto. Additionally, any examples set forth in this specification are intended to be non-limiting and merely set forth some of the many possible embodiments for the appended claims. Further, particular features described herein can be used in combination with other described features in each of the various possible combinations and permutations.

Unless otherwise specifically defined herein, all terms are to be given their broadest reasonable interpretation including meanings implied from the specification as well as meanings understood by those skilled in the art and/or as defined in dictionaries, treatises, etc. It must also be noted that, as used in the specification and the appended claims, the singular forms "a," "an" and "the" include plural referents unless otherwise specified, and that the terms "includes" and/or "including," when used in this specification, specify the presence of stated features, elements, and/or components, but do not preclude the presence or addition of one or more other features, steps, operations, elements, components, and/or groups thereof. In the description, relative terms such as "horizontal," "vertical," "up," "down," "top," and "bottom" as well as derivatives thereof (e.g., "horizontally," "downwardly," "upwardly," etc.) should be construed to refer to the orientation as then described or as shown in the drawing figure under discussion. These relative terms are for convenience of description and normally are not intended to require a particular orientation. Terms including "inwardly" versus "outwardly," "longitudinal" versus "lateral" and the like are to be interpreted relative to one another or relative to an axis of elongation, or an axis or center of rotation, as appropriate. Terms concerning attachments, coupling and the like, such as "connected" and "interconnected," refer to a relationship wherein structures are secured or attached to one another either directly or indirectly through intervening structures, as well as both movable or rigid attachments or relationships, unless expressly described otherwise. The term "operatively or operably connected" is such an attachment, coupling or connection that allows the pertinent structures to operate as intended by virtue of that relationship.

Embodiments of the present disclosure relate generally to heat and mass exchangers, and more particularly, to fin inserts for heat and mass exchangers. Embodiments of the heat and mass exchanger, as well as the fin inserts, are described below with reference to FIGS. **1**-**5**.

FIG. **1** illustrates an example heat and mass exchanger **100** (hereinafter "HMX **100**"). In one or more cases, HMX **100** facilitates heat and mass transfer between at least two fluids. For example, HMX **100** may transfer water vapor (i.e., a mass) between liquid desiccant and process air stream (i.e., fluids) and regulate heat exchange between the fluids. As described herein, the HMX **100** is configured as, for example, a regenerator. However, it should be understood that the HMX **100** may be configured as a conditioner utilizing one or more of the embodiments discussed herein.

In one or more cases, HMX **100** includes one or more heat transfer assemblies **102** and a distribution manifold **110**. For the cases in which the HMX **100** is configured to dehumidify, the HMX **100** includes wicking media **124** disposed between adjacent heat transfer assemblies **102**. Wicking media **124** may be, for example, a three dimensional product that has different cross sections depending on where its cut, such as CELdek® evaporative cooling media. For cases in which one heat transfer assembly **102** is utilized, wicking media **124** is disposed on a side of the heat transfer assembly **102** opposite the liquid desiccant receiving side of the heat transfer assembly **102**. For the cases in which the HMX **100** is configured to humidify, such as the HMX **100** illustrated in FIG. **1**, the HMX **100** includes wicking media **124** disposed between adjacent heat transfer assemblies **102**. Although the HMX **100** is described herein as including wicking media **124** for cases in which the HMX **100** is configured to dehumidify or humidify, it should be understood that in some cases, the wicking media **124** may not be included in the HMX **100**.

The distribution manifold **110** may be a tubular member configured to pass a fluid from a receiving end of the distribution manifold **110** through one or more outlets located on distribution tubes **112** of the distribution manifold **110**. For example, the distribution manifold **110** may deliver liquid desiccant **118** to distribution tubes, such as distribution tubes **112***a*, **112***b*, **112***c*, **112***d*, which then release the liquid desiccant **118** through outlets in the distribution tubes and over the heat transfer assembly **102**. In some cases, the liquid desiccant **118** falls, via gravity, directly onto a surface of the heat transfer assembly **102**, for example, an outer surface of a fin insert **106**. In other cases, wicking media **124** may be disposed between the outlets **112** of the distribution manifold **110** and a side of the heat transfer assembly **102** facing the outlets **112**. In such cases, the liquid desiccant **118** falls onto and passes through the wicking media **124** before passing through the heat transfer assembly **102**. In some cases, the distribution manifold **110** receives the liquid desiccant **118** from a reservoir (not shown) configured to store the liquid desiccant **118**. The distribution tubes **112** may extend perpendicularly outwards from the distribution manifold **110** and over an area of the heat transfer assembly **102**. It should be noted that any number of distribution tubes **112** and outlets may be used to distribute a fluid over the heat transfer assembly **102**. Further, although the distribution tubes **112** are illustrated as linearly extending over the heat transfer assembly **102**, the distribution tubes **112** may be configured in other shapes, for example, but not limited to, a "S" shape, to facilitate the distribution of the liquid over the heat transfer assembly **102**.

The heat transfer assembly **102** includes a heat transfer tube **104** configured to pass a heat exchange fluid **114** therein and a fin insert **106** disposed between two sections of the heat transfer tube **104**, which may be parallel to one another. The heat exchange fluid **114** may be, for example, but not limited to, water, a water and glycol mixture, another refrigerant, and other like heat exchange fluids. In some cases, the heat transfer assembly **102** includes a plurality of spacers **108**, such as spacers **108***a*, **108***b*, **108***c*, coupled to a section of the heat transfer tube **104**, as shown in FIG. **1**. In other cases, the spacers **108** may be integrated into the fin insert **106** as a ridge **208** protruding from an outer surface of the fin insert **106**, such as the fin insert **206** in FIG. **2**C. In either case, the spacers **108** may be periodically disposed along the section of the heat transfer tube **104**, and in between the heat transfer tube **104** and the fin insert **106**. The spacer **108** is formed to create and/or maintain a gap **126** between the heat transfer tube **104** and the fin insert **106** to allow a fluid, such as liquid desiccant **118**, to pass from one side of the heat transfer assembly **102** to an opposite side of the heat transfer assembly **102**. In one or more cases, the gap **126** may range from 1 thousandth of an inch to 100 thousandths of an inch, and more preferably, may range from 5 thousandths of an inch to 25 thousandths of an inch. In one or more cases, the thickness of the spacers **108** may be uniform to create the same size gaps **126** between the heat transfer tube **104** and the fin insert **106** of the HMX **100**. In one or more other cases, to vary the flow rate or distribution of the liquid desiccant **118** between heat transfer assemblies **102**, the spacers **108** of one heat transfer assembly **102** may be thicker or thinner than the spacers **108** of another heat transfer assembly **102**, such as, but not limited to an adjacent heat transfer assembly **102**. In one or more cases, the length of the spacers **108** may be uniform. In some other cases, a ratio of total spacer length to the length of the fin insert **106** can be less than 0.5:1, or less than 0.4:1, or less than 0.25:1. This means that the total length of a fin insert **106** with a gap **126** for liquid flow is greater than 50%, or greater than 60%, or greater than 70% of the length of the fin insert **106**.

In some cases, the heat transfer tube **104** is one continuous tubular member formed in an array of longitudinal sections, such as sections **104***a* and **104***c*, spaced apart from one another via a curved section, such as curved section **104***b*. The longitudinal sections can be arranged parallel to one another. The longitudinal sections and curved sections may form an "S" like repeating pattern. In some cases, such as that shown in FIG. **1**, the heat transfer tube **104** of one heat transfer assembly **102** may connect to the heat transfer tube **104** of another heat transfer assembly **102**, such that the heat exchange fluid **114** may pass from one heat transfer assembly to another heat transfer assembly **102**. It is noted that the heat transfer tube **104** is shown in a cylindrical shape; however, it should be understood that the heat transfer tube **104** may be formed in any other shape that can pass the heat exchange fluid **114** therein. Further, although the heat transfer tube **104** is illustrated as having eight longitudinal sections and seven curved sections, it should be understood that the heat transfer tube **104** can have any number of longitudinal sections and curved sections.

The liquid desiccant **118** may flow through the distribution manifold **110** to the outlets of the distribution tubes **112**. The liquid desiccant **118** may travel downwards in a direction F**1** towards a first heat transfer assembly **102** and contact an outer surface of the heat transfer assembly **102**, for example, a fin insert **106**. The liquid desiccant **118** may travel from the fin insert **106** into a gap **126** formed by a portion of the fin insert **106** and a heat transfer tube **104**. As the liquid desiccant **118** travels through the gap **126**, the liquid desiccant contacts a portion of the heat transfer tube **104** and is cooled as the liquid desiccant flows along the gap **126**. The liquid desiccant **118** may pass through the first heat transfer assembly **102** to either a wicking media or to a subsequent heat transfer assembly **102**, as shown in a direction F**2**. A process air stream **120** passes from one side of the heat transfer assemblies **102** to another side of the heat transfer assemblies **102**. For example, the process air stream **120** may pass through an area, for example, between two heat transfer assemblies **102**, in which the liquid desiccant **118** has been cooled. As the process air stream **120** passes through the area, the process air stream **120** may contact the cooled liquid desiccant **118**, which absorbs the heat and water vapor from the process air stream **120**. The process air stream **120** may exit the HMX **100** with lower water content. It is noted that FIG. **1** illustrates the process air stream **120** passing horizontally across the heat transfer assemblies **102**, but it should be understood that the process air stream **120** may pass across the heat transfer assemblies **102** in any direction or any combinations of directions, such as vertically and/or diagonally. The liquid desiccant **118** may travel to the next heat transfer assembly **102**, and pass through the gap **126** of the next heat transfer assembly **102**. The liquid desiccant **118** is again cooled by the heat transfer tubes **104**, and absorbs heat and water vapor from the air process stream **120** as the liquid desiccant **118** falls downward. This process of cooling the liquid desiccant **118** and absorbing the heat and water vapor from the process air streams **120** continues through each heat transfer assembly **102** of the HMX **100**. Upon passing through the last of the heat transfer assemblies **102** and the liquid desiccant **118** reaching the bottom of the HMX **100**, via passing through gaps **126** in the last of the heat transfer assemblies **102** or the wicking media **124**, the liquid desiccant **118** is collected and delivered to the regenerator to be recharged.

FIG. **2**A illustrates a perspective view of the fin insert **106**. FIG. **2**B illustrates a sectional view of the fin insert **106**. In one or more cases, the fin insert **106** is configured to fit in between two longitudinal sections **104***a* of two adjacent heat transfer tubes **104**. The adjacent heat transfer tubes **104** can be parallel or essentially parallel. The fin insert **106** may be a generally rigid, longitudinally-extending member that includes a top wall **212***b* and side walls **212***a*, **212***c* disposed on opposite edges of the top wall **212***b*. The top wall **212***b* can have a generally peaked or convex shape, while the side walls **212***a*, **212***c* can be concave. In one or more cases, the fin insert **106** is made of a material having high thermal conductivity, for example, but not limited to, copper, steel, aluminum, titanium, platinum, and other like metals and alloys. In one or more other cases, the fin insert **106** is made of plastic or other like material having thermal conductivity properties. In one or more cases, the fin insert **106** extends from one end of the heat transfer assembly **102** to another end of the heat transfer assembly **102**. For example, a fin insert **106** may extend from an end of a longitudinal section **104***a* of a heat transfer tube **104** to an opposite end of the longitudinal section **104***a* of the heat transfer tube **104**.

In some cases, at least a portion of an outer surface **204** of the top wall **212***b* may be curved or angled (peaked or convex) such that the liquid desiccant **118** that contacts the outer surface **204** of the fin insert **106** is directed to flow towards one of the side walls **212***a*, **212***c*, which form a gap **126**, as described above. For example, as illustrated in FIG. **2**B, the top wall **212***b* may include a planar outer surface portion **204***c* disposed in between curved outer portions **204***a* and **204***b*. The curved outer portions **204***a* and **204***b* may be angled or curved downwards, such that liquid desiccant **118** flows onto side walls **212***a* and **212***c*. In another example, the outer surface **204** of the top wall **212***b* may be uniformly curved (e.g., convex) across the entire outer surface **204**. In one or more cases, the outer surface **204** of the fin insert **106** may be modified to enhance the heat transfer properties of the fin insert **106**. For example, the outer surface **204** may be knurled, stamped, coated in a thermally conductive material, or treated by another process that enhances the heat transfer properties of the fin insert **106**.

In one or more cases, a transition section **205** may be disposed between an edge of the top wall **212***b* and a proximal edge of a side wall, such as side wall **212***a*. The transition section **205** may be formed in any shape, for example, in a curved shape, to guide the liquid desiccant **118** into the gap **126**. In one or more cases, the side walls **212***a*, **212***b* are each formed to fit around a portion of a respective heat transfer tube **104**. For example, the side walls **212***a*, **212***b* may have a curved shape (e.g., concave) sized to receive a portion of the heat transfer tube **104**. Although the side walls **212***a*, **212***b* are illustrated as having a curved shape, it should be noted that the side walls **212***a*, **212***b*, may be formed in other shapes, such as oblong, hexagonal, and the like. In one or more cases, the side walls **212***a*, **212***b* are each formed to receive a spacer **108** therein. As described herein, one or more spacers **108** may be positioned along the longitudinal section of a heat transfer tube **104**. The spacer **108** may be secured to the heat transfer tube **104**, such that the spacer **108** does not move along the heat transfer tube **104**. A portion of the side wall, such as side wall **212***a*, may rest on the spacer **108**, thereby spacing another portion of the side wall, not in contact with the spacer **108**, away from the outer surface of the heat transfer tube **104**. By using the one or more spacers **108** to space the side wall of the insert fin **106** away from the heat transfer tube **104**, one or more gaps **126** are formed between the side wall and the heat transfer tube **104** in the areas that do not include the spacers **108**. In one or more cases, two spacers **108** may be positioned on the longitudinal section of the heat transfer tube **104**, such that each spacer **108** is positioned on opposite ends of the fin insert **106**. The end spacers **108** may be configured to direct the liquid desiccant **118** to flow away from the ends of the fin insert **106** and towards the gap **126**.

In one or more cases, the one or more spacers **108** may be integrated as ribs **208** into the fin insert, such as the fin insert **107** illustrated in FIG. **2**C, to form a unitary body. The ribs **208** may protrude from the outer surface **206** of the fin insert **107**, and may be periodically formed or placed along the length of the fin insert **107**. The ribs **208** may be formed in a same or similar shape as the outer surface **206** of the fin insert **107**. In one or more cases, the fin insert **107** includes end ribs **210***a*, **210***b* positioned on opposite ends of the fin insert **107**. The end ribs **210***a*, **210***b* may be configured to guide the liquid desiccant **118** towards the gap **126** and prevent the liquid desiccant **118** from falling over an end of the fin insert **107**. It is noted that, with the exception of the integrated ribs **208**, fin insert **107** includes one or more of the same or similar features of fin insert **106**, and as such, a description of those features is not repeated.

FIG. **3**A illustrates a top view of the heat transfer assembly **102**. FIG. **3**B illustrates a cross-sectional view of the heat transfer assembly **102** of FIG. **3**A taken along cut-line **3**B-**3**B. FIG. **3**C illustrates an enlarged view of detail **F1** highlighted in the cross-sectional view of the heat transfer assembly **102** depicted in FIG. **3**B. FIG. **3**D is a side perspective view of the heat transfer assembly **102**. FIG. **3**E is another top view of the heat transfer assembly **102**.

In one or more cases, the spacers **108** may be spaced along the heat transfer tubes **104** to separate and create one or more gaps **126** between the fin inserts **106** and the heat transfer tubes **104**. In some cases, the spacers **108** of one heat transfer assembly **102** may be positioned over the spacers **108** of the adjacent heat transfer assembly **102**, such that the spacers **108** of each heat transfer assembly **102** are vertically aligned with one another. In other cases, the spacers **108** of one heat transfer assembly **102** may be respectively positioned in an area between the spacers **108** of the adjacent heat transfer assembly **102**. For example, the spacers **108** of the one heat transfer assembly **108** may be positioned over the gaps **126** of the adjacent heat transfer assembly **102**.

As discussed herein, the spacers **108** block or partially block the flow of liquid desiccant **118** from passing from one side of the heat transfer assembly **102** to the other side of the heat transfer assembly. For example, as illustrated in FIG. **3**C, the spacer **108** blocks the flow direction F1B of liquid desiccant **118**, preventing the liquid desiccant **118** from flowing to the opposite side of the heat transfer assembly **102** in the area of the spacer **108**. The HMX **100** may include vertical walls positioned on the ends of the longitudinal sections of the heat transfer tubes **104**, and other vertical walls positioned on the outside of each of the outer heat transfer tubes **104**. The HMX **100** may use the vertical walls to encase the HMX **100**. In one or more cases, spacers **108** may be positioned on the ends of the longitudinal section of the heat transfer tubes **104** that are adjacent to the vertical walls. The spacers **108** positioned on the ends of the heat transfer tubes **104** may be used to prevent liquid desiccant **118** from flowing downward along an inner facing surface of the vertical wall.

The gap **126**, created by the spacers **108**, allows the liquid desiccant **118** to flow from one side of the heat transfer assembly **102** to the other side of the heat transfer assembly. For example, as illustrated in FIG. **3**C, the liquid desiccant **118** that contacts the outer surface of the fin insert **106** may flow in direction F**1**A from the outer surface of the fin insert **106** and into the gap **126**. In another example, the liquid desiccant **118** may flow in direction F**1**C directly into the gap **126**. As the liquid desiccant **118** flows through the gap **126**, the liquid desiccant **118** contacts the outer surface of the heat transfer tube **104**, which cools or heats the liquid desiccant **118**. That is, the gap **126** directs the liquid desiccant **118** to flow around the heat transfer tube **104**, ensuring optimal contact time of the liquid desiccant **118** with the heat transfer tube **104**. In one or more cases, the gap **126** enables optimization of the fluid flow pattern onto the heat transfer tubes **104**, by moving from an external slug flow to an internal sheet flow. In one or more cases, the cooled or heated liquid desiccant **118** may exit the gap **126** at the opening **115** and fall downwards to the wicking media **124** which, as illustrated, includes a first cross-section **124**A and a second cross-section **124**B. As the fin inserts **106** and gap **126** direct the flow of the liquid desiccant **118**, the HMX **100** may utilize standard wicking media inserts that do not have to be re-designed to distribute the liquid desiccate **118** onto the heat transfer tubes **104**. As such, the fin inserts **106** and gap **126** may prevent significant amounts of the desiccant **118** bypassing the heat transfer tubes **104**. In one or more other cases, the cooled or heated liquid desiccant **118** may exit the gap **126** at the opening **115** and fall downwards to the next heat transfer assembly **102**. The end **117***a* of the sidewall **212***a* of one fin insert **106** and the end **117***b* of the sidewall **212***d* of an adjacent fin insert **106** may form the opening **115** of the gap **126**. In some cases, the opening **115** may be positioned over a gap **126** in a lower adjacent heat transfer assembly **102**, such that the liquid desiccant **118** is directed to flow into the gap **126** of the lower adjacent heat transfer assembly **102**.

In one or more cases, the flow rate of the liquid desiccant **118** and distribution of the liquid desiccant **118** along the surface of a heat transfer tube **104** may be varied based on, for example, one or a combination of the thickness of the spacers **108**, the number or length of the spacers **108**, and the distance between two adjacent fin inserts **106**. For example, by increasing the thickness of the spacer **108**, the size of the gap **126** increases, thereby allowing more liquid desiccant **118** to flow through the heat transfer assembly **102**. In contrast, for example, by decreasing the thickness of the spacer **108**, the size of the gap **126** decreases, thereby reducing the flow rate of the liquid desiccant **118** but increasing the amount of liquid desiccant **118** that contacts the surface of the heat transfer tube **104**. In another example, by increasing the length or number of spacers **108** along the heat transfer tube **104**, the size and/or number of gaps **126** decreases, thereby reducing the flow of liquid desiccant **118**. In contrast, by decreasing the length or number of spacers **108** along the heat transfer tube **104**, the size and/or number of gaps **126** increases, thereby increasing the area for liquid desiccant **118** to pass from one side of the heat transfer assembly **102** to the other side of the heat transfer assembly **102**. Varying the flow rate of the liquid desiccant **118** and/or distribution of the liquid desiccant **118** may optimize the HMX **100**. For example, additional thermal contact between the heat transfer tubes **104** and the fin inserts **106** may increase the overall opportunity for heat transfer. In another example, increasing the flow of liquid desiccant **118** through a smaller gap **126** may encourage sheet flow of the desiccant through the gap **126**. In one or more cases, as discussed herein, the maximum total heat transfer to the flowing fluid, e.g., the liquid desiccant **118**, may be optimized based on the amount of contact between the fin insert **106** and the heat transfer tube **104** compared to the amount of space remaining for the fluid to flow through the gap **126**. In one or more cases, as discussed herein, the maximum temperature change to the flowing fluid, e.g., the liquid desiccant **118**, may be optimized based on the amount of contact between the fin insert **106** and the heat transfer tube **104** compared to the amount of space remaining for the fluid to flow through the gap **126**.

FIG. **4**A illustrates a perspective view of another heat transfer assembly **402**. FIG. **4**B illustrates a cross-sectional view of the example heat transfer assembly **402** of FIG. **4**A.

In one or more cases, the heat transfer assembly **402** includes a heat transfer sheet **406** configured to retain one or more heat transfer tubes **104**. The heat transfer sheet **406** may include at least one fluid flow channel, such as fluid flow channels **412***a*, **412***b*, in which the fluid flow channel is disposed between two heat transfer tube mounts, such as heat transfer tube mounts **410***a*, **410***b*, and **410***c*. The heat transfer sheet **406** is corrugated in a longitudinal direction L**1** of the heat transfer sheet **406** by a series of fluid flow channels **412***a*, **412***b* disposed between heat transfer tube mounts **410***a*, **410***b*, and **410***c*, as shown in FIG. **4**A. In one or more cases, in addition to being corrugated in the longitudinal direction of the heat transfer sheet **406**, the heat transfer sheet **406** is corrugated in a transverse direction Ti of the heat transfer sheet **406**, such that the heat transfer tube **104** may reside at least partially within the grooves of the heat transfer sheet **406** that extend in the longitudinal direction.

The fluid flow channel, such as fluid flow channel **412***a*, may be recessed from the adjacent surfaces of the heat transfer tube mounts, such as heat transfer tube mounts **410***a* and **410***b*. Fluid flow channels **412***a*, **412***b* may be formed in any shape, such as a U-shaped valley, that guides the liquid desiccant **118** in the transverse direction of the heat transfer sheet **406** towards a drain hole **415**. In one or more cases, the drain hole **415** may be located at the lowest point in the U-shaped valley of the fluid flow channel. The fluid flow channel **412***a* may include one or more drain holes **415**, in which each drain hole **415** is located at the bottom **416** of each U-shaped valley. In one or more cases, the drain hole **415** may be a cut out portion of the heat transfer sheet **406**. The drain hole **415** may be cut into a variety of shapes, such as, but not limited to, circular. In some cases, the portion of the heat transfer sheet **406** that surrounds the drain hole **415** may be extruded, such that the drain hole **415** forms a funnel-like shape.

In one or more cases, the heat transfer tube mounts **410** may have a curved outer surface **419** (e.g., but not limited to a convex shape), such that the liquid desiccant **118** is directed to flow towards and into an adjacent fluid flow channel. In some cases, the outer heat transfer tube mounts **410** (not shown), positioned on opposite ends of the heat transfer sheet **406**, may have a curved outer surface **419** (e.g., but not limited to a concave or arc shape), such that the liquid desiccant **118** is directed to flow towards an inner adjacent fluid flow channel, and is prevented from falling over an edge of the heat transfer sheet **406**.

The heat transfer tube mounts, such as heat transfer tube mounts **410***a*, **410***b*, and **410***c*, include a series of grooves, such as grooves **418***a*, **418***b*, and **418***c*, configured to receive at least a portion of the heat transfer tube **104**. The grooves **418***a*, **418***b*, **418***c* may be aligned with one another in the longitudinal direction L**1** of the heat transfer sheet **406**. The bottom of the groove **418** may be positioned above the bottom **416** of the fluid flow channel **412**. One or more of the grooves may include retention tabs **408** configured to secure the heat transfer tube **104** to the heat transfer sheet **406**. In one or more cases, before installation of the heat transfer tube **104**, the retention tabs **408** may be configured in an open position, in which the adjacent retention tabs **408** are bent away from one another such that the heat transfer tube **104** may be positioned on to a groove **418**. Having positioned the heat transfer tube **104** onto the groove **418**, the retention tabs **408** may be bent towards one another and over a portion of the heat transfer tube **104**, thereby securing the heat transfer tube **104** to the heat transfer sheet **406**.

In some cases, the retention tabs **408** may include the same material as the heat transfer sheet **406**. In one or more cases, the retention tabs **408** may be integrally formed with the heat transfer sheet **406**. For example, three sides of the retention tab **408** may be cut into the heat transfer sheet **406**, and the fourth side of the retention tab **408** may remain attached to the heat transfer sheet **406** and serve as a pivot point to bend the retention tab **408** upwards or downwards. In one or more other cases, the retention tabs **408** may be a separate piece of material that is attached on a proximal end of the retention tab **408** to the heat transfer sheet **406**, via adhesive, welding, bonding, fastening (e.g., via rivets, nuts and bolts, and the like), and other like attachment methods. In one or more cases, the retention tabs **408** may be used to ensure thermal contact with the heat transfer sheet **406**.

In one or more cases, a fluid, such as, but not limited to, liquid desiccant **118**, may fall onto the heat transfer assembly **402**, and various portions of the heat transfer assembly **402** that are in contact with the liquid desiccant **118** may heat or cool the liquid desiccant **118**, as the liquid desiccant **118** travels towards and through a drain hole **415** in the heat transfer sheet **406**. For example, liquid desiccant **118** that contacts the heat transfer tube **104** may flow in a direction F**4**B over the heat transfer tube **104** and the heat transfer tube mount **410** and into an adjacent fluid flow channel **412**. In another example, liquid desiccant **118** that contacts the heat transfer tube mount **410**, may flow in a direction F**5**B over the heat transfer tube mount **410** and into the adjacent fluid flow channel **412**. Having entered the fluid flow channel **412**, the fluid flow channel **412** guides the liquid desiccant **118** towards a corresponding drain hole **415**, and the liquid desiccant **118** may flow through the drain hole **415**, and falls downward onto a wicking media insert or heat transfer assembly **402**. In other examples, the liquid desiccant **118** may fall into fluid flow channel in a direction F**4**C, and flow towards a corresponding drain hole **415**.

In one or more cases, the heat transfer sheet **406** may be produced using conventional stamping methods or a combination of roll forming or beading and stamping operations. As an example, beading rollers, such as the beading rollers illustrated in FIG. **5**, may perform a beading operation on the heat transfer sheet **406** to form the fluid flow channels **412***a*, **412***b*. Subsequently, a stamping operation may be performed on the heat transfer sheet **406** to form the longitudinal grooves **418***a*, **418***b*, **418***c*. In one or more cases, the stamping operation may also simultaneously punch drain holes **415** and retention tabs **408** in the heat transfer sheet **406**. In one or more other cases, sheet or coil material may be formed into the heat transfer sheet **406** using one or more stamping operations.

FIG. **4**C illustrates a top view of another example heat transfer assembly **403**. FIG. **4**D illustrates a side view of the example heat transfer assembly **402** of FIG. **4**C. It is noted that the heat transfer assembly **403** includes one or more of the same or similar features (e.g., drawing elements having like-reference numbers illustrated in FIGS. **4**A-**4**D) as the heat transfer assembly **402**. As such, a redundant description of these features is not repeated.

In one or more cases, the heat transfer assembly **403** includes retention bridge lances **409**. The lance **409** may be a rigid member that protrudes from a surface of the heat transfer sheet **406**, forming a space between a bottom surface of the lance **409** and the surface of the heat transfer sheet **406**. In some cases, one lance **409** is formed on the heat transfer sheet **406**. In one or more other cases, a series of lances **409** are formed on the heat transfer sheet **406**, such that a spaces formed by each of the lances **409** forms a channel in the longitudinal direction L_1 of the heat transfer assembly **403**. A heat transfer tube **104** may pass under the lances **409**, i.e., through the channel. Having passed the heat transfer tube **104** through the channel, one or more of the lances **409** may be staked in a secondary operation to secure the heat transfer tube **104** to the heat transfer sheet **406**. By staking one or more of the lances **409**, the staked lances **409** ensure thermal contact from the heat transfer tube **104** to the heat transfer sheet **406**.

In some examples, a fin insert includes a generally rigid, longitudinally-extending member that includes a top portion and side portions. The side portions are disposed on opposite sides of the top portion. In addition, the side portions include a concave shape facing away from one another and are each configured to be positioned around a portion of a respective heat transfer tube.

In some examples, the top wall includes a peaked or convex shape.

In some examples, the fin insert includes a material having high thermal conductivity.

In some examples, the fin insert includes a plastic material.

In some examples, the top portion is configured in a shape such that fluid contacting an outer surface of the top portion flows towards at least one of the side portions.

In some examples, the fin insert further includes a plurality of ribs protruding from an outer surface of the fin insert. In some examples, the ribs are configured to block a flow of fluid in a vertical direction of the fin insert.

In other examples, a heat transfer assembly includes two parallel heat transfer tubes spaced apart from one another. The heat transfer assembly also includes a fin insert that includes a generally rigid, longitudinally-extending member. The generally rigid, longitudinally-extending member includes a top portion and side portions disposed on opposite edges of the top portion. The fin insert is disposed between the two parallel heat transfer tubes. The heat transfer assembly further includes a plurality of spacers disposed between the side portions of the fin insert and a respective heat transfer tube, such that the fin insert is spaced apart from the heat transfer tubes. The heat transfer assembly also includes at least one fluid channel formed between at least two spacers.

In some examples, the side portions of the fin insert include a concave shape facing away from one another and are each configured to be positioned around a portion of a respective heat transfer tube.

In some examples, the at least one fluid channel is configured to direct the flow of a fluid around a portion of a respective heat transfer tube. In some examples, the fluid includes liquid desiccant.

In some examples, the top portion of the heat transfer assembly is configured in a shape such that fluid contacting an outer surface of the top portion flows towards at least one of the side portions and into the at least one fluid channel.

In some examples, the plurality of spacers are integrally formed with the fin insert, such that the spacers protrude from an outer surface of the fin insert.

In some examples, two spacers of the plurality of spacers are disposed on opposite ends of one of the heat transfer tubes are configured to block a flow of fluid in a longitudinal direction of the fin insert.

In some examples, the fin insert includes a material having high thermal conductivity.

In some examples, a flow rate of fluid through the at least one fluid channel is varied based on one or more of a thickness of a spacer, a number of spacers disposed between the side portions of the fin insert and the respective heat transfer tube, and a length of the spacer.

In some examples, a distribution of fluid in the at least one fluid channel and along a surface of a respective heat transfer tube is varied based on a thickness of a spacer.

In some examples, the two parallel heat transfer tubes are connected to one another via a connecting tubular section, such that a heat transfer fluid may pass from one heat transfer tube to the other heat transfer tube.

In yet other examples, a method of heat transfer in a heat and mass exchanger includes passing a heat exchange fluid through two parallel heat transfer tubes of a heat transfer assembly, the heat transfer tubes being spaced apart from one another and connected via a connecting tubular section. The method also includes distributing liquid desiccant, via a distribution manifold, onto a fin insert of the heat transfer assembly, where the fin insert includes a generally rigid, longitudinally-extending member that includes a top portion and side portions disposed on opposite edges of the top portion, and the fin insert is disposed between the two parallel heat transfer tubes. Further, the method includes passing a process air stream across the heat transfer assembly and through the distributed liquid desiccant, where the distributed liquid desiccant falls onto an outer surface of the fin insert and flows towards at least one of the side portions and into at least one fluid channel defined by a cavity between at least two spacers disposed between a respective side portion of the fin insert and a respective heat transfer tube, and where the at least one fluid channel is configured to direct the flow of the liquid desiccant around a portion of the respective heat transfer tube.

In some examples, the method includes distributing the liquid desiccant from an opening of the at least one fluid channel of the heat transfer assembly onto an outer surface of a second heat transfer assembly positioned below the heat transfer assembly, where the opening of the at least one fluid channel is positioned to direct the liquid desiccant to fall towards at least one fluid channel of the second heat transfer assembly.

In other examples, a heat transfer assembly includes a generally rigid and corrugated sheet that includes a fluid flow channel disposed between two mounting portions. The heat transfer assembly also includes a heat transfer tube, a portion of which resides on least one of the two mounting portions. In addition, the fluid flow channel includes a groove of the corrugated sheet and is shaped to direct a fluid to flow towards a drain hole of the fluid flow channel, and the two mounting portions are shaped to direct the fluid to flow towards the fluid flow channel.

In some examples, the at least one of the two mounting portions include retention tabs configured to couple the heat transfer tube to the corrugated sheet.

The various embodiments described above are provided by way of illustration only and should not be construed to limit the claims attached hereto. Those skilled in the art will readily recognize various modifications and changes that may be made without following the example embodiments and applications illustrated and described herein, and without departing from the spirit and scope of the following claims.

What is claimed is:

1. A fin insert comprising:

a generally rigid member comprising a top portion and side portions, the side portions being disposed on opposite sides of the top portion,

wherein the side portions comprise a concave shape facing away from one another and are each configured to be positioned to create a fluid channel around a corresponding portion of each of two horizontally adjacent heat transfer tube,

wherein the generally rigid member is formed of a sheet and is elongated in an axial-direction between two horizontally adjacent heat transfer tubes.

2. The fin insert of claim **1**, wherein the top wall comprises a peaked or convex shape.

3. The fin insert of claim **1**, wherein the fin insert comprises a material having high thermal conductivity.

4. The fin insert of claim **1**, wherein the fin insert comprises a plastic material.

5. The fin insert of claim **1**, wherein the top portion is configured in a shape such that fluid contacting an outer surface of the top portion flows towards at least one of the side portions.

6. The fin insert of claim **1**, further comprising a plurality of ribs protruding from an outer surface of the fin insert, wherein the plurality of ribs protrude from the side portions to contact the respective heat transfer tubes and the fluid channel extends between the heat transfer tubes and sections of the side portions between adjacent ones of the plurality of ribs.

7. The fin insert of claim **6**, wherein the ribs are configured to block a flow of fluid in a vertical direction of the fin insert.

8. A heat transfer assembly comprising:

a row of at least three parallel heat transfer tubes horizontally spaced apart from one another with a fin insert disposed between adjacent pairs of the heat transfer tubes;

each fin insert comprising a generally rigid, member comprising a top portion and side portions disposed on opposite edges of the top portion, the fin insert being disposed between the two parallel heat transfer tubes;

wherein each generally rigid member is formed of a sheet and is elongated in an axial-direction between two horizontally adjacent heat transfer tubes;

a plurality of spacers disposed between the side portions of the fin insert and a respective heat transfer tube, such that the side portions are spaced apart from the heat transfer tubes; and

at least one fluid channel formed between the respective side portion and heat transfer tube.

9. The heat transfer assembly of claim **8**, wherein the side portions of the fin insert comprise a concave shape facing away from one another and are each configured to be positioned to create a fluid channel around a corresponding portion of each of two horizontally adjacent heat transfer tube.

10. The heat transfer assembly of claim **8**, wherein the at least one fluid channel is configured to direct the flow of a fluid around a portion of a respective heat transfer tube.

11. The heat transfer assembly of claim **10**, wherein the fluid comprises liquid desiccant.

12. The heat transfer assembly of claim **8**, wherein the top portion is configured in a shape such that fluid contacting an outer surface of the top portion flows towards at least one of the side portions and into the at least one fluid channel.

13. The heat transfer assembly of claim **8**, wherein the plurality of spacers are integrally formed with the fin insert, such that the spacers comprise a plurality of ribs that protrude from an outer surface of the fin insert,

wherein the plurality of ribs protrude from the side portions to contact the respective heat transfer tubes and the fluid channel extends between the heat transfer tubes and sections of the side portions between adjacent ones of the plurality of ribs.

14. The heat transfer assembly of claim **8**, wherein two spacers of the plurality of spacers are bands encircling the heat transfer tubes, wherein the two spacers are disposed on opposite ends of one of the heat transfer tubes are configured to block a flow of fluid in a longitudinal direction of the fin insert.

15. The heat transfer assembly of claim **8**, wherein the fin insert comprises a material having high thermal conductivity.

16. The heat transfer assembly of claim **8**, wherein a flow rate of fluid through the at least one fluid channel is varied based on one or more of a thickness of a spacer of the plurality of spacers, a number of spacers of the plurality of spacers disposed between the side portions of the fin insert and the respective heat transfer tube, and a length of the spacer.

17. The heat transfer assembly of claim **8**, wherein a distribution of fluid in the at least one fluid channel and along a surface of a respective heat transfer tube is varied based on a thickness of a spacer.

18. A heat transfer assembly, comprising

a generally rigid corrugated sheet; and

a row of horizontally-spaced heat transfer tubes,

wherein the corrugated sheet is corrugated in both an axial-direction of the heat transfer tubes and a transverse-direction of the heat transfer tubes;

wherein the corrugation in the axial-direction of the heat transfer tubes comprises mounting portion peaks and fluid flow channel grooves between adjacent mounting portions;

wherein a portion of each heat transfer tube contacts each of the mounting portions;

wherein each fluid flow channel is spaced apart from the heat transfer tube to which is it attached, and

wherein each mounting portion is shaped to direct the fluid to flow towards the fluid flow channel.

19. The heat transfer assembly of claim **18**, wherein at least one of the two mounting portions comprise retention tabs, wherein the retention tabs are configured to extend above the heat transfer tube to support the corrugated sheet hanging below the heat transfer tube.

20. The heat transfer assembly of claim **18**, wherein each drain hole is located immediately below a heat transfer tube.

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