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(54) **MICROCHANNEL HEAT EXCHANGER FIN**

(75) Inventors: **Michael F. Taras**, Fayetteville, NY (US); **Arindom Joardar**, East Syracuse, NY (US); **Jack Leon Esformes**, Jamesville, NY (US); **Sunil S. Mehendale**, Manlius, NY (US)

(73) Assignee: **CARRIER CORPORATION**, Farmington, CT (US)

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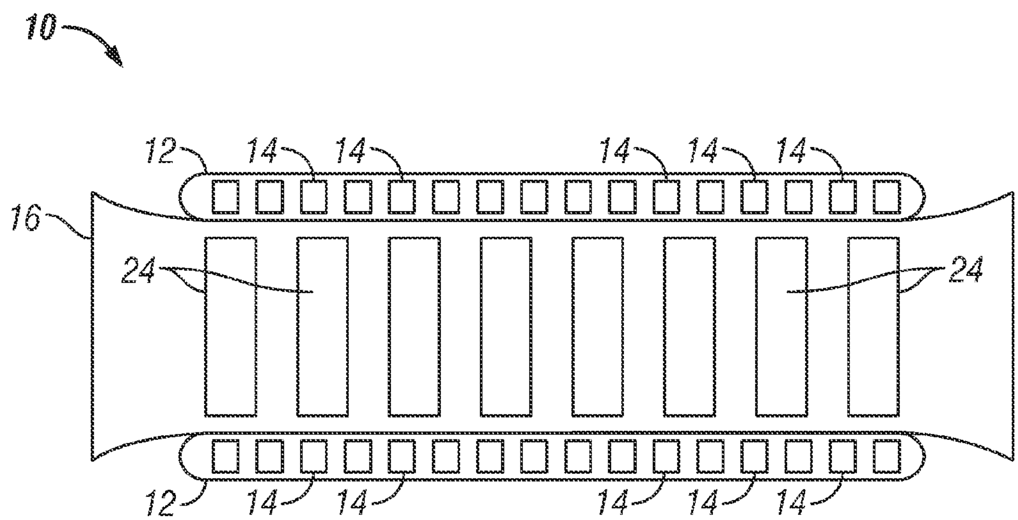
(57) **ABSTRACT**

A heat exchanger includes a plurality of tubes (**12**), each tube configured for a flow of fluid therethrough and one or more fins located between adjacent tubes of the plurality of tubes. The one or more fins are spaced by a fin pitch (Fp,**18**) and are configured to improve thermal energy transfer between the plurality of tubes and ambient air. Each fin includes a fin face extending between the adjacent tubes, a substantially planar fin cap (**22**) connected to the fin face secured to one or the tubes, and a fin radius (Rc,**26**) connecting the fin face to the fin cap such that the fin radius is reduced to promote condensate removal from the heat exchanger.



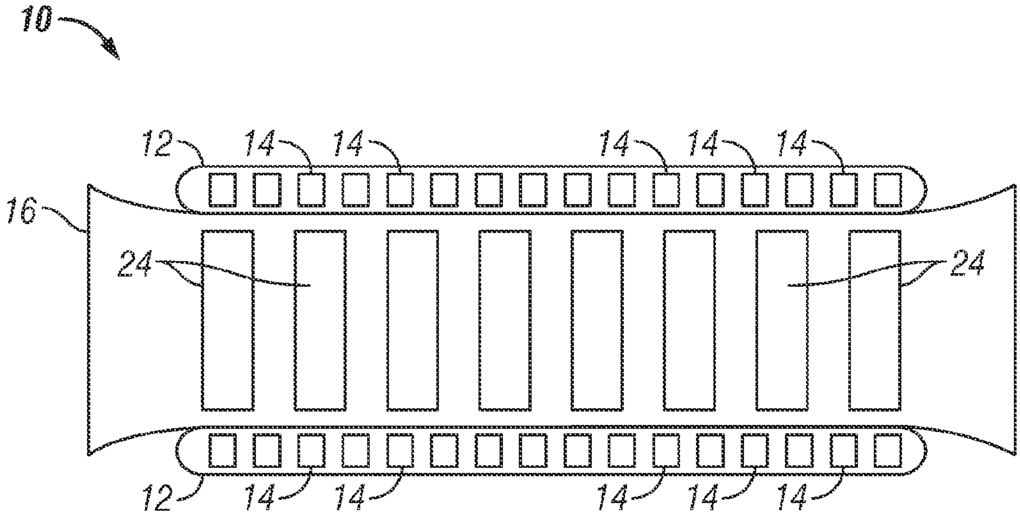

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FIG. 1

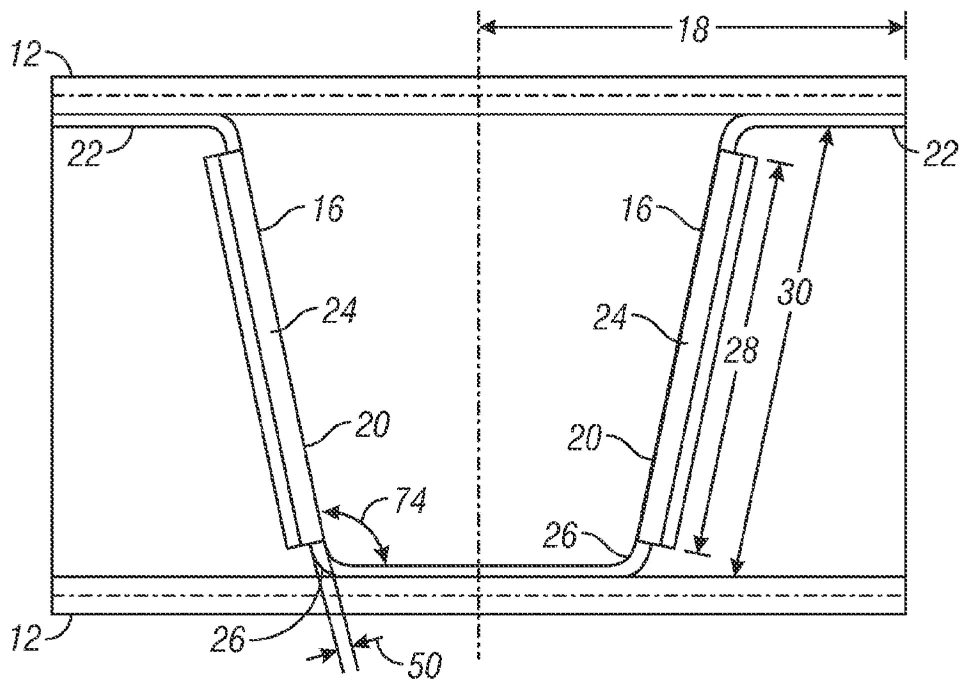
18
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FIG. 2

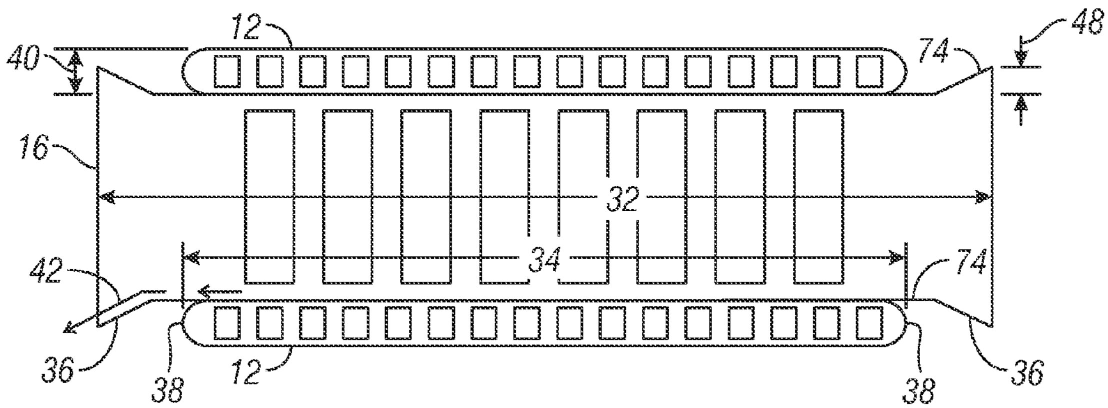

FIG. 3

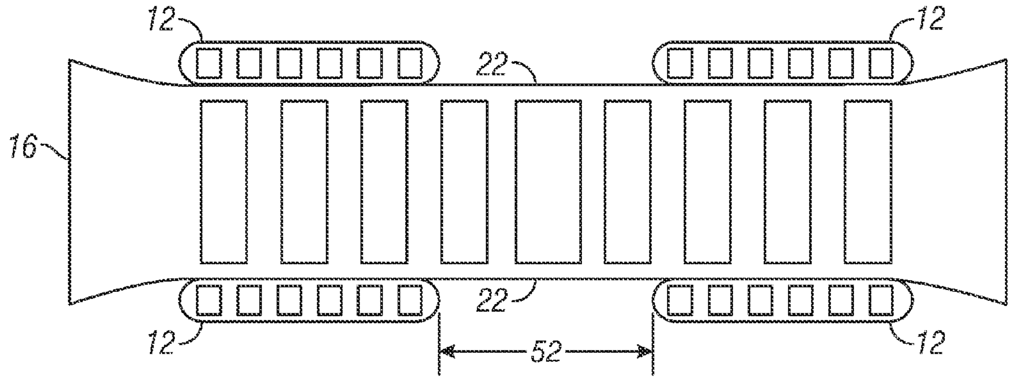

FIG. 4

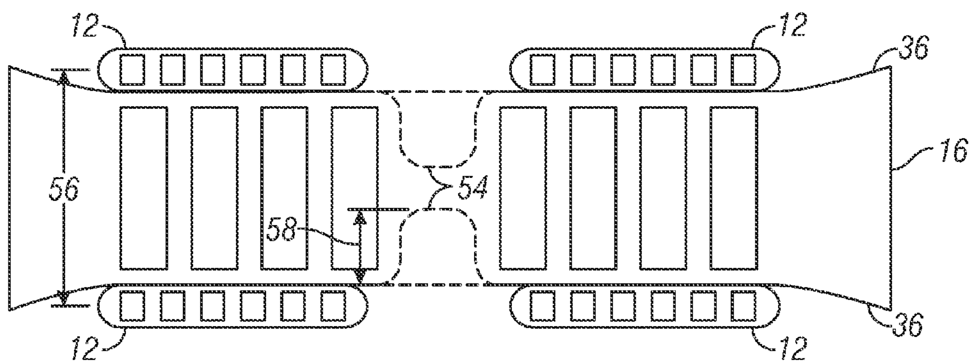

FIG. 5

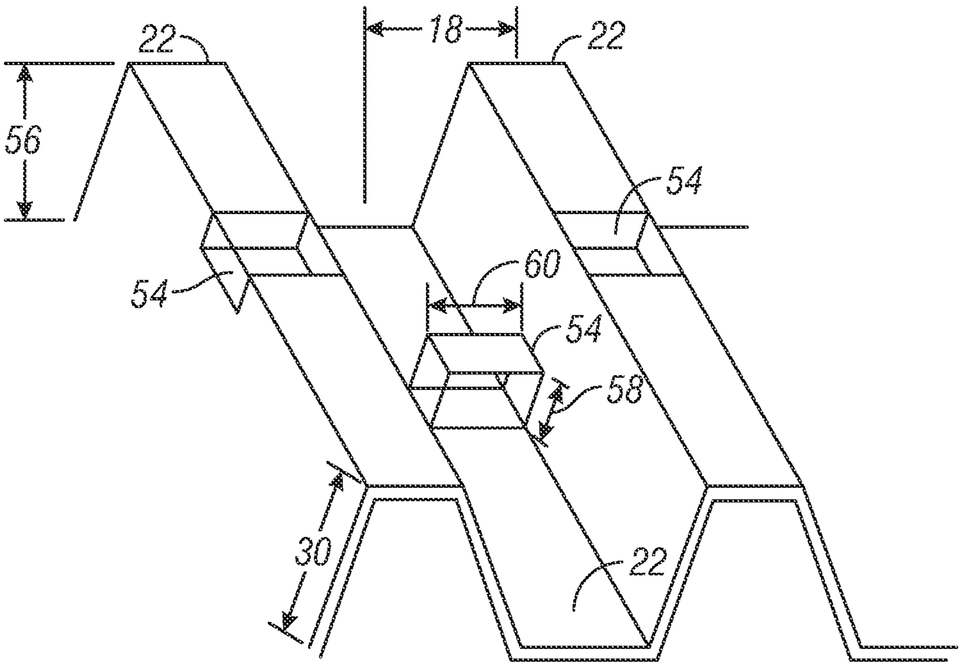

FIG. 6

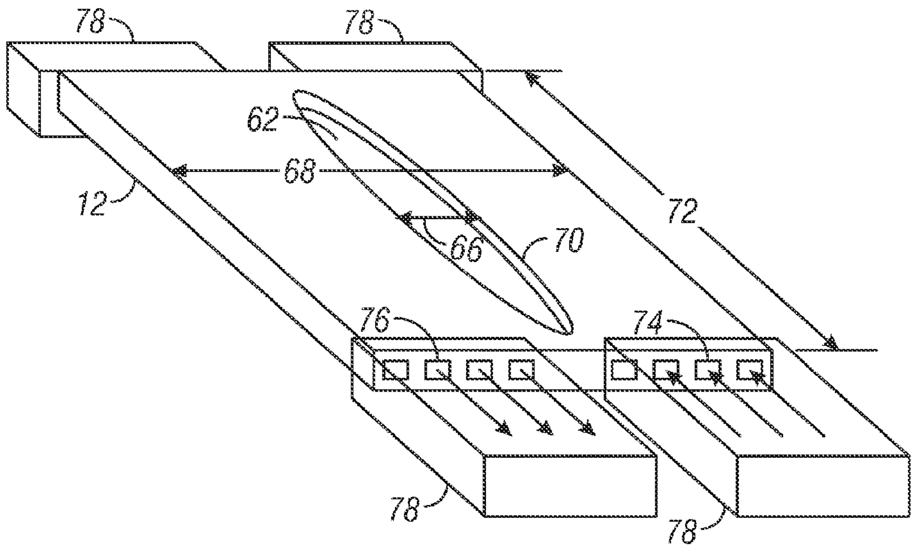

FIG. 7

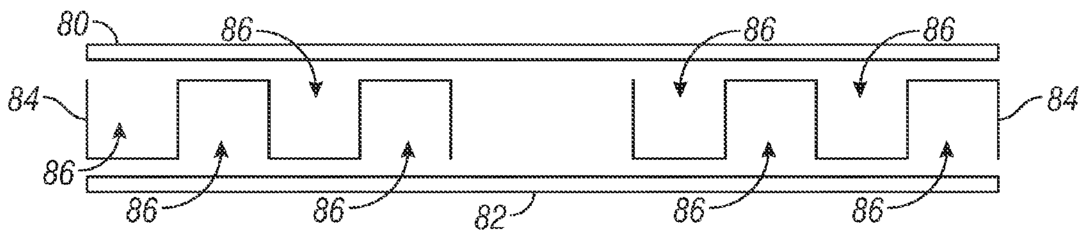

FIG. 8

MICROCHANNEL HEAT EXCHANGER FIN

BACKGROUND OF THE INVENTION

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

[0002] Heating, ventilation, air conditioning and refrigeration (HVAC & R) systems include heat exchangers to reject or accept heat between the refrigerant circulating within the system and surroundings. One type of the heat exchanger that has become increasingly popular, due to its compactness, structural rigidity and superior performance is a microchannel or minichannel heat exchanger (MCHX) which includes two or more containment forms, such as tubes, through which a cooling or heating fluid (such as refrigerant or glycol solution) is circulated. The tubes typically have a flattened cross-section and multiple parallel channels. Fins are typically arranged to extend between the tubes to aid in the transfer of thermal energy between the cooling/heating fluid and the surrounding environment. The fins have a corrugated pattern, incorporate louvers to boost heat transfer and are typically secured to the tubes via brazing. Typical MCHX fin and tube arrangements, however, have the disadvantage of retaining large quantities of moisture, water or condensate, within the fin and tube structure, due to their high compactness and thus increased surface tension. The accumulated moisture accelerates corrosion of the fin and tube structure which leads to decreased thermo-hydraulic performance or effectiveness of the heat exchanger and eventual failure of the heat exchanger when the tubes are corroded sufficiently to be perforated, thus releasing the cooling/heating fluid. Further, along with retention of moisture, the typical structure leads to the buildup of corrodant substances and mechanical stresses in the structure leading to stress corrosion which further accelerates deterioration of the fin and tube structure and resultant failure of the heat exchanger. The art would well receive a fin and tube structure which reduces the accumulation of moisture in the heat exchanger matrix thereby reducing corrosion of the heat exchanger.

BRIEF DESCRIPTION OF THE INVENTION

[0003] According to one aspect of the invention, a heat exchanger includes a plurality of tubes, each tube configured for a flow of fluid therethrough and one or more fins located between adjacent tubes of the plurality of tubes. The one or more fins are spaced by a fin pitch (F_P) and are configured to improve thermal energy transfer between the plurality of tubes and ambient air. Each fin includes a fin face extending between the adjacent tubes, a substantially planar fin cap connected to the fin face secured to one or the tubes, and a fin radius (R_C) connecting the fin face to the fin cap such that the fin radius is minimized to promote removal of condensate from the heat exchanger.

[0004] According to another aspect of the invention, a heat exchanger includes a plurality of tubes, each tube configured for a flow of fluid therethrough. One or more fins are located between adjacent tubes of the plurality of tubes. The one or more fins are spaced by a fin pitch (F_P) and are configured to improve thermal energy transfer between the plurality of tubes and ambient air. Each fin includes a fin extension extending beyond a tube width. The extended portion of the fin is laterally flared and shaped to reduce capillary effects and enhance water drainage.

[0005] 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

[0006] 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:

[0007] FIG. **1** is cross-sectional view of an embodiment of a heat exchanger;

[0008] FIG. **2** is another cross-sectional view of an embodiment of a heat exchanger illustrating a fin face, fin cap, fin radius and louver of the heat exchanger;

[0009] FIG. **3** is a cross-sectional view of an embodiment of a heat exchanger illustrating a fin extension;

[0010] FIG. **4** is a cross-sectional view of an embodiment of a heat exchanger including multiple heat exchanger tubes;

[0011] FIG. **5** is a cross-sectional view of an embodiment of a heat exchanger including a fin notch;

[0012] FIG. **6** is a perspective view of an embodiment of a heat exchanger including a fin notch;

[0013] FIG. **7** is a perspective view of an embodiment of a slotted heat exchanger tube; and

[0014] FIG. **8** is a cross-sectional view of a welded slotted heat exchanger tube.

[0015] 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

[0016] Shown in FIG. **1** is an embodiment of a tube and fin arrangement of a heat exchanger **10**. The heat exchanger **10** includes a plurality of tubes **12**. Each tube **12** in the embodiment shown includes multiple channels **14** through which cooling fluid is circulated. In the embodiment of FIG. **1**, each tube includes sixteen channels **14**, but it is to be appreciated that any number of channels **14** may be utilized. A plurality of fins **16** extend between the tubes **12** to aid in increasing heat transfer between the tubes **12** and the surrounding air. In some embodiments, the fins **16** are secured to the tubes **12** by, for example, brazing, or other suitable means such as for instance soldering or gluing, and in some embodiments, the fins **16** may have a fin thickness (F_{TH}) of between about 50 and about 100 microns. It is to be appreciated that the fin thickness is merely exemplary, and other fin thicknesses outside of the described range may be utilized within the scope of the present disclosure. The heat exchanger **10** of FIG. **1** is typically a horizontal tube heat exchanger of the type used in, for example, air conditioning condenser applications. It is to be appreciated that other tube orientations are feasible and within the scope of the invention.

[0017] Referring now to FIG. **2**, the fins **16** are arranged along the tubes **12** and spaced from each other at a fin pitch (F_P) **18**. The fins **16** of some embodiments are folded or corrugated fins **16**. The fin **16** includes a fin face **20** extending between the tubes **12** at a fin angle **74** which, in some embodiments, is nonperpendicular to the tubes **12**, and a fin cap **22**

disposed at each end of the fin face **20** at the tubes **12** and extending along the tubes **12**. The fin **16** is secured to the tubes **12** at the fin cap **22**. The fin cap **22** is substantially planar, and in some embodiments, the fin face **20** is also substantially planar.

[0018] Each fin face **20** includes a plurality of through openings, for example, louvers **24** arrayed along a lateral extent of the fin **16**. The louvers **24** improve heat transfer and also assist in reducing water retention in the heat exchanger by providing an alternate passage for moisture, water, and/or condensate to drain through the heat exchanger **10**. A transition between each fin cap **22** and fin face **20** is a fin radius (R_C) **26**. It is desired to reduce the fin radius **26** in order for a louver height (L_H) **28** to be increased relative to a fin height (F_H) **30**, thus increasing an overall size of the louver **24** opening within the fin **16**. In some embodiments, a ratio of louver height **28** to fin height **30**, L_H/F_H, is between about 0.8 and about 0.95, and the preferred range is between about 0.85 and about 0.92. Further, the fin radius **26** relates to fin pitch **18** such that a ratio of fin radius **26** to fin pitch **18**, R_C/F_P, is between about 0.1 and about 0.4. The preferred range of R_C/F_P is between about 0.2 and about 0.3

[0019] Referring now to FIG. **3**, in some embodiments, a fin width (F_W) **32** extends beyond a tube width **34** by an extension **36** at at least one tube side **38**, and in some embodiments, both tube sides **38**. In some embodiments, the extension **36** extends laterally away from the tube side **38** as well as transversely at least partially across a tube thickness **40**. The resulting extension **36** extends upwardly or downwardly in a horizontal tube **12** heat exchanger **10**, and may be substantially linear or planar in profile, or in other embodiments may be substantially arcuate, a combination of linear and arcuate or other profile. As shown in FIG. **3**, the extension **36** may comprise two planar extension portions **74**, and further, the extension **36** may have a substantially squared-off cross-section. It is to be appreciated, however, that the squared-off cross section is merely exemplary and other cross-sectional shapes are contemplated within the scope of the present disclosure. Extending the extensions **36** upwardly or downwardly reduces surface tension effects and utilizes gravitational forces to encourage flow of condensate **42** away from the tubes **12** thereby reducing corrosion of the tubes **12**. To achieve the desired drainage, it is not required that an extension width (E_W) **44** be overly large relative to the overall fin width (F_W) **32**. In some embodiments, a ratio of extension width **44** to fin width **32**, E_W/F_W, is between about 0.02 and about 0.1, while the preferred E_W/F_W range is between about 0.02 and about 0.04, to enhance the desired drainage effect while minimizing the amount of space utilized by the fins **16** Likewise, a transverse component (E_T) **48** of the extension **36** does not need to be overly great appreciable relative to the tube thickness (T_T) **40** to produce the desired effect. A ratio of the transverse component **48** to the tube thickness **40**, E_T/T_T, is between about 0.05 and about 0.4, while the preferred E_T/T_T range is between about 0.05 and about 0.15. It is desired, however, that the transverse component **48** be relatively large when compared to a fin thickness (F_T) **50** (shown in FIG. **2**). For example, in some embodiments, a ratio between the transverse component **48** and the fin thickness **50**, E_T/F_T, is between about 1 and about 3, while the preferred E_T/F_T range is between about 1.75 and about 2.5. Further, the transverse component **48** is related to the fin radius **26**, such that a ratio of the transverse component **48** to the fin radius, E_T/R_C, is between about 0.2 and about 2.

[0020] Referring now to FIG. **4**, in some embodiments, each fin **16** spans two or more tubes **12** located at each fin cap **22** with a gap (T_G) **52** between adjacent tubes **12**. As shown in FIGS. **5** and **6**, some embodiments include a fin notch **54** substantially aligned with the tube gap **52**. A relationship exists between a tube pitch (T_P) **56**, which is a distance between tubes **12** located at opposing fin caps **22** and a notch height (N_H) **58** of the fin notch **54**. A ratio of the notch height **58** to the tube pitch **56**, $N_H/(T_P-T_T)$ is about 0.15 to about 0.3. In some embodiments, $N_H/(T_P-T_T)$ is about 0.1 to about 0.2 to encourage moisture flow outward toward the extensions **36**. Shown clearly in FIG. **6**, each fin notch **54** has a notch width (N_W) **60** extending in a direction along the length of the tube **12**. The notch width **60** is sized relative to the fin pitch **18**, the fin height **30**, and the tube pitch **56** in order to maximize the gravitational effects and reduction in surface tension desired. The relationship is expressed as follows:

$$N_w/(F_P-\mathrm{Sqrt}(F_H^2-(T_P-T_T)^2)$$

In some embodiments, the relationship equals about 0.3 to about 0.9, while the preferred range of the relationship is about 0.4 to about 0.7.

[0021] Another embodiment is illustrated in FIG. **7**. The embodiment of FIG. **7** illustrates a tube **12** including a tube slot **62** extending therethrough. The tube slot **62** defines an additional egress location for moisture, condensate, and/or water from the heat exchanger **10**. The slot **62** has a slot width (S_W) **66**. A ratio of the slot width **66** to a tube width (T_W) **68**, S_W/T_W, is between about 0.05 and about 0.2 to provide the moisture egress while not significantly reducing an amount of fluid the tube **12** is capable of carrying or effecting heat transfer and pressure drop characteristics of heat exchanger **10**. The slot **62** has a slot length (S_L) **70** extending along a tube length (T_L) **72** of the tube **12**. It is desired for the slot length **70** to be as large as possible given the tube length **72**, to spread its effect over the entire tube length **72**. Thus, a ratio of the slot length **70** to the tube length **72**, S_L/T_L, is between about 0.8 and about 0.95. As shown, the slotted tube **12** may include one or more refrigerant inlets **74** and one or more refrigerant outlets **76**, and may be connected to one or more coolant manifolds **78** at either end of the tube length **72**. The slotted tube **12** may be formed one of many ways including extrusion of the slotted tube **12**. The slot **62** may be formed in a secondary operation by, for example, punching. Referring to FIG. **8**, the slotted tube **12** may be formed by welding of an inner sheet **80** and an outer sheet **82** to a corrugated sheet **84** which forms dividers between adjacent coolant passages **86**.

[0022] 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, each tube configured for a flow of fluid therethrough;

one or more fins disposed between adjacent tubes of the plurality of tubes, the one or more fins spaced by a fin pitch (F_P) and configured to improve thermal energy transfer between the plurality of tubes and ambient air, each fin including:

a fin face extending between the adjacent tubes;

a substantially planar fin cap connected to the fin face secured to one or the tubes; and

a fin radius (R_C) connecting the fin face to the fin cap such R_C is reduced to promote condensate flow from the heat exchanger.

2. The heat exchanger of claim **1** such that a ratio of the fin radius to the fin pitch, R_C/F_P, is between about 0.1 and about 0.4.

3. The heat exchanger of claim **2**, wherein the ratio of the fin radius to the fin pitch, R_C/F_P, is between about 0.2 and about 0.3.

4. The heat exchanger of claim **1**, wherein each fin face includes one or more louvers.

5. The heat exchanger of claim **4**, wherein a ratio of a louver height (L_H) to a fin height (F_H), L_H/F_H, is between about 0.8 and about 0.95.

6. The heat exchanger of claim **5**, wherein L_H/F_H, is between about 0.85 and about 0.92.

7. The heat exchanger of claim **1**, wherein each fin includes a fin extension extending beyond a tube width.

8. The heat exchanger of claim **7**, wherein the fin extension extends laterally beyond the tube width and transversely at least partially across a tube thickness.

9. The heat exchanger of claim **7**, wherein the fin extension is configured to direct moisture accumulated in the fin structure away from the tubes.

10. The heat exchanger of claim **7**, wherein a ratio of an extension width (E_W) to a fin width (F_W), E_W/F_W is between about 0.02 and about 0.1.

11. The heat exchanger of claim **10**, wherein E_W/F_W is between about 0.02 and about 0.04.

12. The heat exchanger of claim **7**, wherein a ratio of a transverse component (E_T) of the fin extension to a tube thickness (T_T), E_T/T_T, is between about 0.05 and about 0.4.

13. The heat exchanger of claim **12**, wherein E_T/T_T is between about 0.05 and about 0.15.

14. The heat exchanger of claim **7**, wherein a ratio of a transverse component (E_T) of the fin extension to a fin thickness (F_T), E_T/F_T, is between about 1 and about 3.

15. The heat exchanger of claim **14**, wherein E_T/F_T, is between about 1.75 and about 2.5.

16. The heat exchanger of claim **7**, wherein a ratio of a transverse component (E_T) of the fin extension to the fin radius, E_T/R_C, is between about 0.2 and about 2.

17. The heat exchanger of claim **1**, wherein each fin of the one or more fins spans two or more tubes along a fin width.

18. The heat exchanger of claim **17**, wherein each fin includes a fin notch in the fin face disposed substantially aligned with a tube gap between two tubes of the two or more tubes.

19. The heat exchanger of claim **18**, wherein a ratio of a notch height (N_H) to a tube pitch (T_P), N_H/T_P, is between about 0.15 and about 0.3.

20. The heat exchanger of claim **19**, wherein N_H/T_P, is between about 0.1 and about 0.2.

21. The heat exchanger of claim **1**, wherein each tube of the plurality of tubes, includes a through slot extending along a length of the tube.

22. The heat exchanger of claim **21**, wherein a ratio of a slot width (S_W) to a tube width (T_W), S_W/T_W, is between about 0.05 and about 0.2.

23. The heat exchanger of claim **21**, wherein a ratio of slot length (S_L) to a tube length (T_L), S_L/T_L, is between about 0.8 and about 0.95.

24. A heat exchanger comprising:

a plurality of tubes, each tube configured for a flow of fluid therethrough;

one or more fins disposed between adjacent tubes of the plurality of tubes, the one or more fins spaced by a fin pitch (Fp) and configured to improve thermal energy transfer between the plurality of tubes and ambient air, each fin including a fin extension extending beyond a tube width.

25. The heat exchanger of claim **24**, wherein the fin extension is configured to direct moisture accumulated in the fin structure away from the tubes.

26. The heat exchanger of claim **24**, wherein a ratio of an extension width (E_W) to a fin width (F_W), E_W/F_W is between about 0.02 and about 0.1.

27. The heat exchanger of claim **26**, wherein E_W/F_W is between about 0.02 and about 0.04.

28. The heat exchanger of claim **24**, wherein a ratio of a transverse component (E_T) of the fin extension to a tube thickness (T_T), E_T/T_T, is between about 0.05 and about 0.4.

29. The heat exchanger of claim **28**, wherein E_T/T_T is between about 0.05 and about 0.15.

30. The heat exchanger of claim **24**, wherein a ratio of a transverse component (E_T) of the fin extension to a fin thickness (F_T), E_T/F_T, is between about 1 and about 3.

31. The heat exchanger of claim **30**, wherein E_T/F_T, is between about 1.75 and about 2.5.

32. The heat exchanger of claim **24**, wherein each fin includes:

a fin face extending between the adjacent tubes and;

a substantially planar fin cap connected to the fin face secured to one or the tubes; and

a fin radius (R_C) connecting the fin face to the fin cap such that a ratio of the fin radius to the fin pitch, R_C/F_P, is between about 0.1 and about 0.4.

33. The heat exchanger of claim **32**, wherein the ratio of the fin radius to the fin pitch, R_C/F_P, is between about 0.2 and about 0.3.

34. The heat exchanger of claim **32**, wherein each fin face includes one or more louvers.

35. The heat exchanger of claim **34**, wherein a ratio of a louver height (L_H) to a fin height (F_H), L_H/F_H, is between about 0.8 and about 0.95.

36. The heat exchanger of claim **35**, wherein L_H/F_H, is between about 0.85 and about 0.92.

* * * * *