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(54) **HEAT EXCHANGER**

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CPC ***F28F 1/00*** (2013.01)
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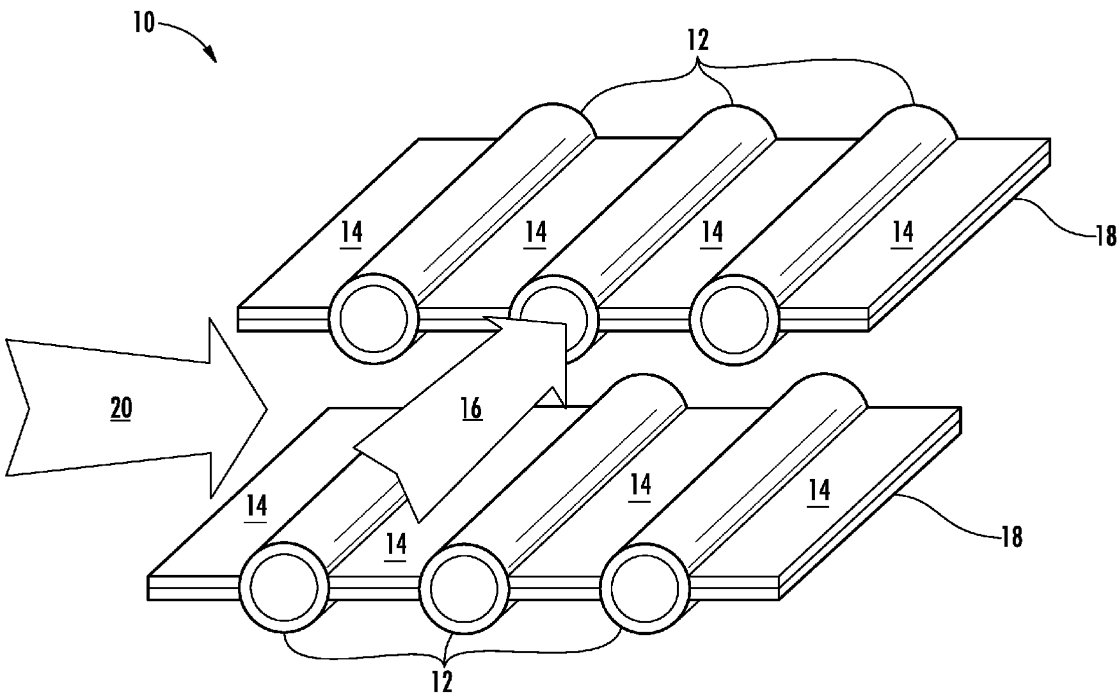
(57) **ABSTRACT**

A heat exchanger includes a plurality of tubes positioned substantially transverse to a direction of airflow through the heat exchanger and arranged in a plurality of tube rows extending substantially along the direction of airflow. The heat exchanger further includes a plurality of webs substantially integral to two or more tubes of the plurality of tubes, each web extending between and connected to adjacent tubes of the plurality of tubes. At least one tube of the plurality of tubes has a cross section with an aspect ratio greater than 1:1, relative to a substantially horizontal web.



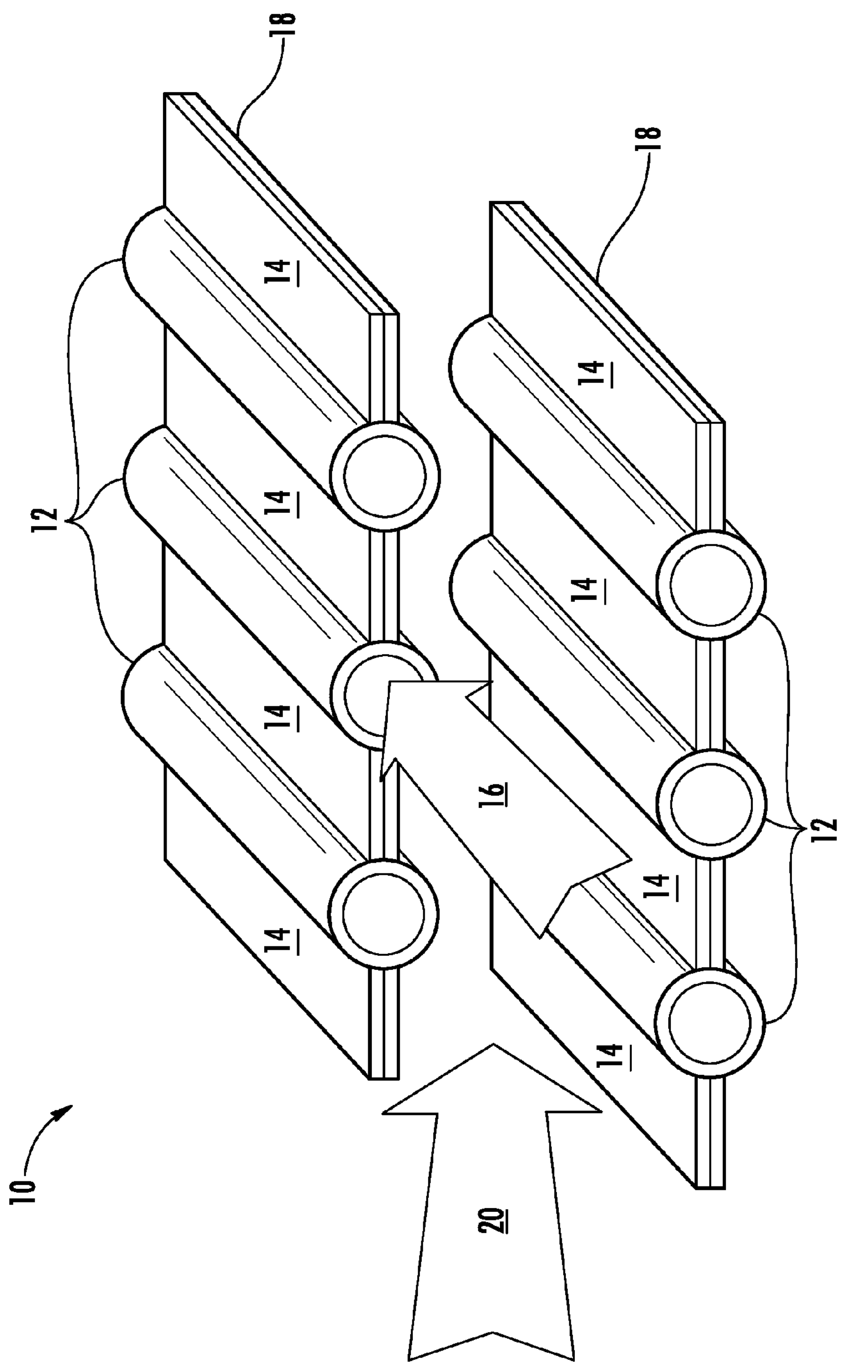


FIG. 1

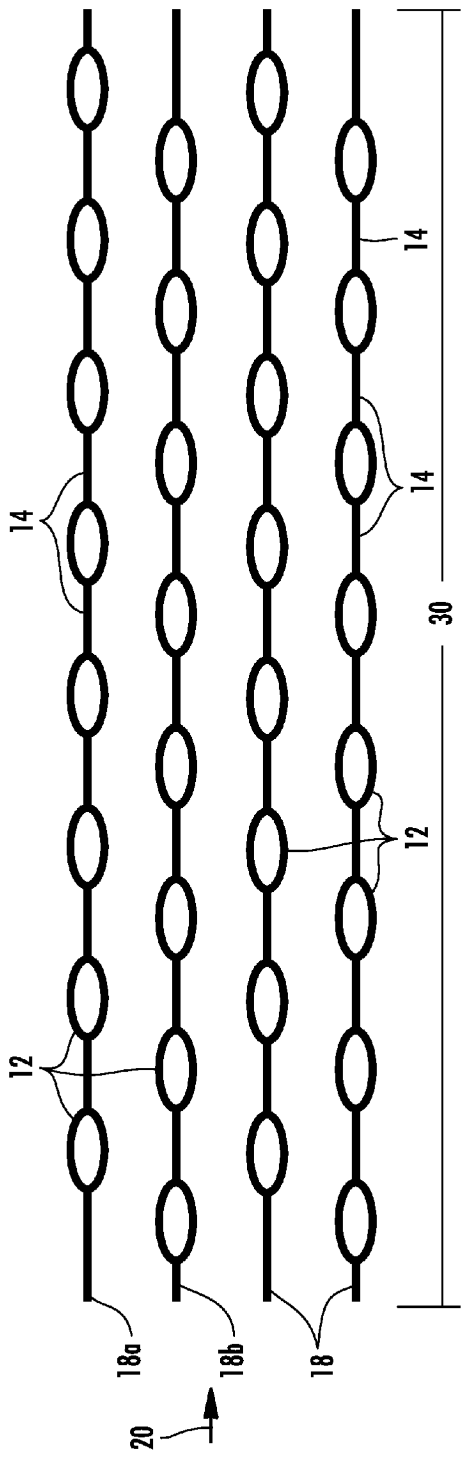


FIG. 2

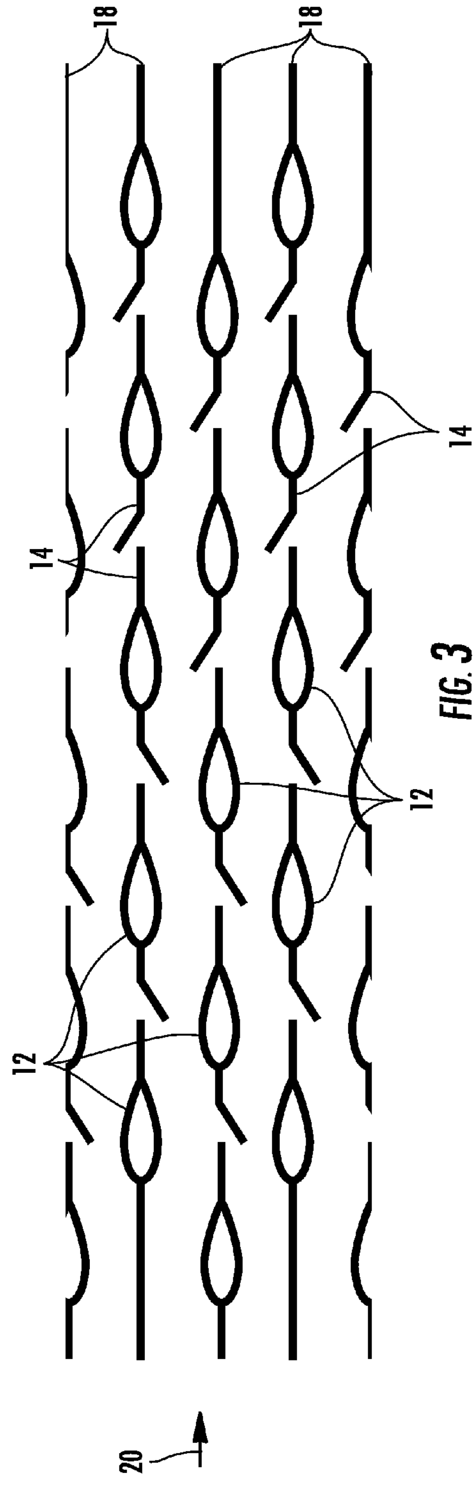


FIG. 3

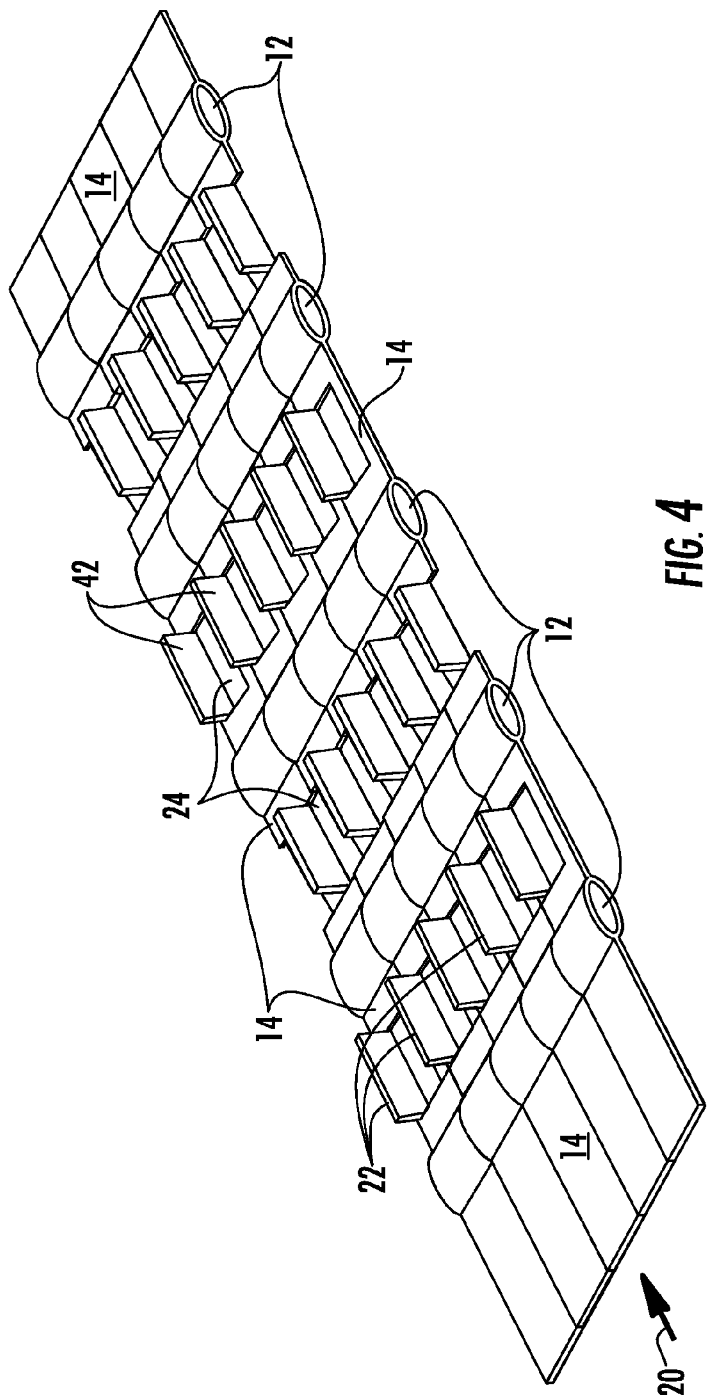


FIG. 4

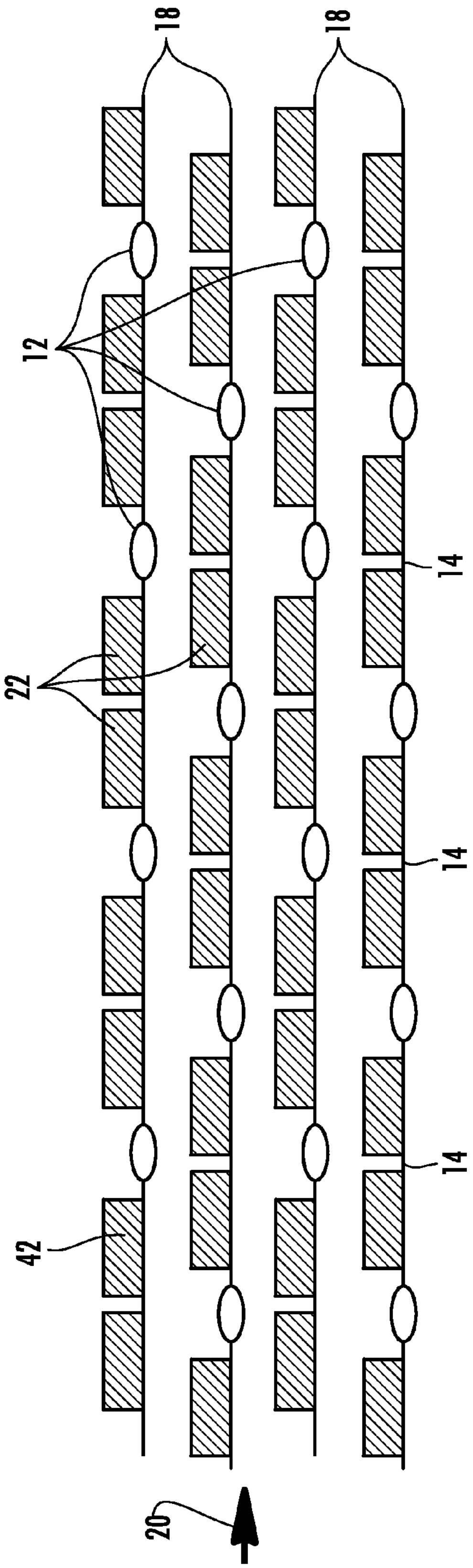


FIG. 5

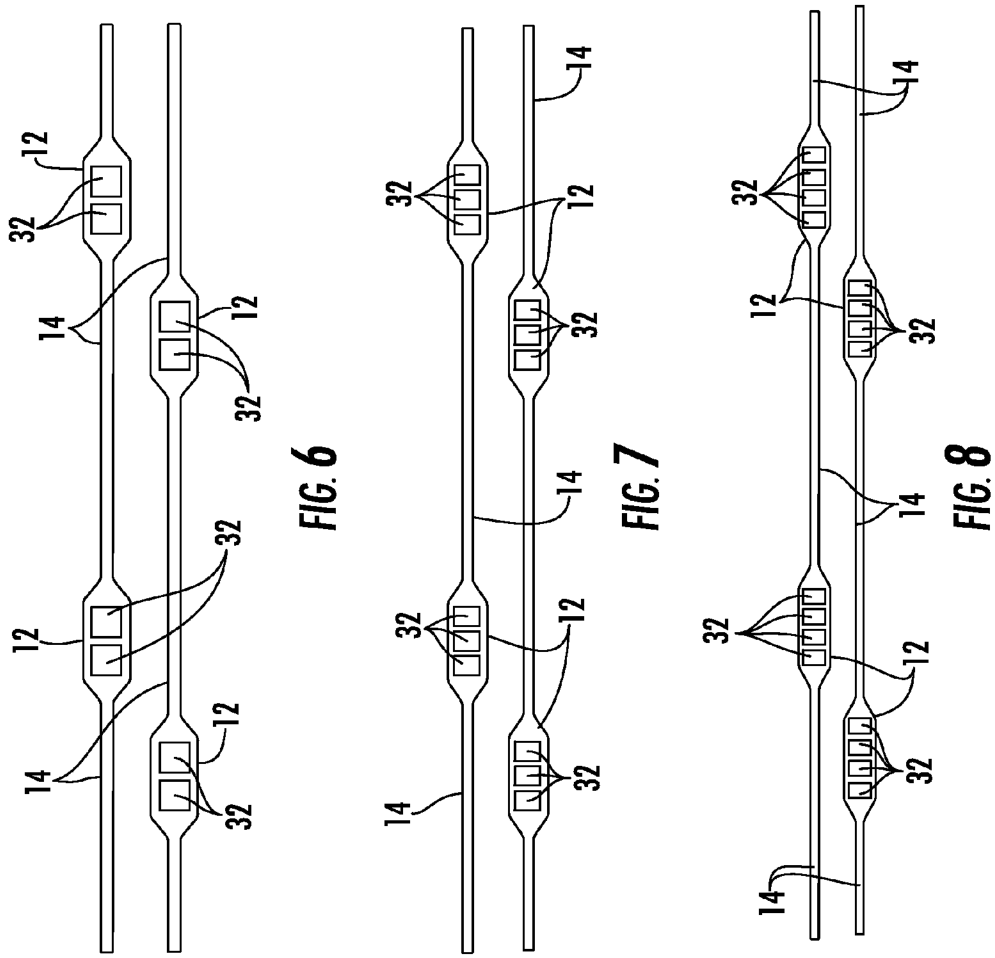


FIG. 6

FIG. 7

FIG. 8

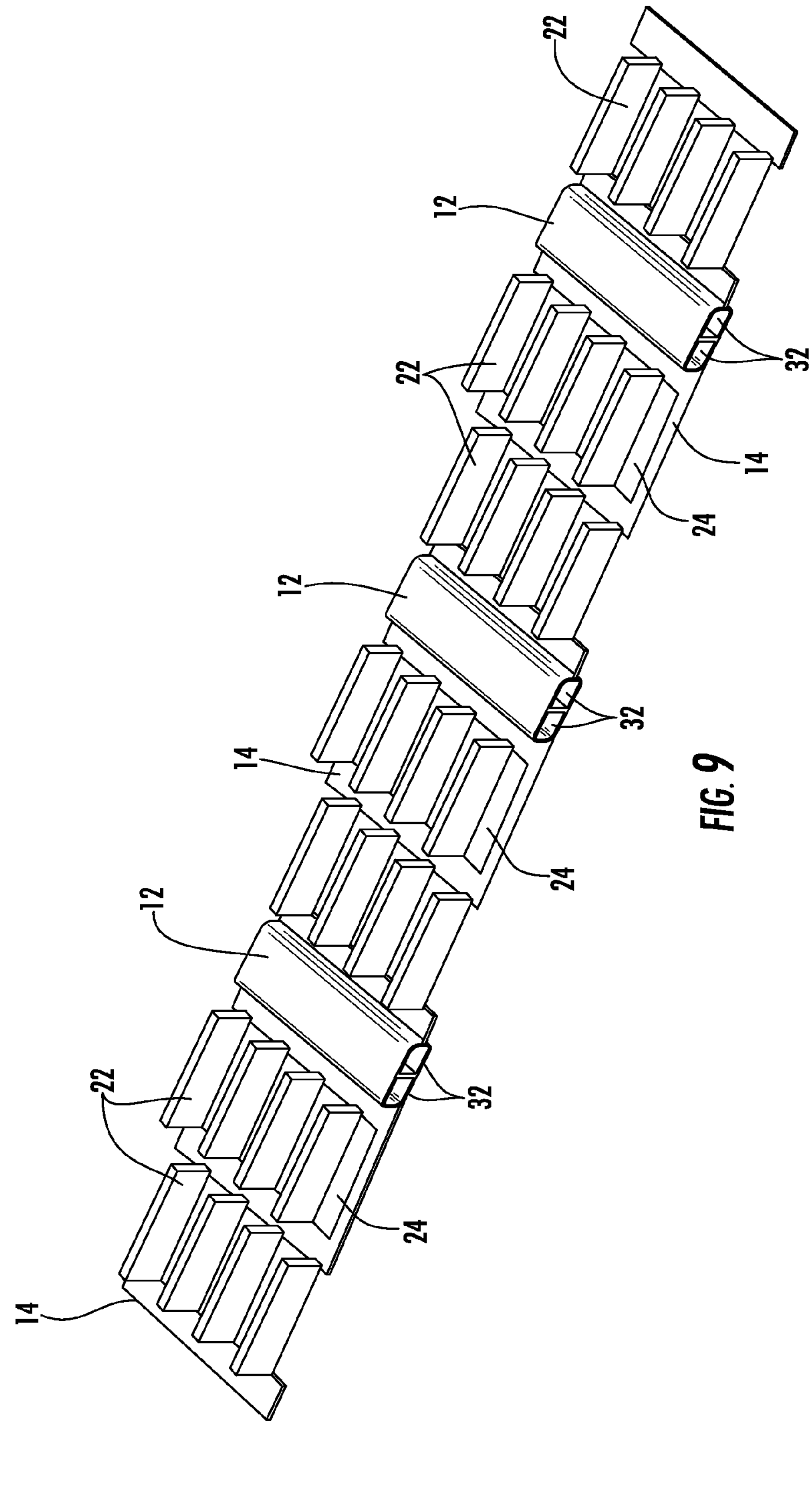


FIG. 9

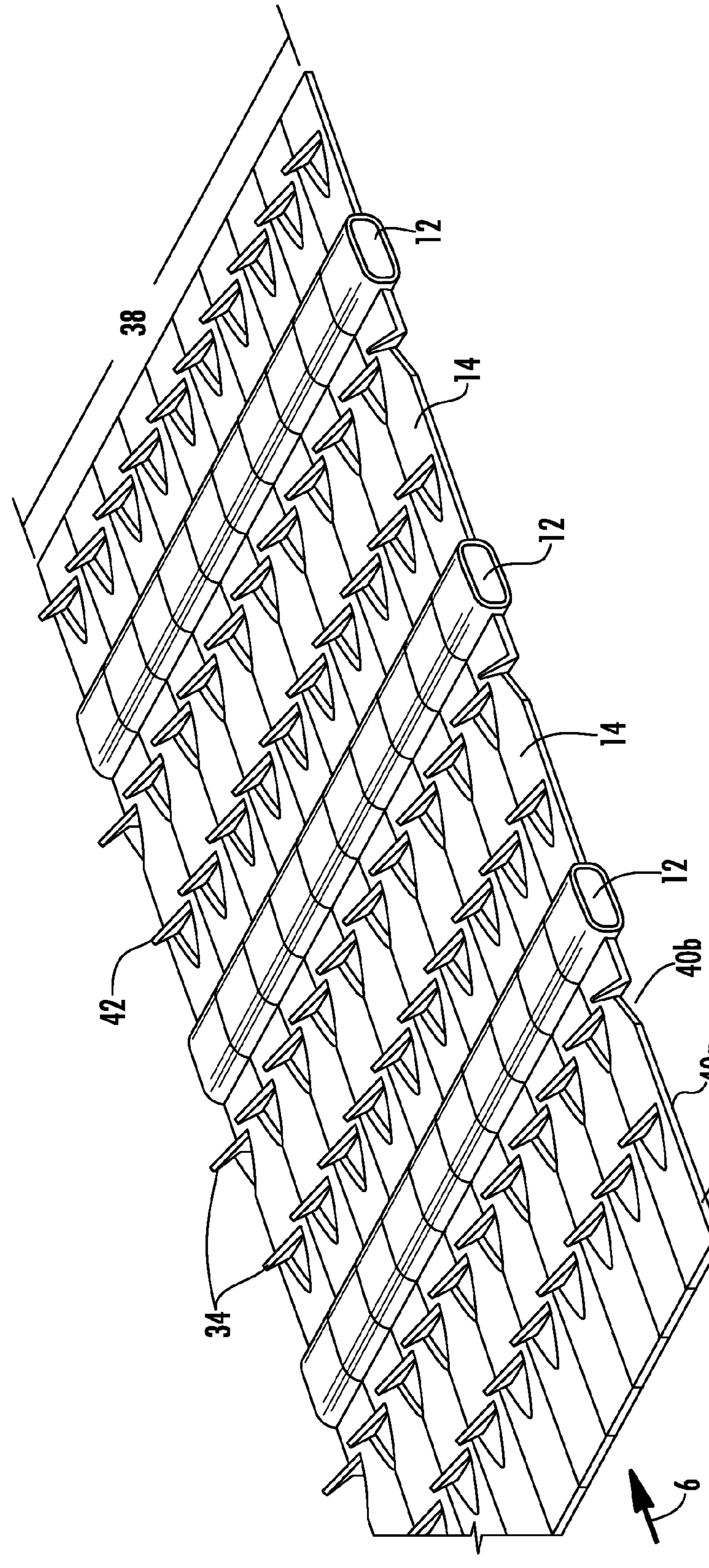


FIG. 10

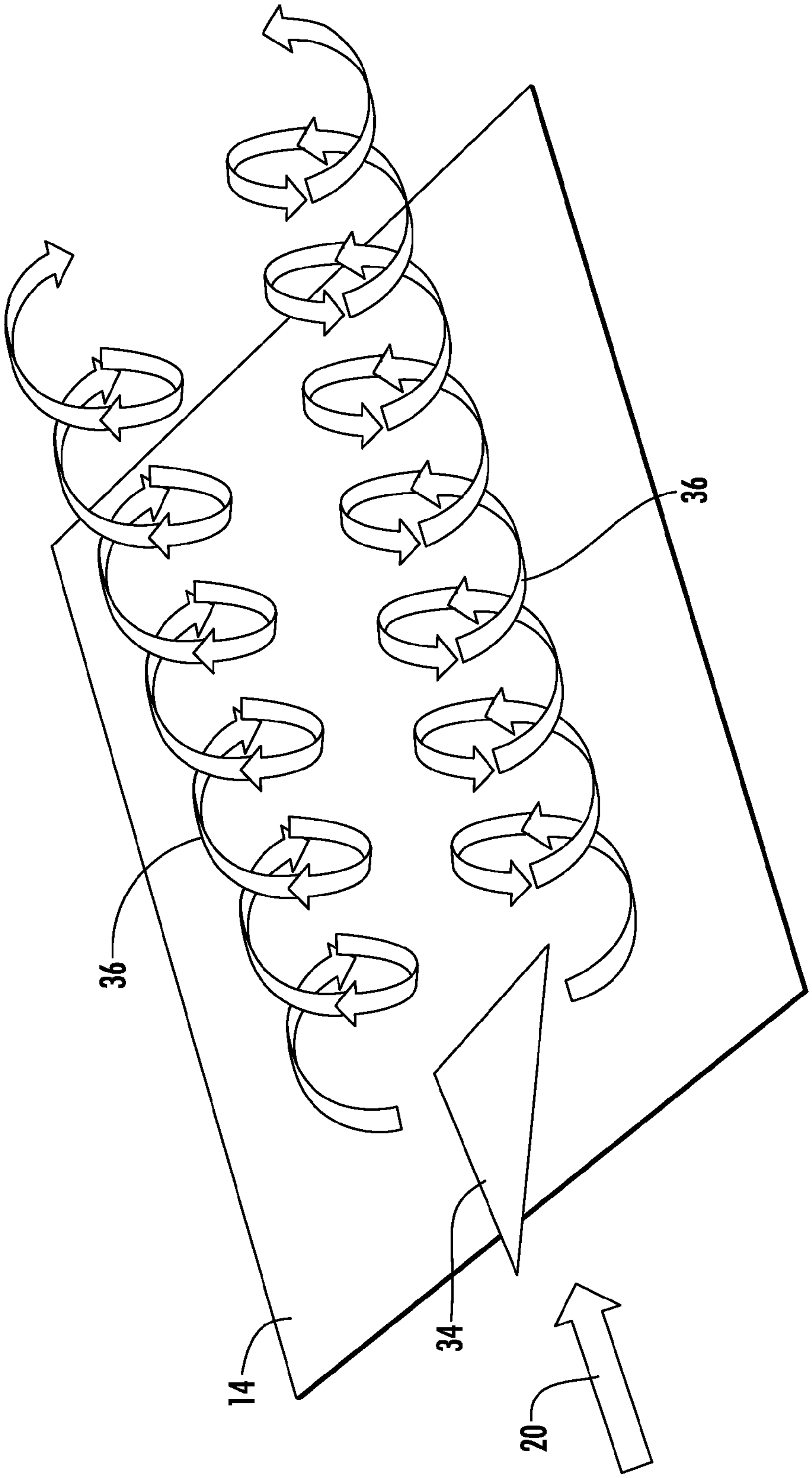


FIG. 11

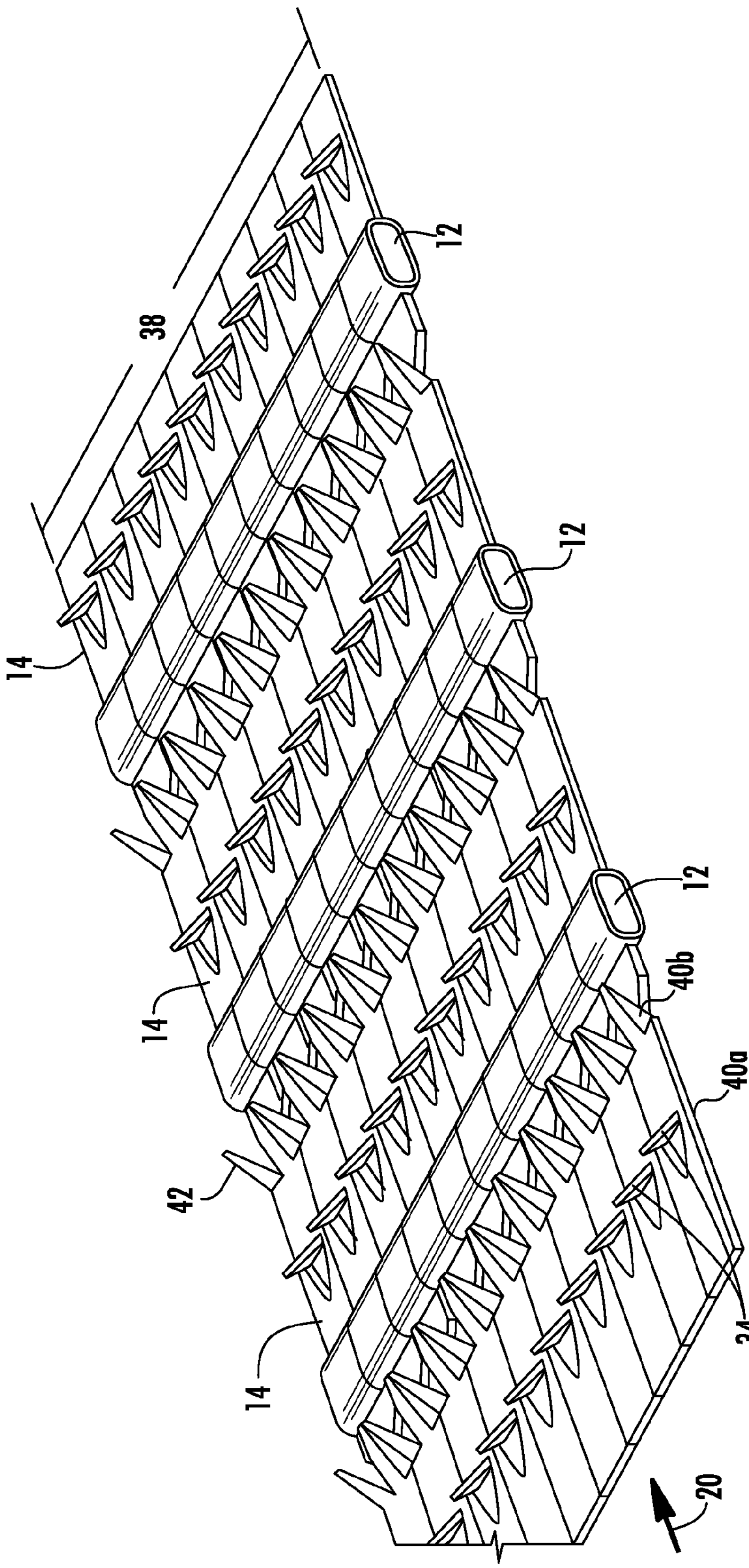


FIG. 12

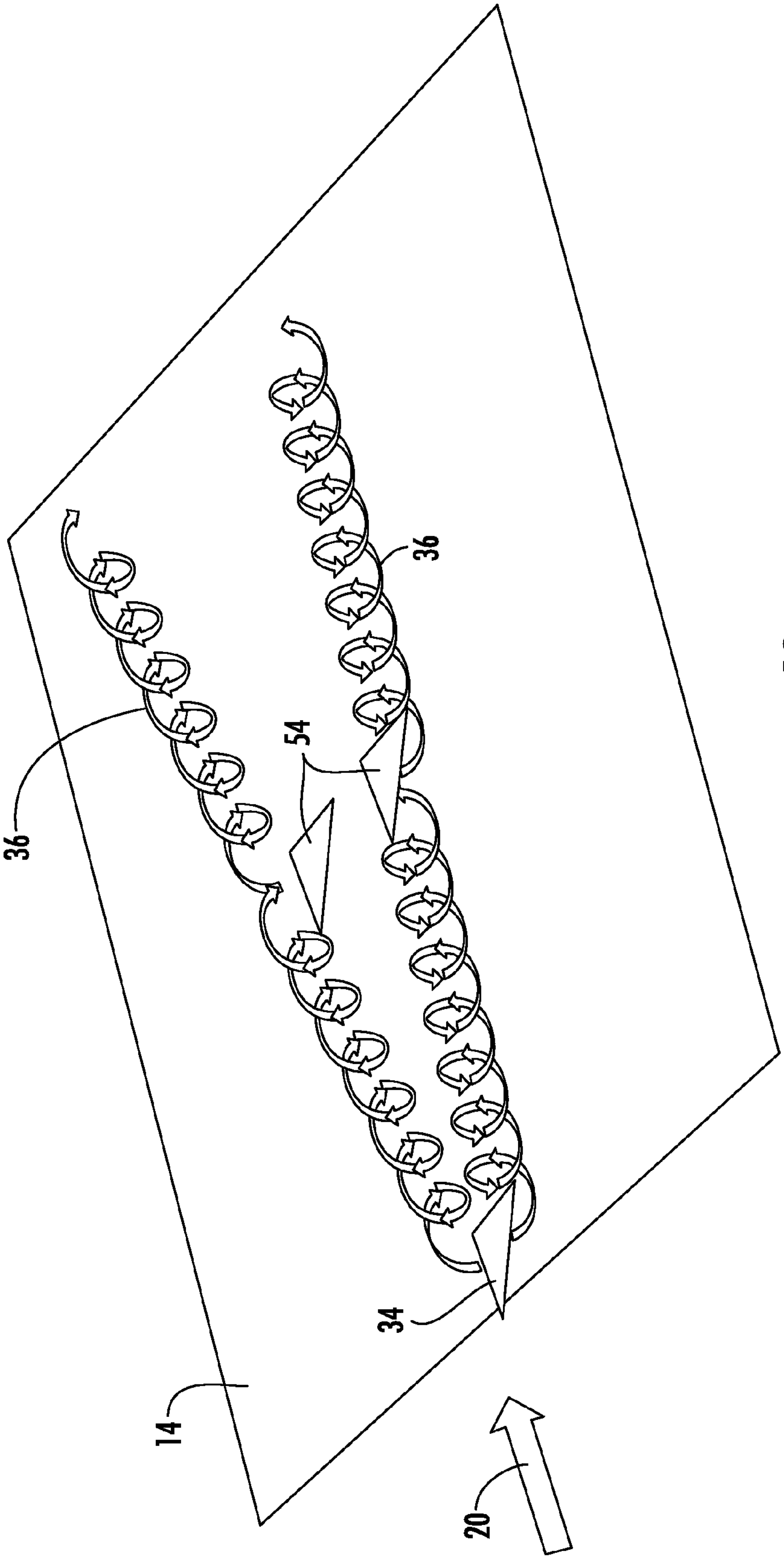


FIG. 13

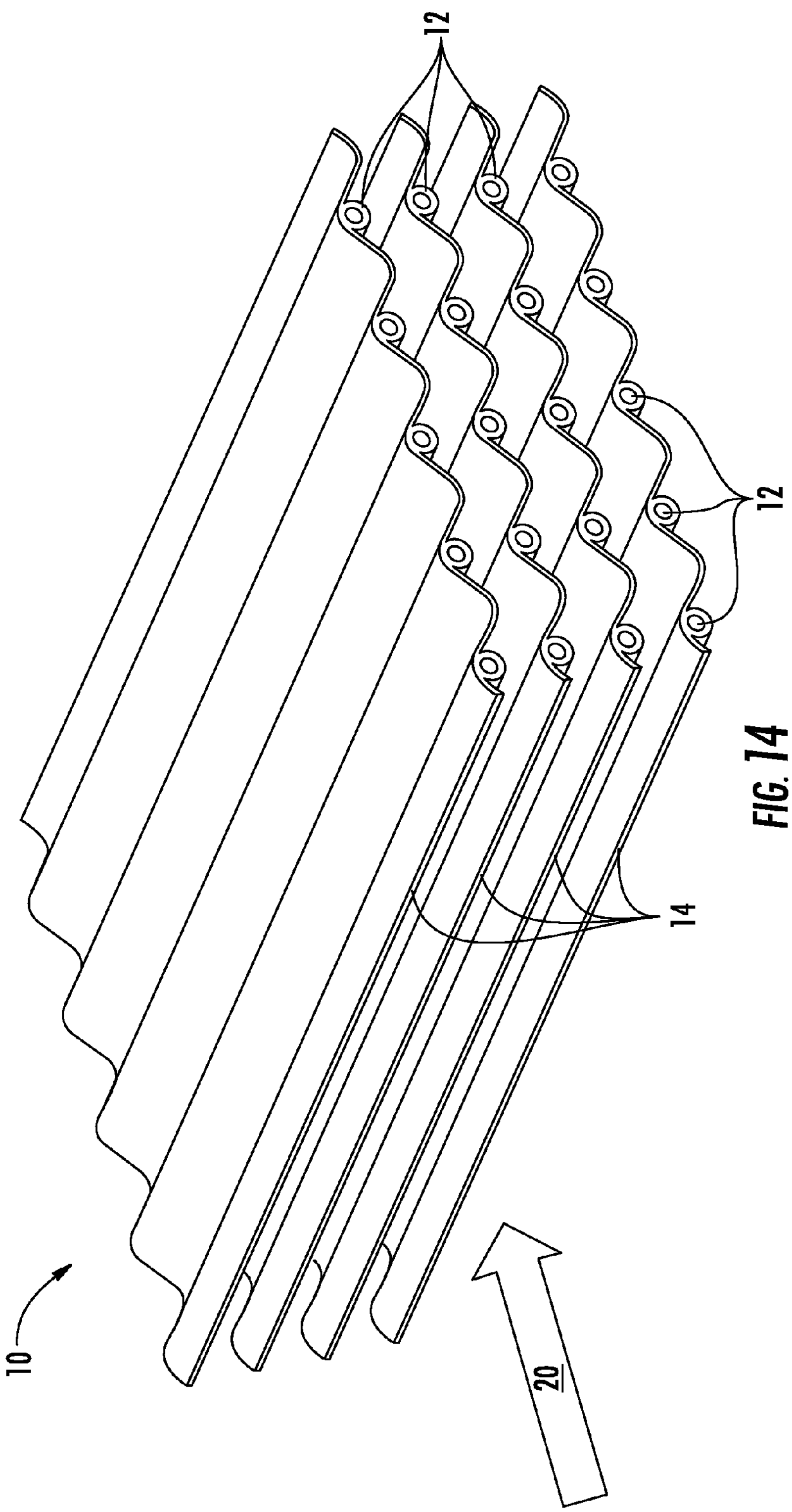


FIG. 14

HEAT EXCHANGER

BACKGROUND OF THE INVENTION

[0001] The subject matter disclosed herein relates to heat exchangers. More specifically, the subject disclosure relates to tube and fin configuration for heat exchangers.

[0002] Micro-channel heat exchangers have represented the typical construction of heat exchangers for, for example, automotive and heating, ventilation and air conditioning (HVAC) applications, for several years. These heat exchangers are finding wider application in residential and even aerospace HVAC products due to their compactness, relatively low cost, and reduced refrigerant charge when compared to other heat exchanger configurations.

[0003] In micro-channel heat exchangers, liquid or two-phase refrigerant flows through small ports internal to extruded tubes. Air flows through folded fins arranged between the tubes. Due to the high surface density of this construction, and a flat shape of the typical tube, these heat exchangers are prone to moisture and condensate retention and subsequent frost accumulation issues. This is especially problematic when the tubes are arranged horizontally. Water collects on the horizontal surfaces of the tubes, resulting in higher flow and thermal resistance as well as corrosion and pitting of the tube surfaces.

BRIEF DESCRIPTION OF THE INVENTION

[0004] According to one aspect of the invention, a heat exchanger includes a plurality of tubes positioned substantially transverse to a direction of airflow through the heat exchanger and arranged in a plurality of tube rows extending substantially along the direction of airflow. The heat exchanger further includes a plurality of webs substantially integral to two or more tubes of the plurality of tubes, each web extending between and connected to adjacent tubes of the plurality of tubes. At least one web has an enhanced surface such as a louver, tab, or vortex generator. (the main claim should be the combination of the tube, web, and surface enhancements. We may have a configuration with round tubes with some form of web surface enhancement. I don't believe this is covered in the claims)

[0005] According to another aspect of the invention, a heat exchanger includes a plurality of tubes positioned substantially transverse to a direction of airflow through the heat exchanger and arranged in a plurality of tube rows extending substantially along the direction of airflow. At least one tube of the plurality of tubes includes two or more fluid-conveying pathways. A plurality of webs are substantially integral to two or more tubes of the plurality of tubes. Each web extends between and is connected to adjacent tubes of the plurality of tubes.

[0006] According to yet another aspect of the invention, a heat exchanger includes a plurality of tubes positioned substantially transverse to a direction of airflow through the heat exchanger and arranged in a plurality of tube rows extending substantially along the direction of airflow. A plurality of webs are substantially integral to at least two tubes of the plurality of tubes. Each web extends between and is connected to adjacent tubes of the plurality of tubes. A plurality of tabs are located at the plurality of webs substantially transverse to the airflow to generate vortices in the airflow.

[0007] These and other advantages and features will become more apparent from the following description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The subject matter, which is regarded as the invention, is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

[0009] FIG. **1** is a perspective view of an embodiment of an integral tube and fin heat exchanger;

[0010] FIG. **2** is an embodiment of an integral tube and fin heat exchanger having elliptical tubes;

[0011] FIG. **3** is an embodiment of an integral tube and fin heat exchanger having airfoil-shaped tubes;

[0012] FIG. **4** is an embodiment of an integral tube and fin heat exchanger having web louvers;

[0013] FIG. **5** is an embodiment of an integral tube and fin heat exchanger having multiple web louvers;

[0014] FIG. **6** is an embodiment of an integral tube and fin heat exchanger having multiple fluid pathways per tube;

[0015] FIG. **7** is another embodiment of an integral tube and fin heat exchanger having multiple fluid pathways per tube;

[0016] FIG. **8** is yet another embodiment of an integral tube and fin heat exchanger having multiple fluid pathways per tube;

[0017] FIG. **9** is still another embodiment of an integral tube and fin heat exchanger having multiple fluid pathways per tube;

[0018] FIG. **10** is an embodiment of an integral tube and fin heat exchanger including web tabs;

[0019] FIG. **11** is a schematic of vortex flow through an embodiment of an integral tube and fin heat exchanger;

[0020] FIG. **12** is another embodiment of an integral tube and fin heat exchanger including web tabs;

[0021] FIG. **13** is another schematic of vortex flow through an embodiment of an integral tube and fin heat exchanger; and

[0022] FIG. **14** is another embodiment of a heat exchanger **10**.

[0023] The detailed description explains embodiments of the invention, together with advantages and features, by way of example with reference to the drawings.

DETAILED DESCRIPTION OF THE INVENTION

[0024] Shown in the FIG. **1** is a heat exchanger **10** structure. In some embodiments, the heat exchanger **10** is a micro-channel heat exchanger (MCHX). The heat exchanger **10** has an integrated tube-fin structure where a plurality of tubes **12** are arranged with a plurality of webs **14** extending between adjacent tubes **12** of the plurality of tubes **12**, and acting as fins in this structure. The webs **14** in some embodiments are substantially integral to the tubes **12**. A refrigerant flow **16**, for example, a liquid or two phase refrigerant, is flowed through the plurality of tubes **12**. While the term "refrigerant flow" is utilized throughout the present application, it is to be appreciated that any selected liquid, gas, or two-phase fluid may be flowed through the plurality of tubes **12** for the purposes of heat transfer. In some embodiments, the plurality of tubes **12** are arranged in rows **18**. An airflow **20** flows across the plurality of tubes **12** and the plurality of webs **14** such that thermal energy is transferred between the airflow **20** and the refrigerant flow **16** via the tube **12** and web **14** structure. In some embodiments, a direction of the airflow **20** is substantially perpendicular to the refrigerant flow **16**.

[0025] Referring now to FIG. **2**, the tubes **12** have a cross-section that improves air flow **20** and thus heat transfer between the airflow **20** and the heat exchanger **10**. In some embodiments, as shown in FIG. **2**, the cross-section of the tubes **12** are elliptical or may be airfoil shaped as shown in FIG. **3**. Elliptic or airfoil shapes reduce the wake size behind the tubes **12**, which decreases pressure drop and improves heat transfer. Referring to FIG. **4**, the webs **14** include a plurality of louvers **22** formed in the webs **14** which extend into the airflow **20**. The louvers **22** may be formed by, for example, a punching operation which cuts the web **14** on three sides of the louver **22** and folds the louver **22** into position, resulting in a web opening **24** in the web **14**. In some embodiments, the louvers **22** each have a louver face **42** which is aligned substantially parallel to the airflow **20**. In some embodiments, as shown in FIG. **5**, the webs **14** may be configured with multiple rows of multiple louvers **22** between adjacent tubes **12**. Utilizing louvers **22** and web openings **24** allows for reduction in material and refrigerant volume compared to a conventional micro-channel heat exchanger and allows for drainage of condensate through the web openings **24** to reduce condensate/ice buildup and/or corrosion.

[0026] In some embodiments, the webs **14** between adjacent tubes **12** are substantially equal in web length **26**. It is to be appreciated, however, that the web length **26** may vary as desired. In some embodiments, as also shown in FIG. **2**, the tubes **12** in a first row **18***a* of tubes **12** can be offset or staggered relative to an adjacent second row **18***b* of tubes **12** along a length **30** of the heat exchanger **10** to allow for a more compact structure and to increase heat transfer between the airflow **20** and the refrigerant flow **16**.

[0027] Referring now to FIG. **6**, some embodiments it is desired to increase a distance between the tubes **12** or reduce the number of tubes **12** because heat transfer via the webs **14** is highly effective. Further, reducing a number of tubes **12** reduces necessary connections of tubes **12** to a header (not shown) which distributes refrigerant flow **16** to the tubes **12**. A reduction of the number of tubes **12** alone, however, increases a refrigerant flow pressure drop for the same capacity and flow rates. Further, a reduction of the number of tubes **12** combined with an increase in the cross-sectional area of the tubes **12** to increase flow capacity, results in a reduction in heat transfer due to an increase in a hydraulic diameter of the tubes **12** and a reduction in a total refrigerant side heat transfer area.

[0028] The embodiments of FIGS. **6-8** address this problem by providing multiple smaller refrigerant pathways **32** in each tube **12** of the plurality of tubes **12**. As shown in FIGS. **6**, **7**, and **8**, respectively, two, three, or four pathways **32** may be arranged in each tube **12** to decrease the pressure drop compared to a similar-sized tube **12** with a single pathway while increasing the heat transfer capability of the tube **12** and reducing connections to the header. While it is possible to include more than four pathways **32** in the tube **12**, the heat transfer effectiveness of the additional pathways will be decreased since heat conduction from innermost pathways will be limited compared to the outermost pathways. As shown in FIG. **9**, louvers **22** may be utilized with these multi-pathway **32** configurations to increase heat transfer and to provide condensate drainage through the web openings **24**.

[0029] Referring now to FIG. **10**, the heat exchanger **10** may include vortex generators, for example, tabs **34** disposed along the web **14**. The tabs **34** are oriented across the airflow **20**, as shown schematically in FIG. **11**, in order to generate streamwise votices **36** in the airflow **20** as the airflow passes along the web **14**. The presence of vortices **36** can increase heat transfer between the web **14** and the airflow **20**. Referring again to FIG. **10**, the tabs **34** are triangular in shape, or may be other shapes, for example, trapezoidal, or asymmetrically polygonal, or the like, to generate the desired vortices **36**. The tabs **34** may be disposed in rows **40** extending along a tube length **38**, with multiple rows, for example, two or three rows of tabs **34** between adjacent tubes **12**. The positions of tabs **34** in a first row **40***a* may be staggered relative to the positions of tabs **34** in a second row **40***b*, or may be aligned, depending on the vortex **36** desired.

[0030] Comparing FIGS. **10** and **12**, it can be seen that in some embodiments the tabs **34** are aligned such that a tab tip **42** of the tabs **34** faces the same direction, while in other embodiments, as shown in FIG. **12**, tab tips **42** of tabs **34** or rows of tabs **34** may face opposing directions. Further, as shown in FIG. **13**, tabs **34** may be located and oriented to boost a strength of the vortices **36** along the web **14**.

[0031] Referring to FIG. **14**, in some embodiments, the webs **14** may not be substantially planar, but may be a wave or ruffle shape to further have a desired effect on the airflow **20**, such as increased vortex generation. The wavy web **14** may be utilized in conjunction with the louvers **22**, and/or tabs **34**.

[0032] While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

1. A heat exchanger comprising:

a plurality of tubes disposed substantially transverse to a direction of airflow through the heat exchanger and arranged in a plurality of tube rows extending substantially along the direction of airflow; and

a plurality of webs integral to at least two or more tubes of the plurality of tubes, each web extending between and connected to adjacent tubes of the plurality of tubes;

wherein at least one web of the plurality of webs includes one or more of a louver, or a tab extending into the airflow from the web.

2. The heat exchanger of claim **1**, wherein at least one tube of the plurality of tubes has an oval or airfoil-shaped cross-section.

3. The heat exchanger of claim **1**, further comprising two or more louvers disposed in two or more louver rows at a web between adjacent tubes of the plurality of tubes.

4. The heat exchanger of claim **1**, wherein the louver has a louver face aligned substantially parallel to the direction of airflow.

5. The heat exchanger of claim **1**, wherein the louver has a louver face at an angle to the direction of airflow.

6. The heat exchanger of claim **1**, wherein at least one tube of the plurality of tubes comprises two or more fluid-conveying pathways.

7. The heat exchanger of claim **6**, wherein the number or fluid-conveying pathways of the at least one tube is in the range of two to four.

8. The heat exchanger of claim **1**, wherein the tab is substantially transverse to the airflow to generate vortices in the airflow.

9. The heat exchanger of claim **1**, wherein the plurality of webs form a ruffled or wavy surface.

10. The heat exchanger of claim **1**, wherein the plurality of tubes in a first tube row of the plurality of tube rows are substantially staggered in position relative to the plurality of tubes in an adjacent second tube row of the plurality of tube rows.

11. A heat exchanger comprising:

a plurality of tubes disposed substantially transverse to a direction of airflow through the heat exchanger and arranged in a plurality of tube rows extending substantially along the direction of airflow, at least one tube of the plurality of tubes including two or more fluid-conveying pathways; and

a plurality of webs substantially integral to two or more tubes of the plurality of tubes, each web extending between and connected to adjacent tubes of the plurality of tubes.

12. The heat exchanger of claim **10**, wherein at least one tube of the plurality of tubes has a cross section with an aspect ratio greater than 1:1, relative to a substantially horizontal web.

13. The heat exchanger of claim **11**, wherein at least one tube of the plurality of tubes has an oval or airfoil-shaped cross-section.

14. The heat exchanger of claim **10**, wherein the number or fluid-conveying pathways of the at least one tube is in the range of two to four.

15. The heat exchanger of claim **10**, further comprising one or more louvers disposed in the plurality of webs.

16. The heat exchanger of claim **14**, further comprising two or more louvers disposed in two or more louver rows at a web between adjacent tubes of the plurality of tubes.

17. The heat exchanger of claim **14**, wherein the one or more louvers have a louver face aligned substantially parallel to the direction of airflow.

18. The heat exchanger of claim **10**, further comprising a plurality of tabs disposed at the plurality of webs substantially transverse to the airflow to generate vortices in the airflow.

19. A heat exchanger comprising:

a plurality of tubes disposed substantially transverse to a direction of airflow through the heat exchanger and arranged in a plurality of tube rows extending substantially along the direction of airflow;

a plurality of webs substantially integral to at least two tubes of the plurality of tubes, each web extending between and connected to adjacent tubes of the plurality of tubes; and

a plurality of tabs disposed at the plurality of webs substantially transverse to the airflow to generate vortices in the airflow.

20. The heat exchanger of claim **18**, wherein the plurality of tabs are substantially triangular or trapezoidal.

21. The heat exchanger of claim **18**, wherein a first group of tabs between a first pair of adjacent tubes of the plurality of tubes extend in a first direction and a second group of tabs between a second pair of adjacent tubes of the plurality of tubes extend in a second direction different than the first direction.

22. The heat exchanger of claim **18**, wherein at least one tube of the plurality of tubes has a cross section with an aspect ratio greater than 1:1, relative to a substantially horizontal web.

23. The heat exchanger of claim **19**, wherein at least one tube of the plurality of tubes has an oval or airfoil-shaped cross-section.

24. The heat exchanger of claim **22**, wherein at least one tube of the plurality of tubes comprises two or more fluid-conveying pathways.

25. The heat exchanger of claim **23**, wherein the number or fluid-conveying pathways of the at least one tube is in the range of two to four.

26. The heat exchanger of claim **18**, further comprising one or more louvers disposed in the plurality of webs.

27. The heat exchanger of claim **25**, further comprising two or more louvers disposed in two or more louver rows at a web between adjacent tubes of the plurality of tubes.

28. The heat exchanger of claim **25**, wherein the one or more louvers have a louver face aligned substantially parallel to the direction of airflow.

* * * * *