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(54) **NON-METALLIC BAFFLE FOR HEAT EXCHANGER**

(57) NON-METALLIC BAFFLE FOR HEAT EXCHANGERA tube bundle assembly (64) includes at least one tube (66) and a baffle (72). The baffle (72) includes at least one hole (74) for receiving the at least one tube (66). The at least one hole (74) has a non-uniform diameter such that only a portion of a periphery of the at least one hole (74) is positionable in contact with the at least one tube (66).

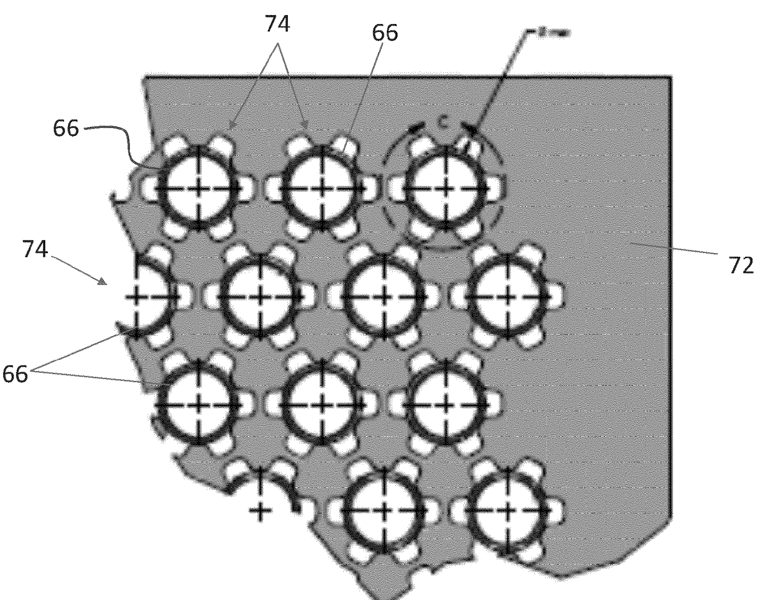

FIG. 5

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Description

[0001] Embodiments of the present invention pertain to the art of heat exchangers, and more particularly, to a baffle used to support a plurality of tubes of a heat exchanger.

[0002] Heat exchangers commonly used in vapor compression system (e.g., chillers) include a tube bundle conventionally formed from copper tubes. These tube bundles are typically supported by a rigid connection formed between the tubes of the tube bundle and two or more spaced steel support plates or baffles, which are commonly metallic. To form this rigid connection, the tubes can be swaged into the baffles.

[0003] During operation of the vapor compression system, the tube bundle is subject to vibrations along with expansion and contraction due to changes in temperature during the heat exchange process. As a result, significant abrasion and wear can occur on the tubes at the locations where they contact the baffles, which can result in a friction failure over time. Accordingly, there remains a need for a solution to improve the interface between the tube bundle and the baffles.

[0004] According to a first aspect of the present invention, a tube bundle assembly includes at least one tube and a baffle having at least one hole for receiving the at least one tube. The at least one hole has a non-uniform diameter such that only a portion of a periphery of the at least one hole is positionable in contact with the at least one tube.

[0005] Optionally, the baffle is formed from a non-metallic material.

[0006] Optionally, the baffle is formed from a polymeric or elastomeric material.

[0007] Optionally, the at least one tube is formed from an aluminum material.

[0008] Optionally, the at least one hole has a plurality of lobes protruding inwardly towards a center of at least one hole.

[0009] Optionally, the plurality of lobes are equidistantly spaced about the at least one hole.

[0010] Optionally, the plurality of lobes includes between three and ten lobes.

[0011] Optionally, a configuration of each of the plurality of lobes is substantially identical.

[0012] Optionally, each of the plurality of lobes has a land positionable in contact with the at least one tube.

[0013] Optionally, the land is positionable in line contact with the at least one tube.

[0014] Optionally, the land has a convex curvature.

[0015] Optionally, the convex curvature has a radius C and a diameter B extends between an origin of the radius C for oppositely positioned lobes at the at least one hole, wherein the radius C is between .09 and . 15 times the diameter B.

[0016] According to a second aspect of the present invention, a vapor compression system includes a compressor for circulating a refrigerant and a tube bundle assembly for transferring the refrigerant through a shell of the vapor compression system. The tube bundle assembly comprising a plurality of tubes and at least one baffle. The at least one baffle includes a plurality of holes for receiving the plurality of tubes, wherein each respective hole comprises a non-uniform diameter such that only a portion of a periphery of each hole is positionable in contact with each tube.

[0017] Optionally, the plurality of holes are arranged in a plurality of rows, and a diameter A is defined by an outermost surface of the plurality of holes surrounding each hole of the plurality of holes.

[0018] Optionally, holes in adjacent rows are separated by a first axial distance P and the first axial distance P is between .75 and 1.2 times the diameter A.

[0019] Optionally, adjacent holes within the same row are separated by a second axial distance Rw and the second axial distance Rw is between .8 and 1.5 times the diameter A.

[0020] Optionally, each respective hole comprises a plurality of lobes protruding inwardly towards a center of the respective hole.

[0021] Optionally, each of the plurality of lobes comprises a land positionable in contact with the tube.

[0022] Optionally, the land of each of the plurality of lobes defines a maximum allowable diameter of the at least one tube and the diameter A is between .81 and 1.16 times the maximum allowable diameter.

[0023] Optionally, a base of each of the plurality of lobes has a fillet radius Z and the fillet radius Z is between .05 and 1.1 times the diameter A.

[0024] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

FIG. 1 is a schematic diagram of an exemplary vapor compression system;

FIG. 2 is a cross-sectional view of an exemplary heat exchanger of a vapor compression system, embodied as a chiller;

FIG. 3 is a perspective view of an exemplary tube bundle of a heat exchanger;

FIG. 4 is an end view of an exemplary baffle for use with the tube bundle of FIG. 3;

FIG. 5 is a detailed view of a portion of the baffle of FIG. 4

FIG. 6 is a detailed view of a hole formed in the baffle; and

FIG. 7 is a detailed view of a plurality of holes formed in the baffle.

[0025] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0026] With reference now to FIG. 1, an example of a vapor compression system 20, and more particularly a chiller system, having a closed fluid loop within which a refrigerant R or other fluid circulates is provided. As shown, the vapor compression system 20 includes a compressor 22 having a suction port (inlet) 24 and a discharge port (outlet) 26. The vapor compression system 20 further includes a first, heat rejection heat exchanger 28, for example a condenser. The vapor compression system 20 additionally includes a second, heat absorption heat exchanger 30, for example an evaporator, located downstream from the heat rejection heat exchanger 28. Further, an expansion device 32 is located along the fluid flow path downstream of the compressor 22 and upstream of the evaporator heat absorption heat exchanger. As shown, the expansion device 32 may be located at a position along the fluid loop between the heat rejection heat exchanger 28 and the heat absorption heat exchanger 30.

[0027] In the illustrated-non-limiting embodiment, the heat rejection heat exchanger 28 is a water-cooled heat exchanger such that the refrigerant within the heat exchanger is cooled by a flow of an external flow of water. Accordingly, the vapor compression system of FIG. 1 may be referred to herein as a water-cooled chiller. The flow of water may be delivered from a source 36, such as a cooling tower for example, located directly adjacent to the heat rejection heat exchanger 28, or alternatively, located remotely from a heat rejection heat exchanger 28, such as at a different location within a building being conditioned by the vapor compression system 20 for example. As shown, a pump 38 may be used to circulate a flow of cool water from the cooling tower 36 to the heat rejection heat exchanger 28 and also to return a flow of heated water to the cooling tower 36 from the heat rejection heat exchanger 28. Within the cooling tower 36, the water may be cooled via a flow of an external gas driven by a fan 40, such as an air-flow for example, before being returned to the heat rejection heat exchanger 28. Although the heat rejection heat exchanger 28 is described herein as the water-cooled heat exchanger, in other embodiments the heat absorption heat exchanger may alternatively, or additionally be configured as an air-cooled heat exchanger. It should be understood that the vapor compression system 20 illustrated and described herein is a simplified system and that a vapor compression system 20 having additional components is also within the scope of the invention.

[0028] With reference now to FIGS. 2-3, various detailed views of a heat exchanger 50, such as the heat rejection heat exchanger of the water-cooled chiller are provided. In the illustrated, non-limiting embodiment, the heat exchanger 50 has a shell and tube configuration. As shown, the shell 52 has a generally cylindrical body with a hollow interior 54 and is capped at opposite ends by manifolds 56, 58. An inlet port 60 for the refrigerant may be formed at a first location of the shell 52, such as near a bottom of the shell 52 for example, and an outlet port 62 may be formed at a second location of the shell 52, such as near a top portion thereof for example. A tube bundle 64 including a plurality of tubes 66 is positioned within the hollow interior 54 of the shell 52. Although the tubes 66 are illustrated as having a circular cross-section, embodiments where the tubes 66 have another configuration are also contemplated herein. The tube bundle 64 generally spans the width of the shell 52, extending between the manifolds 56, 58. A tube inlet 68 and a tube outlet 70 are arranged in fluid communication with the at least one tube of the tube bundle.

[0029] In operation, a refrigerant circulating through the vapor compression system 20 is provided to the heat exchanger 50 via the inlet 60. At the same time, a secondary fluid W, such as water for example, is provided to the tube bundle 64 via the tube inlet 68. As the secondary fluid W flows within the tubes 66 between the tube inlet 68 and the tube outlet 70, heat is transferred between the refrigerant R and the secondary fluid W. Accordingly, in embodiments where the heat exchanger 50 is a heat rejection heat exchanger, a warmed secondary fluid W is provided at the tube outlet 70 and a cooled liquid refrigerant R is provided at the outlet 62. Although both the tube inlet 68 and the tube outlet 70 are illustrated as being arranged at the same manifold 56, embodiments where the tube inlet 68 and the tube outlet 70 are arranged at opposite manifolds are also within the scope of the present invention.

[0030] The tube bundle 64 may be operably coupled to one or more tube sheets or baffles 72 to not only maintain the relative position of the tubes 66 within the tube bundle 64, and also to maintain the position of the tube bundle 64 relative to the shell 52. In the illustrated, non-limiting embodiment, the heat exchanger 50 includes a plurality of baffles 72 (shown in FIG. 3) spaced at intervals over an axial length of the tube bundle 64, between the manifolds 56, 58. Each baffle 72 has at least one hole 74 (shown in FIG. 4) formed therein for receiving the plurality of tubes 66 of the tube bundle 64. As shown, the total number of holes 74 may be equal to the total number of tubes 66 within the tube bundle 64 such that each tube 66 is receivable within a corresponding hole 74 of the baffle 72. The plurality of tubes 66 is laced through the plurality of holes 74 and may be arranged in direct contact with the baffle 72 at the hole 74.

[0031] One or more of the baffles 72, such as each baffle for example, is formed from a non-metallic material. In an embodiment, the baffle 72 is formed from a polymeric or elastomeric material with or without internal reinforcements. Further, a configuration of the holes 74 formed in the baffle 72 may be selected to engage and restrict movement of a tube 66 received therein without another mechanical connection. As shown, one or more of the holes 74 formed in the baffle 72 has a non-uniform diameter. With reference now to FIGS. 5-7, in an embodiment, a hole 74 includes a one or more teeth or lobes 76 that protrude inwardly towards the center of the hole 74. Although the holes 74 illustrated in the FIGS. include six lobes 76, it should be understood that embodiments having any suitable number of lobes 76 is contemplated herein. For example, in an embodiment, a hole 74 formed in the baffle 72 has between three and ten lobes 76, and in some embodiment between 4 and 8 lobes 76. In embodiments where a hole 74 includes a plurality of lobes 74, a configuration of each of the plurality of the lobes 76 may be substantially identical, or may vary. Further, the plurality of lobes 76 may be equidistantly spaced about a periphery of the hole 74, or alternatively, may be non-uniformly spaced.

[0032] As shown, the lobes 76 may have a fillet radius Z formed at the curve of a base thereof. Further, each of the lobes 76 has a land 78 arranged at the innermost surface thereof. In an embodiment, the diameter of the land 78 defines the maximum allowable diameter of the tube 66 receivable within the hole 74. The contour or configuration of the land 78 may be selected to maintain contact with a tube 66 over the substantially entire surface of the land 78, or alternatively, may be designed such that only a portion of the land 78 is arranged in contact with the tube 66. In the illustrated, non-limiting embodiment, the land 78 has a convex curvature defined by a radius C such that the land 78 is arranged in line contact with a tube 66 (and in point contact in the cross-sectional view of FIG. 6). The friction between the land 78 and the exterior surface of the tube 66 may form a self-locking interface, thereby restricting movement of the tube 66 relative to the baffle 72. In an embodiment, a diameter B is defined between an origin of the radius of curvature C for oppositely positioned lobes 76.

[0033] As shown in FIGS. 5 and 7, the holes 74 may be arranged in a plurality of rows positioned over the height of the baffle 72, and the holes 74 within adjacent rows may be offset or staggered relative to one another. With reference to FIG. 7, a first axial distance between the center of holes 74 located in adjacent rows of the baffle 72 and extending in a first direction is represented by P. Similarly, a second axial distance between a center of adjacent holes 74 within the same row and extending in a second direction, oriented orthogonal to the first direction, is represented by Rw. In the illustrated, non-limiting embodiment, the second axial distance Rw is measured within a horizontally oriented plane. Although the distance P is illustrated as being a vertical distance and the distance Rw is illustrated as a horizontal distance, embodiments where one or both of P and Rw are measured along another axis are also contemplated herein. In some embodiments, P and Rw are substantially identical, and in other embodiments, P and Rw may vary.

[0034] Further, A is a diameter defined by the outermost surface of a plurality of holes 74 within the same row and the adjacent rows. For example, at a centrally located hole within a central row, the diameter A is defined by the outermost surface of the holes to the left and right of the centrally located hole, and by the outermost surface of the adjacent holes in the row above and below the central row. The diameter A relative to the maximum allowable tube diameter defined by the lobes may be between about .81 and 1.16. In an embodiment, the distance P is between about .75 and about 1.2 times the diameter A, and the distance Rw is between .8 and about 1.5 times the diameter A. The diameter A may be between about .77 and about 1.33 times the diameter B. With reference now to the curvatures of the lobes, the fillet radius Z may be between about .05 and 1.1 times the diameter A and in an embodiment, the radius C of the land 78 may be between about .09 and about .15 times the diameter B.

[0035] By using a non-metallic baffle 72, the tubes 66 can be formed from an aluminum material rather than a costly copper material. Further, by forming holes 74 in the baffle 72 having one or more lobes 76 configured to frictionally engage, and therefrom grip a respective tube 66, the need to swage the tubes into the baffles, in applications that currently requires swaging is eliminated. The non-metallic baffles 72 disclosed herein may also be used in applications where swaging is not needed currently, by sizing the lobe geometries accordingly to reduce the amount of gripping force. As a result, the cost of material and labor associated with the heat exchanger 50 is reduced.

[0036] The term "about" is intended to include the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application.

[0037] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.

[0038] While the present invention has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements of the described embodiment(s) without departing from the scope of the present invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings herein without departing from the scope of the present invention. Therefore, it is intended that the present invention not be limited to the particular embodiment disclosed, but that the present invention will include all embodiments falling within the scope of the claims.

Claims

1. A tube bundle assembly (64) comprising:

   at least one tube (66); and
   a baffle (72) comprising at least one hole (74) for receiving the at least one tube, wherein the at least one hole comprises a non-uniform diameter such that only a portion of a periphery of the at least one hole is positionable in contact with the at least one tube.

2. The tube bundle assembly of claim 1, wherein the baffle is formed from a non-metallic material,
   optionally wherein the baffle is formed from a polymeric or elastomeric material and/or the at least one tube is formed from an aluminum material.

3. The tube bundle assembly of claim 1 or 2, wherein the at least one hole has a plurality of lobes (76) protruding inwardly towards a center of at least one hole.

4. The tube bundle assembly of claim 3, wherein the plurality of lobes are equidistantly spaced about the at least one hole.

5. The tube bundle assembly of claim 3 or 4, wherein the plurality of lobes comprises between three and ten lobes.

6. The tube bundle assembly of claim 3, 4 or 5, wherein a configuration of each of the plurality of lobes is substantially identical.

7. The tube bundle assembly of any of claims 3 to 6, wherein each of the plurality of lobes has a land (78) positionable in contact with the at least one tube,

8. The tube bundle assembly of claim 7, wherein the land has a convex curvature,
   optionally wherein the convex curvature has a radius C and a diameter B extends between an origin of the radius C for oppositely positioned lobes at the at least one hole, wherein the radius C is between .09 and .15 times the diameter B.

9. A vapor compression system (20) comprising:

   a compressor (22) for circulating a refrigerant; and
   a tube bundle assembly (64) for transferring the refrigerant through a shell of the vapor compression system, the tube bundle assembly comprising a tube bundle assembly according to any preceding claim,
   wherein the at least one tube comprises a plurality of tubes;
   wherein the at least one hole comprises a plurality of holes for receiving the plurality of tubes; and
   wherein each respective hole comprises a non-uniform diameter such that only a portion of a periphery of each hole is positionable in contact with each tube.

10. The vapor compression system of claim 9, wherein the plurality of holes are arranged in a plurality of rows, and a diameter A is defined by an outermost surface of the plurality of holes surrounding each hole of the plurality of holes.

11. The vapor compression system of claim 9 or 10, wherein holes in adjacent rows are separated by a first axial distance P and the first axial distance P is between .75 and 1.2 times the diameter A.

12. The vapor compression system of claim 9, 10 or 11, wherein adjacent holes within the same row are separated by a second axial distance Rw and the second axial distance Rw is between .8 and 1.5 times the diameter A.

13. The vapor compression system of any of claims 9 to 12, wherein each respective hole comprises a plurality of lobes protruding inwardly towards a center of the respective hole.

14. The vapor compression system of claim 13, wherein each of the plurality of lobes comprises a land positionable in contact with the tube,
    optionally wherein the land of each of the plurality of lobes defines a maximum allowable diameter of the at least one tube and the diameter A is between .81 and 1.16 times the maximum allowable diameter.

15. The tube bundle of claim 13 or 14, wherein a base of each of the plurality of lobes has a fillet radius Z and the fillet radius Z is between .05 and 1.1 times the diameter A.

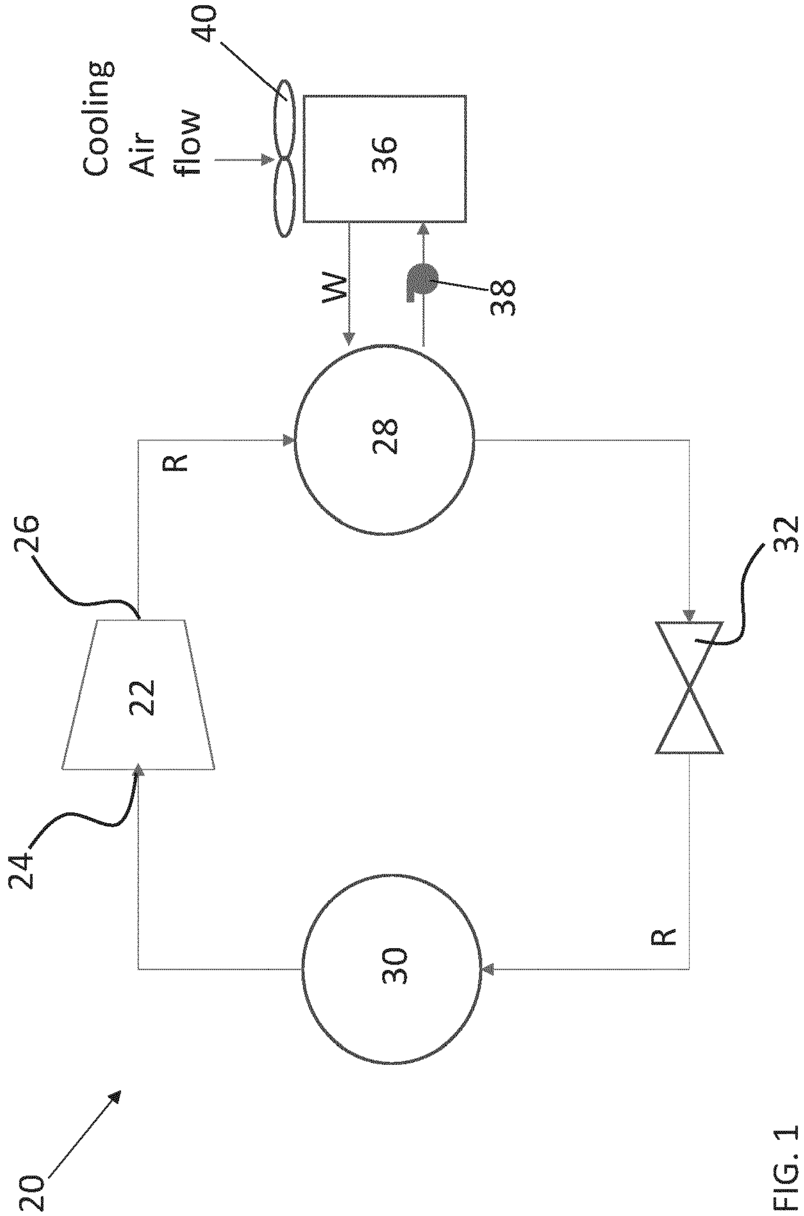

FIG. 1

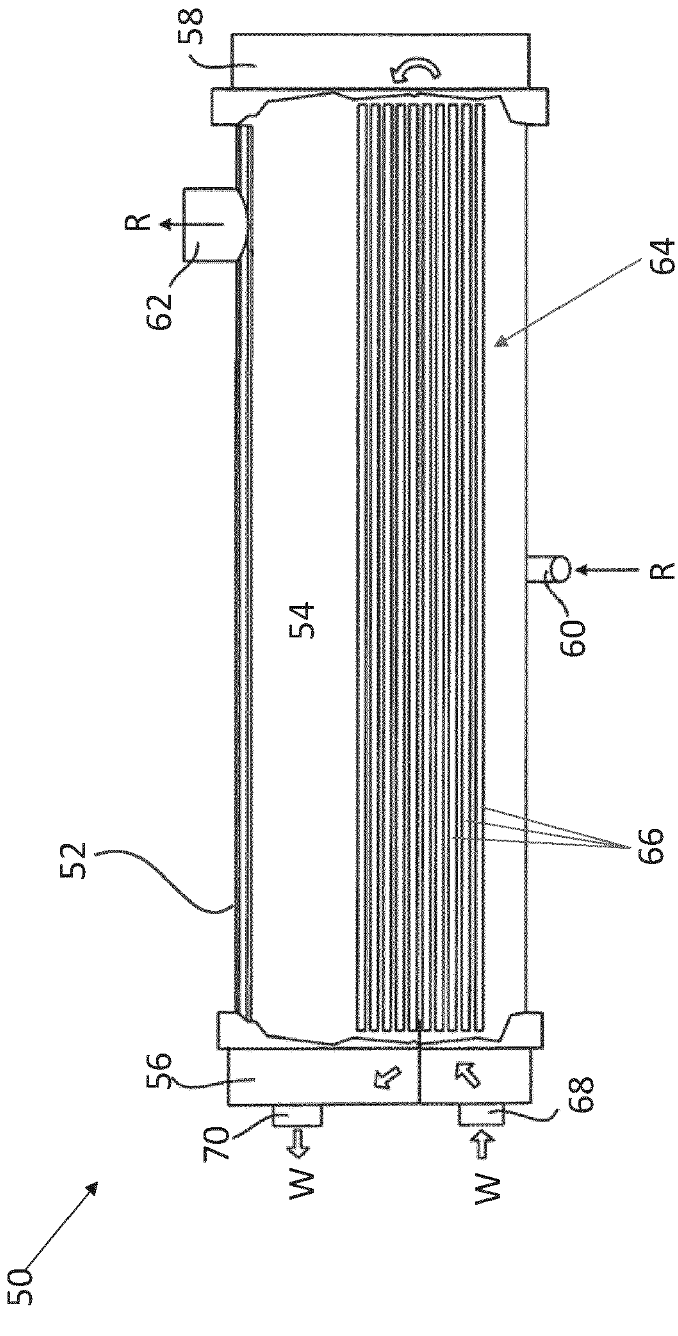

FIG. 2

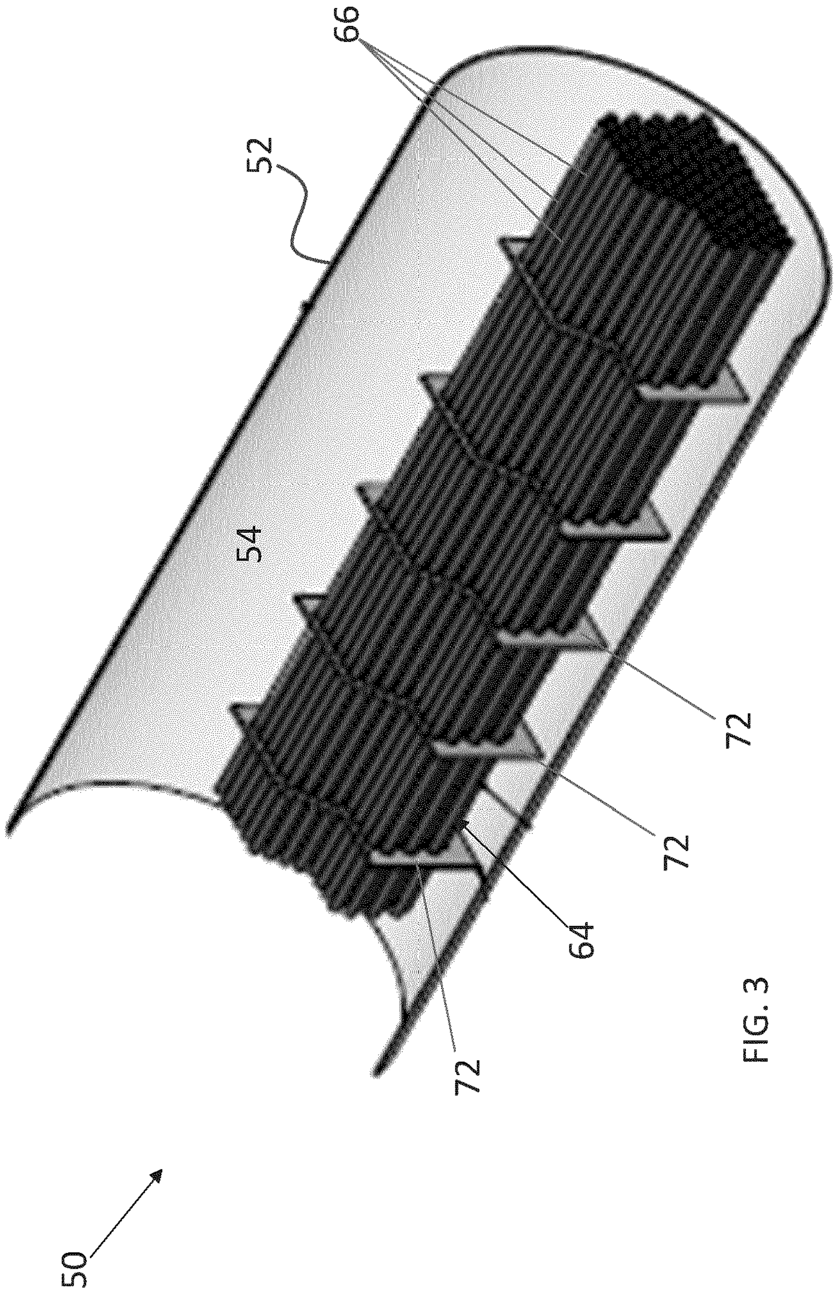

FIG. 3

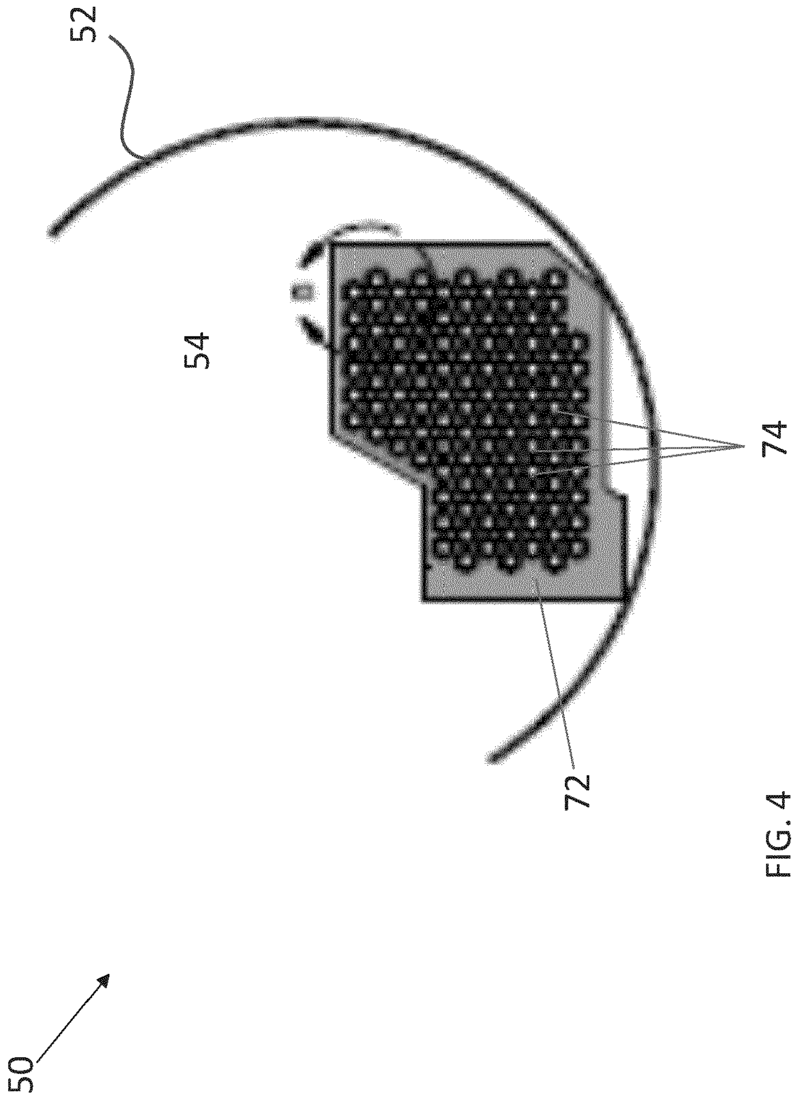

FIG. 4

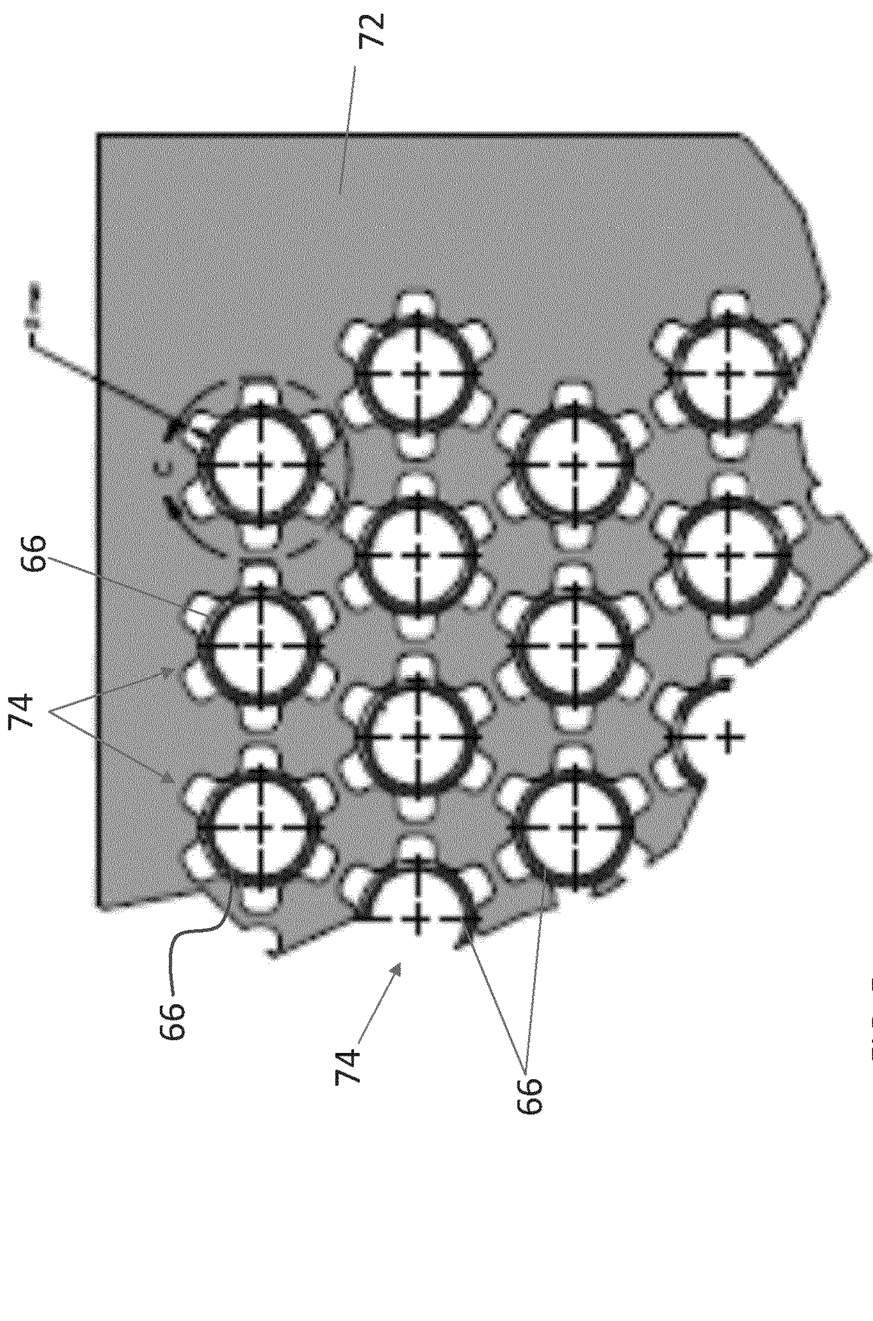

FIG. 5

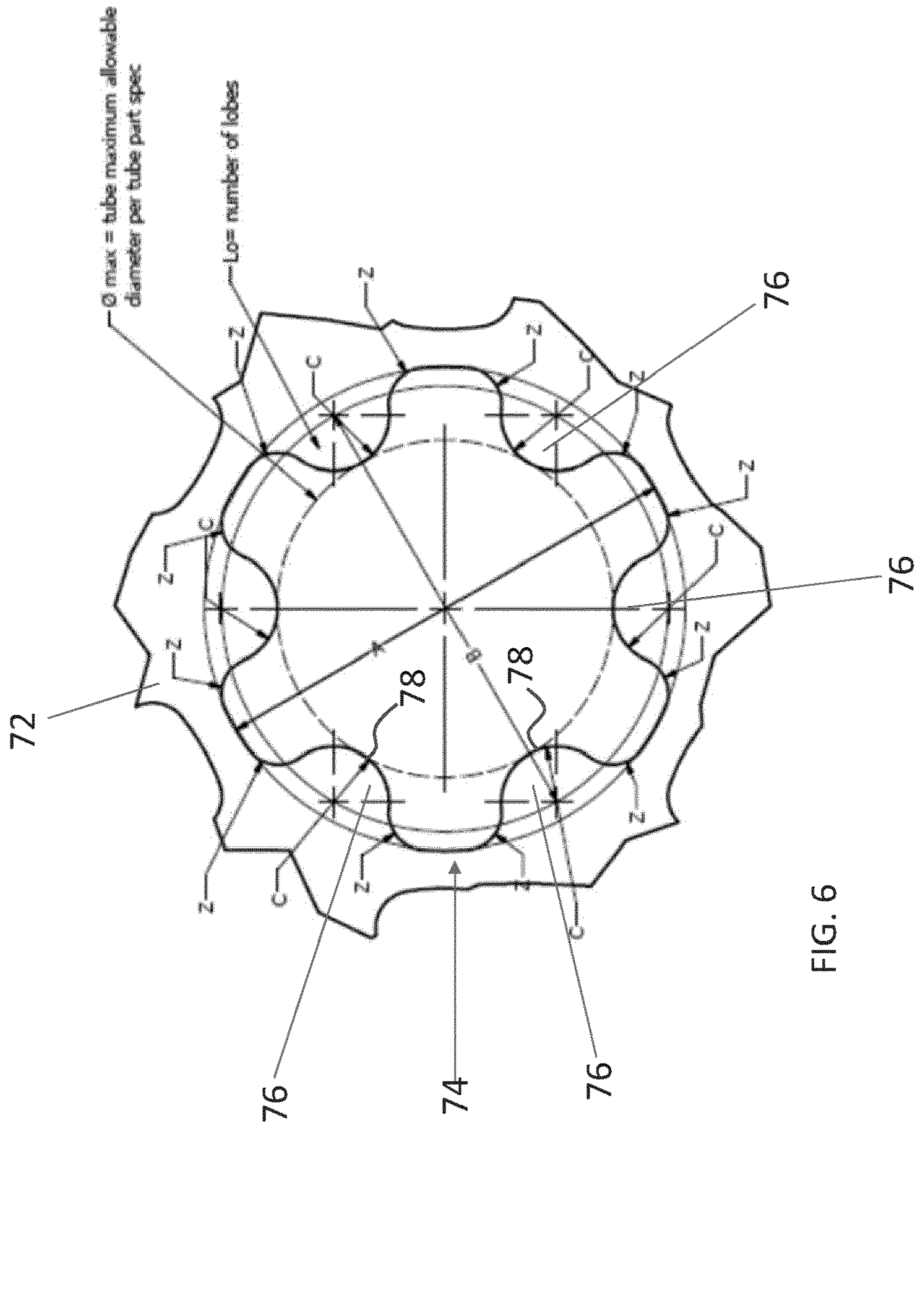
Ø max = tube maximum allowable diameter per tube part spec
Lo= number of lobes
72
74
76
76
76
76
78
78
Z
C
A
B

FIG. 6

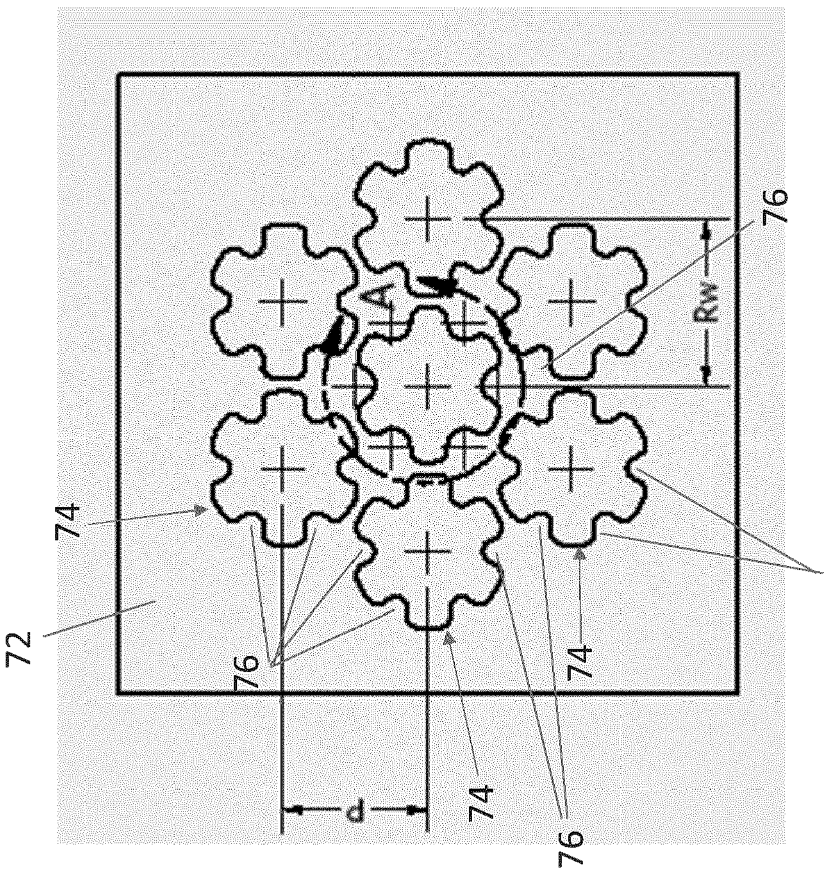

FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	30 June 2023	Mellado Ramirez, J

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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