(19) Europäisches Patentamt
European Patent Office
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(11) EP 4 174 431 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
**03.05.2023 Bulletin 2023/18**

(21) Application number: **22204917.3**

(22) Date of filing: **01.11.2022**

(51) International Patent Classification (IPC):
***F28F 1/02*** (2006.01) ***F28D 1/03*** (2006.01)

(52) Cooperative Patent Classification (CPC):
**F28D 1/0391; F28D 1/05391; F28F 1/022;**
F28B 1/06; F28D 1/024; F28D 2021/007;
F28F 1/128

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
**BA**
Designated Validation States:
**KH MA MD TN**

(30) Priority: **02.11.2021 US 202163274719 P**

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(54) **FABRICATED HEAT EXCHANGE TUBE FOR MICROCHANNEL HEAT EXCHANGER**

(57) A heat exchange tube segment 46 for use in a heat exchanger 40 includes a fabricated tube body having an upper surface 54, a lower surface 56, a leading edge 50, a trailing edge 52, and a plurality of fluidly distinct flow channels 60 formed therein. The fabricated tube body has a length L, width W, height, and a total tube cross-sectional area measured between the upper surface 54, the lower surface 56, the leading edge 50, and the trailing edge 52. A ratio of the width W to the height of the fabricated tube body is between about 10 and 20 and a ratio of the width W to a number of the plurality of fluidly distinct flow channels 60 is between 1 and 2.5. Each of the plurality of fluidly distinct flow channels 60 forms an open area in a cross-section of the fabricated tube body, and a ratio of the open area to the total tube cross-sectional area is between 0.3 and 0.44.

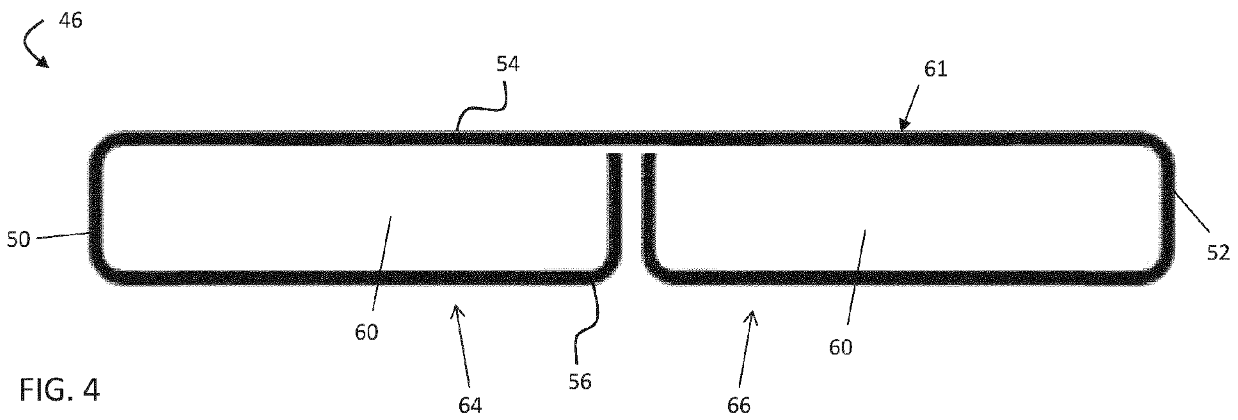


FIG. 4

EP 4 174 431 A1

## Description

**[0001]** Embodiments of the present disclosure relate to the art of heat exchangers, and more particularly, to a heat exchange tube segment for use in a heat exchanger.

**[0002]** Heat exchange tubes typically used in existing microchannel heat exchangers are extruded. Because the weight and the cost of fabricated heat exchange tubes are reduced compared to extruded heat exchange tubes, fabricated heat exchange tubes are becoming more common in heating, ventilation, and air conditioning (HVAC) applications. However, when fabricated heat exchange tubes are used in place of extruded heat exchange tubes, in certain circumstances, the oil entrained within the refrigerant may accumulate within the heat exchange tubes, thereby reducing the efficiency of the system.

**[0003]** According to an aspect, a heat exchange tube segment for use in a heat exchange includes a fabricated tube body having an upper surface, a lower surface, a leading edge, a trailing edge, and a plurality of fluidly distinct flow channels formed therein. The fabricated tube body has a length, width, height, and a total tube cross-sectional area measured between the upper surface, the lower surface, the leading edge, and the trailing edge. A ratio of the width to the height of the fabricated tube body is between about 10 and 20, and a ratio of the width to a number of the plurality of fluidly distinct flow channels is between 1 and 2.5. Each of the plurality of fluidly distinct flow channels forms an open area in a cross-section of the fabricated tube body, and a ratio of the open area to the total tube cross-sectional area is between 0.3 and 0.44.

**[0004]** The ratio of the width to the number of the plurality of fluidly distinct flow channels may be between 1.3 and 2.5.

**[0005]** The ratio of the open area to the total tube cross-sectional area may be between 0.36 and 0.40.

**[0006]** The plurality of fluidly distinct flow channels may be configured to receive a refrigerant optionally selected from methylene fluoride and difluoromethylene.

**[0007]** The fabricated tube body may include a single piece of material folded to form the upper surface, the lower surface, the leading edge, the trailing edge, and the plurality of fluidly distinct flow channels.

**[0008]** According to an aspect, a heat exchanger includes a first manifold, a second manifold, and a plurality of heat exchange tube segments extending between and fluidly coupling the first manifold and the second manifold. At least one the plurality of heat exchange tube segments further includes a fabricated tube body having an upper surface, a lower surface, a leading edge, a trailing edge, and a plurality of fluidly distinct flow channels formed therein. The fabricated tube body has a length measured parallel to the plurality of fluidly distinct flow channels, a width measured between the leading edge and the trailing edge, a height measured between the upper surface and the lower surface, and a total tube cross-sectional area measured between the upper surface, the lower surface, the leading edge, and the trailing edge. A ratio of the width to the height of the fabricated tube body is between about 10 and 20, a ratio of the width to a number of the plurality of fluidly distinct flow channels is between 1 and 2.5. Each of the plurality of fluidly distinct flow channels forms an open area in a cross-section of the fabricated tube body and a ratio of the open area to the total tube cross-sectional area is between 0.3 and 0.44.

**[0009]** The heat exchanger may have a multi-pass configuration.

**[0010]** The heat exchanger may have a first pass and a second pass, and a number of heat exchange tube segments associated with the first pass may be greater than a number of heat exchange tube segments associated with the second pass.

**[0011]** A ratio of the number of heat exchange tube segments associated with the first pass to the number of heat exchange tube segments associated with the second pass may be between 1 and 3.

**[0012]** A ratio of the number of heat exchange tube segments associated with the first pass to the number of heat exchange tube segments associated with the second pass may be between 1.2 and 3.

**[0013]** The ratio of the width to the number of the plurality of fluidly distinct flow channels may be between 1.3 and 2.5.

**[0014]** The ratio of the open area to the total tube cross-sectional area may be between 0.36 and 0.40.

**[0015]** The plurality of fluidly distinct flow channels may be configured to receive a refrigerant, the refrigerant optionally being one of methylene fluoride and difluoromethylene.

**[0016]** The fabricated tube body may comprise a single piece of material folded to form the upper surface, the lower surface, the leading edge, the trailing edge, and the plurality of fluidly distinct flow channels.

**[0017]** The heat exchanger may be a condenser in a chiller.

**[0018]** The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike.

**[0019]** Certain exemplary embodiments will now be described in greater detail by way of example only and with reference to the accompanying drawings in which:

FIG. 1 is a perspective view of an exemplary chiller;

FIG. 2A is a perspective view of an exemplary heat exchanger;

FIG. 2B is a side view of another exemplary heat exchanger;

FIG. 3 is a cross-sectional view of an exemplary heat exchange tube segment of a heat exchanger;

FIG. 4 is a cross-sectional view of an exemplary heat exchange tube segment;

FIG. 5 is a cross-sectional view of another exemplary heat exchange tube segment;

FIG. 6 is a perspective view of another exemplary heat exchange tube segment; and

FIG. 7 is a perspective view of another exemplary heat exchange tube segment.

**[0020]** 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.

**[0021]** FIG. 1 shows an exemplary embodiment of a chiller or outdoor unit 20 comprising at least one coil unit 22. The chiller 20 may be configured to perform heating, cooling, and air exchange via a vapor compression cycle as is known. In the illustrated, non-limiting embodiment, the chiller 20 includes a plurality of axially aligned or stacked coil units 22, such as three coil units for example; however, it should be understood that a chiller 20 having any number of coil units 22 including a single coil unit, two coil units, or more than three coil units are within the scope of the disclosure. Each of the coil units 22 typically includes a frame 24 having a heat exchanger assembly 26 mounted therein. In embodiments of the chiller 20 including a plurality of coil units 22, the heat exchanger assembly 26 of a coil unit 22 may, but need not be fluidly coupled with the heat exchanger assembly 26 of at least one other coil unit 22 relative to a flow of refrigerant. The refrigerant may be configured to flow through the heat exchanger assemblies 26 in series or in parallel.

**[0022]** Each coil unit 22 additionally includes a fan assembly 28 having at least one fan configured to move a flow of ambient air across the adjacent heat exchanger assembly 26. A plurality of compressors 30, such as positioned within the frame 24 of one or more of the coil units 22, are fluidly coupled to the heat exchanger assemblies 26 and are configured to pump refrigerant through a vapor compression cycle. The compressors 30 may be arranged in series, or alternatively, may be arranged in parallel relative to the flow of refrigerant. For example, in the illustrated, non-limiting embodiment, three compressors 30 are illustrated as being fluidly coupled to the heat exchanger assemblies 26 of two coil units 22. However, any number of compressors 30 may be in fluid communication with any number of heat exchanger assemblies 26. The chiller or outdoor unit 20 illustrated and described herein are intended as an example only, and it should be understood that other configurations of the chiller and of the coil units are contemplated herein.

**[0023]** Referring now to FIG. 2A, a perspective view of an example of a heat exchanger 40, such as suitable for use in a coil unit 22, is illustrated. In an embodiment, the heat exchanger 40 is suitable for use as a condenser in a vapor compression cycle. As shown, the heat exchanger 40 includes a first manifold or header 42, a second manifold or header 44 spaced apart from the first manifold 42, and a plurality of heat exchange tube segments 46 extending in a spaced parallel relationship between and fluidly connecting the first manifold 42 and the second manifold 44. In the illustrated, non-limiting embodiments, the first manifold 42 and the second manifold 44 are oriented generally vertically, and the heat exchange tube segments 46 extend generally horizontally between the two manifolds 42, 44. The manifolds 42, 44 may comprise hollow, closed end cylinders having a circular cross-section. However, manifolds 42, 44 having other cross-sectional shapes, such as semi-elliptical, square, rectangular, hexagonal, octagonal, or other cross-sections for example, are within the scope of the disclosure.

**[0024]** In an embodiment, best shown in FIG. 2B, the heat exchanger 40 has a multi-pass configuration relative to a secondary fluid A (e.g., air, air having dilute ethylene gas therein, nitrogen, and the like). To achieve a multi-pass configuration, one or more partition plates 48 are mounted within at least one of the first manifold 42 and the second manifold. In the illustrated, non-limiting embodiment, a partition plate is arranged within the first manifold 42, thereby separating the first manifold 42 into a first chamber 42a and a second chamber 42b. In operation, refrigerant R is configured to flow from the first manifold 42 to the second manifold 44 through the portion of the heat exchange tube segments 46 fluidly connected to the first chamber 42a in a first direction. From the second manifold 44, the flow of refrigerant will be directed in a second direction through the portion of heat exchange tube segments 46 arranged in fluid communication with the second chamber 42b of the first manifold 42. In an embodiment, the refrigerant is selected from a HFC-32 Methylene Fluoride or a difluoromethylene ($C_H2F_2$). However, embodiments where the refrigerant is another suitable fluid are also within the scope of the disclosure.

**[0025]** With reference now to FIG. 3, each heat exchange tube segment 46 comprises a leading edge 50, a trailing edge 52, a first upper surface 54, and a second lower surface 56. The leading edge 50 of each heat exchange tube segment 46 is upstream of its respective trailing edge 52 with respect to the flow of the heat transfer fluid A through the heat exchanger 40. The interior flow passage of each heat exchange tube segment 46 may be divided by interior walls 58 into a plurality of fluidly distinct flow channels 60 that extend longitudinally over the length of the heat exchange tube segment 46 and establish fluid communication between the respective first and second manifolds 42, 44. The discrete flow channels 60 may have a circular cross-section, a rectangular cross-section, a trapezoidal cross-section, a triangular cross-section, or another non-circular cross-section (e.g., elliptical, star shaped, closed polygon having straight or curved sides).

**[0026]** The heat exchange tube segments 46 disclosed herein may further include a plurality of fins 62. In an embodiment, each fin 62 is formed of a single continuous strip of fin material tightly folded in a ribbon-like serpentine fashion thereby providing a plurality of closely spaced fins that extend generally orthogonal to the heat exchange tube segments 46. Typically, the fin density of the closely spaced fins of each continuous folded fin may be about 16 to 25 fins per inch (or around 6 to 10 fins per cm), but higher or lower fin densities may also be used. Heat exchange between the refrigerant flow, R, and air flow, A, occurs through the outside surfaces 54, 56, respectively, of the heat exchange tube segments 46, collectively forming a primary heat exchange surface, and also through the heat exchange surface of the fins 62, which forms the secondary heat exchange surface.

**[0027]** With reference now to FIGS. 4-6, in an embodiment, the heat exchange tube segments 46 are fabricated tube segments, having a tube body formed using one or more generally planar pieces or sheets of material 61. The materials that may be used include, but are not limited to, sheet metal and non-metallic materials, such as polymers, thermally enhanced polymer-based composites, or other suitable materials for example. In the illustrated, non-limiting embodiment of FIG. 4, a single, flat piece of material 61 is folded such that a single surface of the piece of material defines the leading edge 50, trailing edge 52, first surface 54, and second surface 56 of the heat exchange tube segment 46. By folding opposing edges of the sheet of material to extend between the first and second surfaces 54, 56 of the heat exchange tube segment 46, a first portion 64 and a second portion 66 of the heat exchange tube segment 46 are formed, each having a single flow channel 60.

**[0028]** In another embodiment, illustrated in FIG. 5, at least one of the opposing ends of the sheet of material 61 is bent to define a plurality of flow channels 60 within at least one of the first portion 64 and the second portion 66 of the heat exchange tube segment 46. Although the ends of the sheet of material 61 are illustrated as being bent to form a plurality of similar flow channels 60 having a generally rectangular cross-section, embodiments where the flow channels 60 vary in size, shape, cross-sectional flow area, have varying surface characteristics (e.g., having differing surface roughness or textures, coatings, embossed patterns, and the like), or further include inserts of same or different configuration are also within the scope of the disclosure. Further, in the illustrated, non-limiting embodiment, the first portion 64 and the second portion 66 of a heat exchange tube segment 46 are substantially identical. However, embodiments where the first portion 64 and the second portion 66 vary in size and/or configuration, such as number and/or shape of flow channels 60, are also within the scope of the disclosure.

**[0029]** Alternatively, the heat exchange tube segment 46 may have a two-piece design where the flow channels 60 are formed using a corrugation form 68 inserted into an outer shell or sleeve 70 as shown in FIG 6. The corrugated internal sheet 68 can be a different thickness and material than the outer shell 70 altogether, or can be made of the same or similar materials. The fabricated or folded heat exchange tube segments illustrated and described herein are intended as an example only. Further configurations and details for fabricated heat exchange tube segment are disclosed in U.S. Patent Nos. 4,805,693; 5491997; 6,209,202; and 7,657,986, and U.S. Application Serial Number 16/067,009 filed on June 28, 2018.

**[0030]** In embodiments where a vapor compression cycle includes a plurality of compressors arranged in series relative to the flow of refrigerant, the total number of compressors used to propel the flow through the cycle may vary based on one or more operating conditions, such as the ambient air temperature or the load on the system. Accordingly, a velocity of the refrigerant in instances where all of the compressors are being used to move the refrigerant through the cycle is greater than the velocity of the refrigerant in instances where only one of the plurality of compressors is operational. When the refrigerant at this lower velocity associated with operation of only a portion of the compressors flows through a heat exchanger 40 having fabricated heat exchange tube segments 46, excessive oil mixed with the refrigerant may accumulate within one or more of the flow channels 60 of a heat exchange tube segments 46. Accordingly, one or more parameters of the fabricated heat exchange tube segment may be controlled to minimize the accumulation of oil within the flow channels.

**[0031]** With reference now to FIG. 7, an example of a fabricated heat exchange tube segment 46 configured to limit oil build-up therein is illustrated. As shown, the heat exchange tube segment 46 has a tube length L that extends parallel to the direction of flow of refrigerant R through the heat exchange tube segment 46. A width W of the heat exchange tube segment 46 is measured parallel to the direction of the secondary fluid A provided to the heat exchanger 40. The height H of the heat exchange tube segment 46 extends perpendicularly or orthogonally to both the length L and the width W of the heat exchange tube segment 46. In an embodiment, each heat exchange tube segment 46 within the heat exchanger 40 has a substantially identical length, width W and height H.

**[0032]** In an embodiment, the ratio of the width W of the heat exchange tube segment 46 to the height H of the heat exchange tube segment 46 is between 10 and 20, and in some embodiments is between 12 and 20, 14 and 20, or 16 and 20. Further, in an embodiment, a ratio of the width W of the heat exchange tube segment 46 to the total number of flow channels 60 formed in the heat exchange tube segment 46 is between 1.3 and 2.5. The ratio of the width W to the total number of flow channels 60 may further be between 1.5 and 2.5, between 1.7 and 2.5, or between 2.0 and 2.5.

**[0033]** Further, a fabricated heat exchange tube segment 46 typically requires less material than an extruded heat exchange tube segment. Because of this, the open area defined by the plurality of fluidly distinct flow channels 60 occupies a greater percentage of the area of the heat exchange tube segment 46. This percentage of the open area may be described as porosity. In an embodiment, a ratio of the cross-sectional area of the open areas of a heat exchange tube segment 46, such as formed by the flow channels 60 for example, to the total tube cross-sectional area of a heat exchange the tube segment 46 is between about 0.30 and 0.44. For example, the ratio of the cross-sectional area of the open areas of the heat exchange tube segment 46 to the total tube cross-sectional area of a heat exchange tube segment 46 may be between about 0.34 and 0.44, between about 0.30 and 0.40, between about 0.36 and 0.44, between about 0.36 and 0.40, such as 0.38 for example.

**[0034]** With continued reference to FIG. 7 and further reference to FIG. 2B, in embodiments where the heat exchanger 40 having a plurality of fabricated heat exchange tube segments 46 has a multi-pass configuration, such as a two-pass configuration for example, the number of heat exchange tube segments 46 associated with each pass may vary. For example, the number of heat exchange tube segments associated with the first pass may be greater than the number of heat exchange tube segments associated with the second pass. In an embodiment, the ratio of the heat exchange tube segments 46 associated with the first pass to the heat exchange tube segments 46 associated with the second pass is between 1 and 3. Further, the ratio of the heat exchange tube segments 46 associated with the first pass to the ratio of heat exchange tube segments 46 associated with the second pass may be between 1.2 and 3, between 1 and 2.5, or between 1.2 and 2.5.

**[0035]** By customizing the configuration of the fabricated heat exchange tube segments 46 and the heat exchanger 40, the velocity of the refrigerant R may be improved, thereby mitigating the oil accumulation within the flow channels 60 of the heat exchange tube segments 46. Further, the use of fabricated heat exchange tube segments as described herein provides a low-cost solution relative to an oil separator. It should be appreciated that the heating, ventilation, and air conditioning (HVAC) system described herein may be devoid of an oil separator, in certain instances.

**[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 disclosure. 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 disclosure 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 thereof without departing from the scope of the claims. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the scope of the claims. Therefore, it is intended that the present disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this present disclosure, but that the present disclosure will include all embodiments falling within the scope of the claims.

## Claims

**1.** A heat exchange tube segment (46) for use in a heat exchanger (40), the heat exchange tube segment (46) comprising:

a fabricated tube body having an upper surface (54), a lower surface (56), a leading edge (50), a trailing edge (52), and a plurality of fluidly distinct flow channels (60) formed therein;
wherein the fabricated tube body has a length (L) measured parallel to the plurality of fluidly distinct flow channels (60), a width (W) measured between the leading edge (50) and the trailing edge (52), a height measured between the upper surface (54) and the lower surface (56), and a total tube cross-sectional area measured between the upper surface (54), the lower surface (56), the leading edge (50), and the trailing edge (52);
wherein a ratio of the width (W) to the height of the fabricated tube body is between about 10 and 20, a ratio of the width (W) to a number of the plurality of fluidly distinct flow channels (60) is between 1 and 2.5; and
wherein each of the plurality of fluidly distinct flow channels (60) forms an open area in a cross-section of the fabricated tube body, and a ratio of the open area to the total tube cross-sectional area is between 0.30 and 0.44.

**2.** The heat exchange tube segment (46) of claim 1, wherein the ratio of the width (W) to the number of the plurality of fluidly distinct flow channels (60) is between 1.3 and 2.5.

**3.** The heat exchange tube segment (46) of claim 1 or 2, wherein the ratio of the open area to the total tube cross-sectional area is between 0.36 and 0.40.

**4.** The heat exchange tube segment (46) of claim 1, 2 or 3, wherein the plurality of fluidly distinct flow channels (60) are configured to receive a refrigerant (R), the refrigerant (R) is selected from methylene fluoride and difluoromethylene.

**5.** The heat exchange tube segment (46) of any preceding claim, wherein the fabricated tube body comprises a single piece of material (61) folded to form the upper surface (54), the lower surface (56), the leading edge (50), the trailing edge (52), and the plurality of fluidly distinct flow channels (60).

**6.** A heat exchanger (40) comprising:

a first manifold (42);
a second manifold (44);
a plurality of heat exchange tube segments (46) extending between and fluidly coupling the first manifold (42) and the second manifold (44), wherein at least one the plurality of heat exchange tube segments (46) is as claimed in any preceding claim.

**7.** The heat exchanger (40) of claim 6, wherein the heat exchanger (40) has a multi-pass configuration.

**8.** The heat exchanger (40) of claim 7, wherein the heat exchanger (40) has a first pass and a second pass, and a number of heat exchange tube segments (46) associated with the first pass is greater than a number of heat exchange tube segments (46) associated with the second pass.

**9.** The heat exchanger (40) of claim 8, wherein a ratio of the number of heat exchange tube segments (46) associated with the first pass to the number of heat exchange tube segments (46) associated with the second pass is between 1 and 3.

**10.** The heat exchanger (40) of claim 9, wherein a ratio of the number of heat exchange tube segments (46) associated with the first pass to the number of heat exchange tube segments (46) associated with the second pass is between 1.2 and 3.

**11.** The heat exchanger (40) of any of claims 6-10, wherein the heat exchanger (40) is a condenser in a chiller (20).

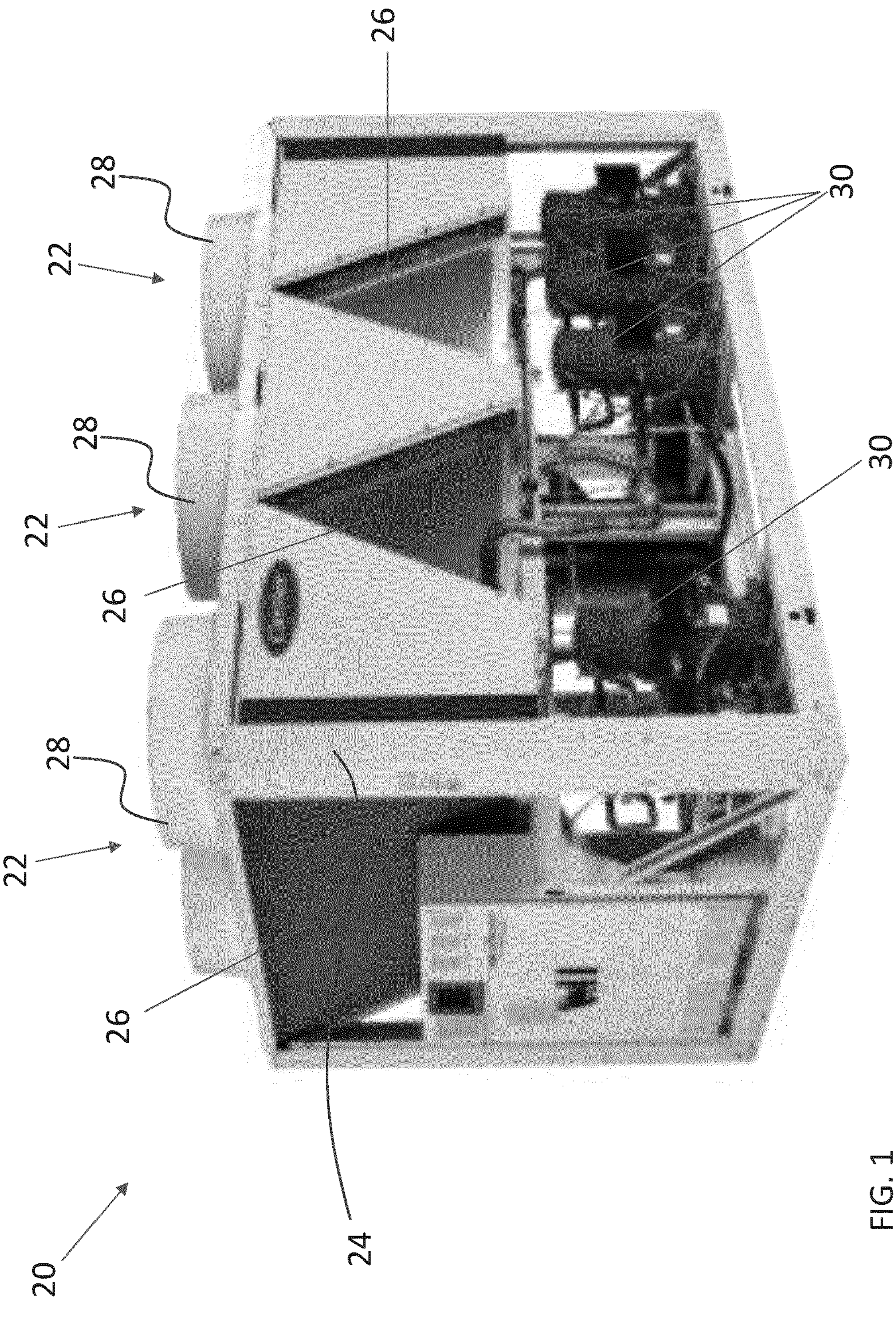


FIG. 1

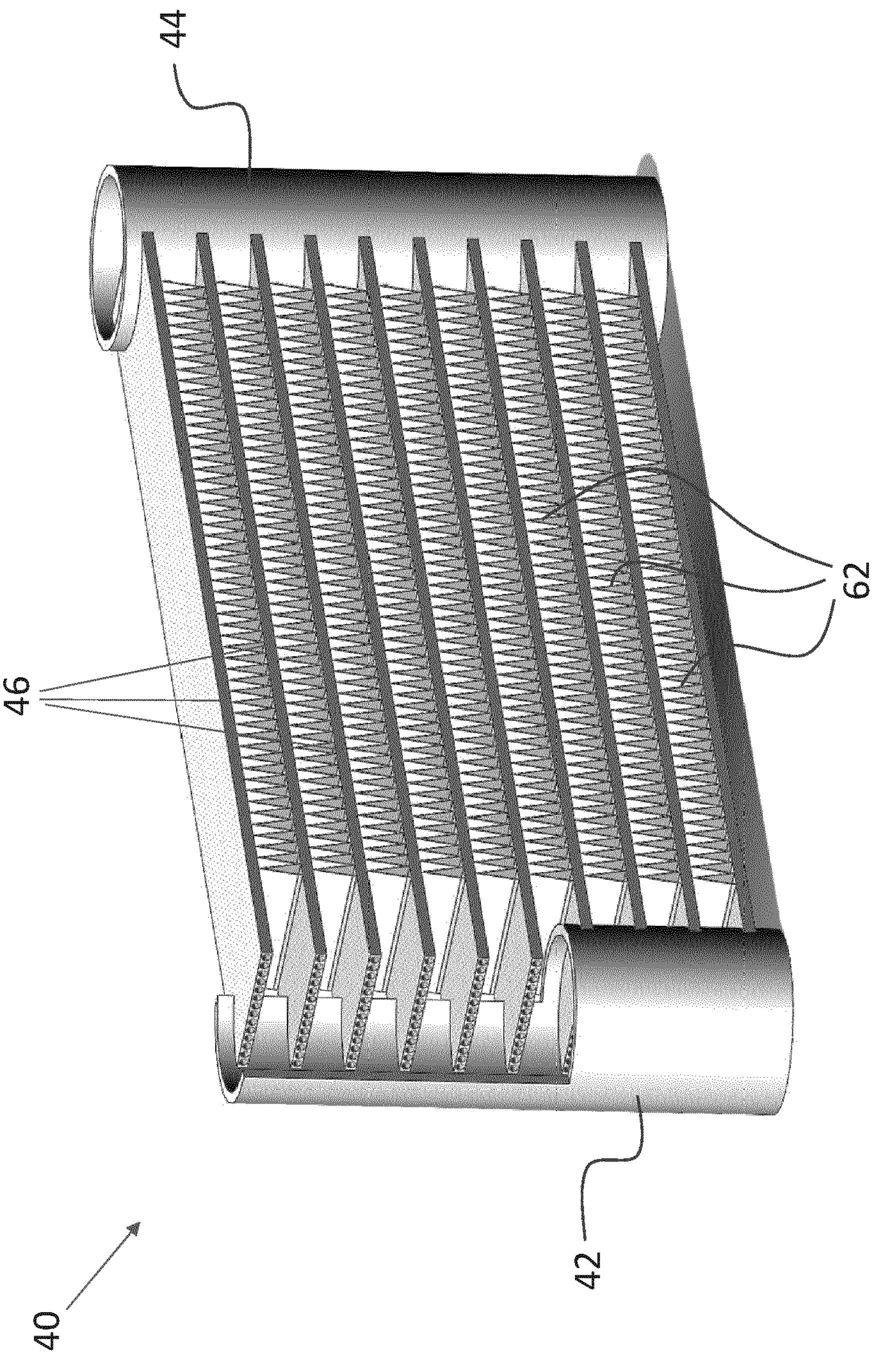


FIG. 2A

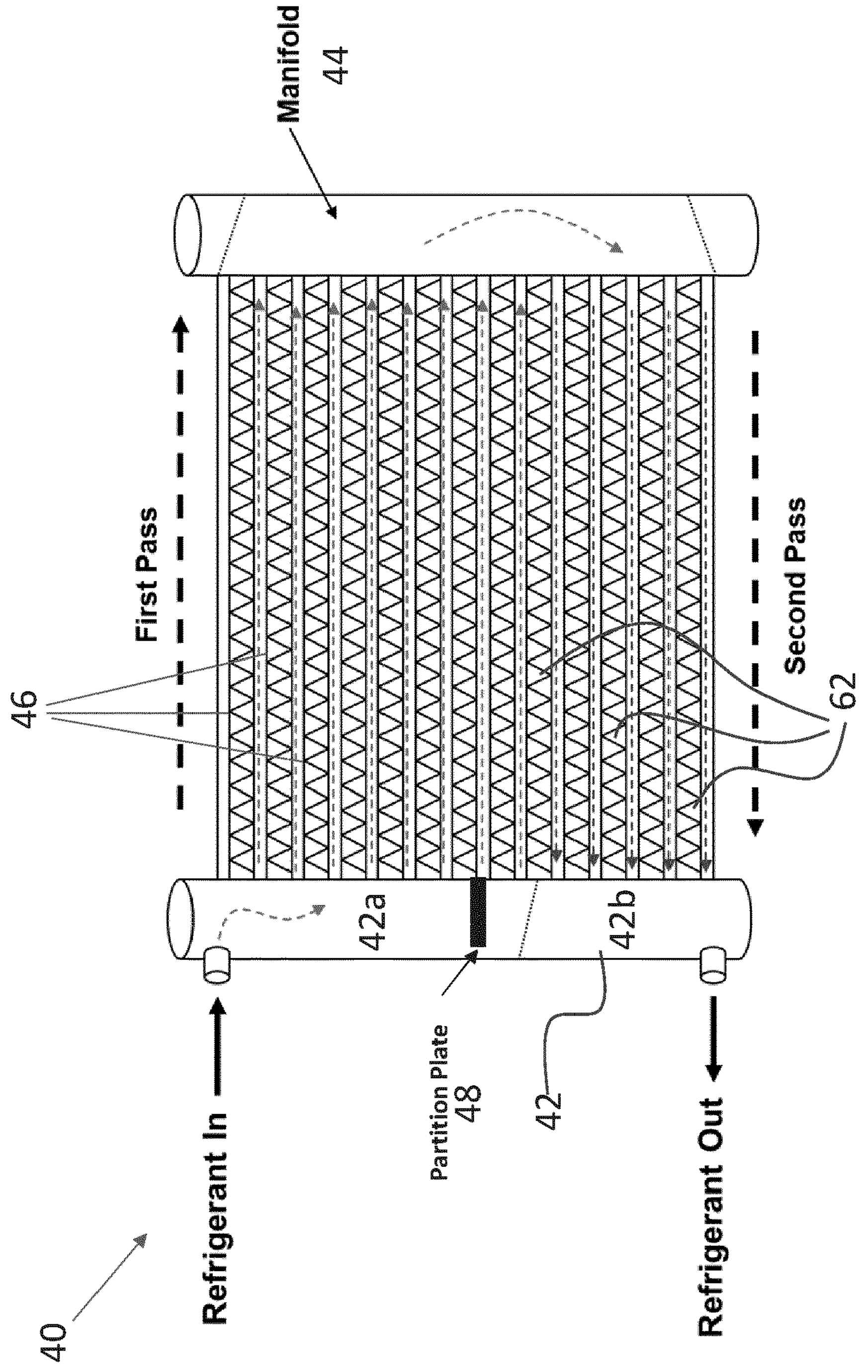
Manifold
44
First Pass
Second Pass
46
62
42a
42b
Partition Plate
48
42
Refrigerant In
Refrigerant Out
40

FIG. 2B

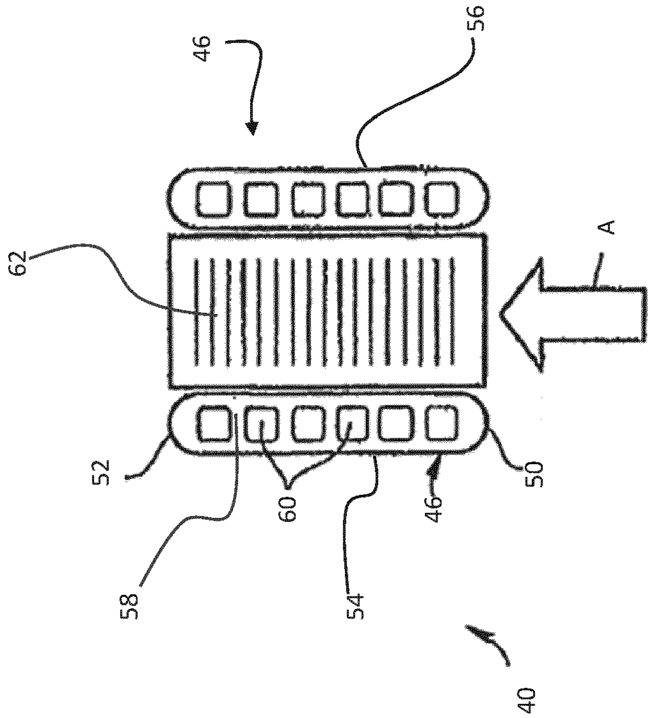


FIG. 3

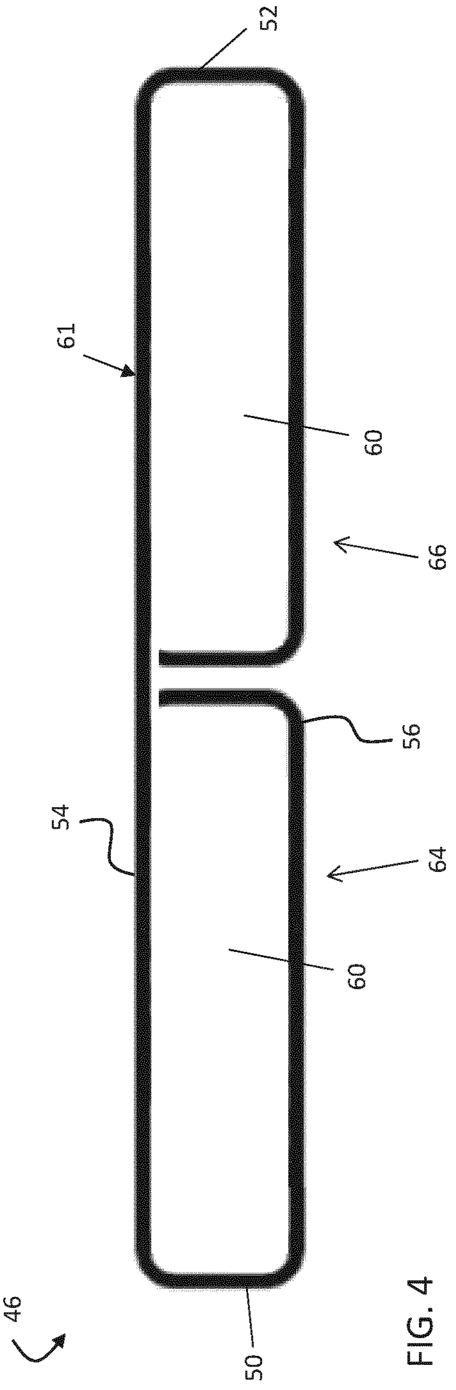


FIG. 4

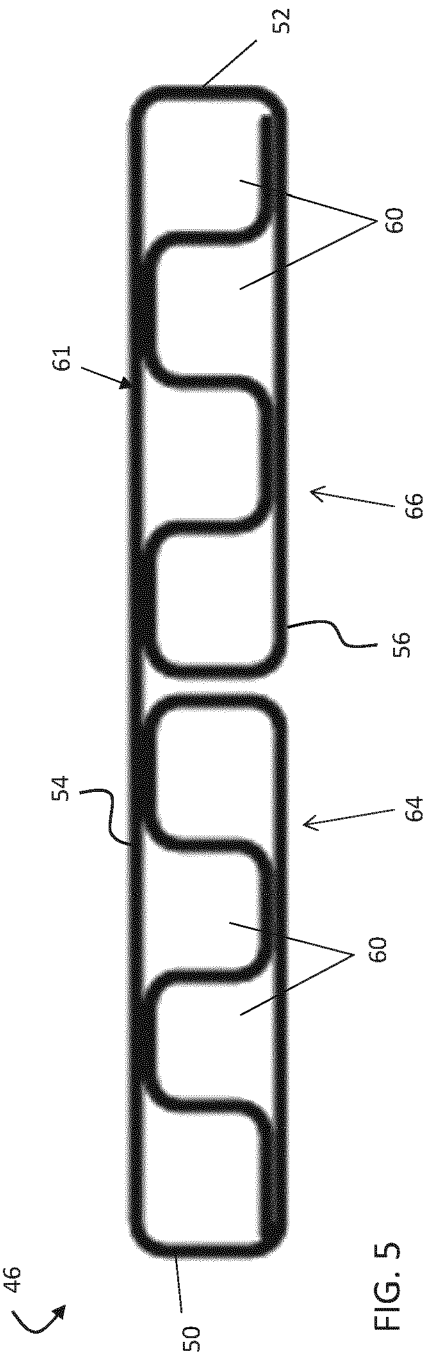


FIG. 5

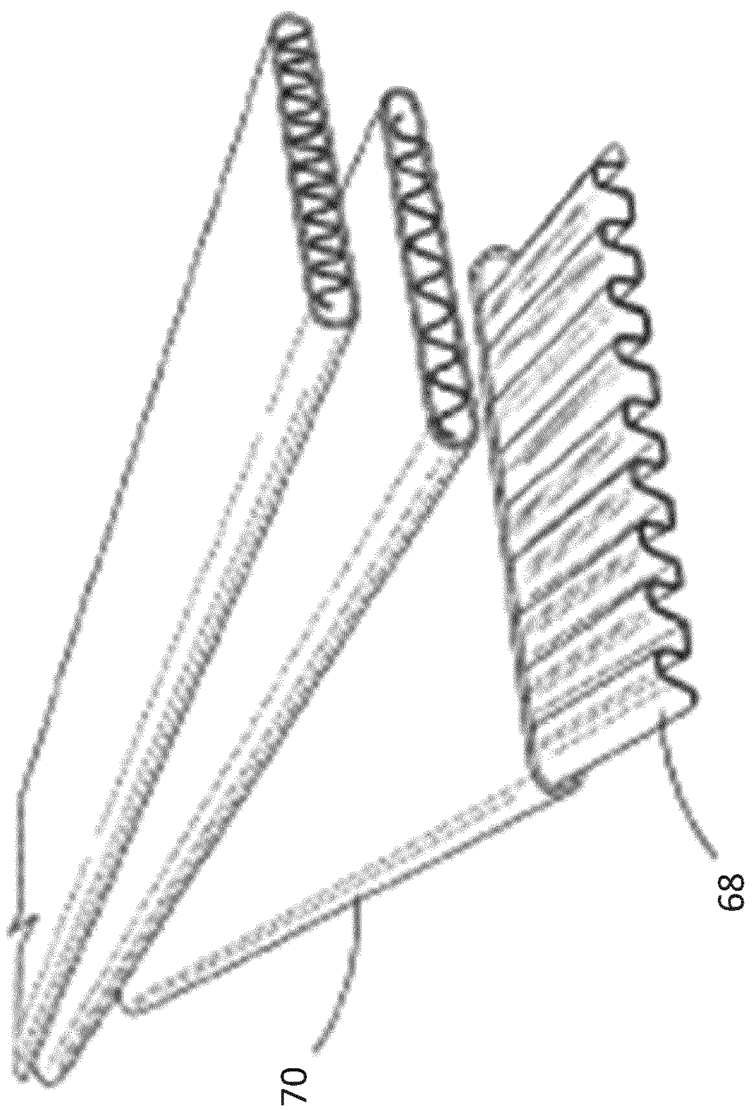


FIG. 6

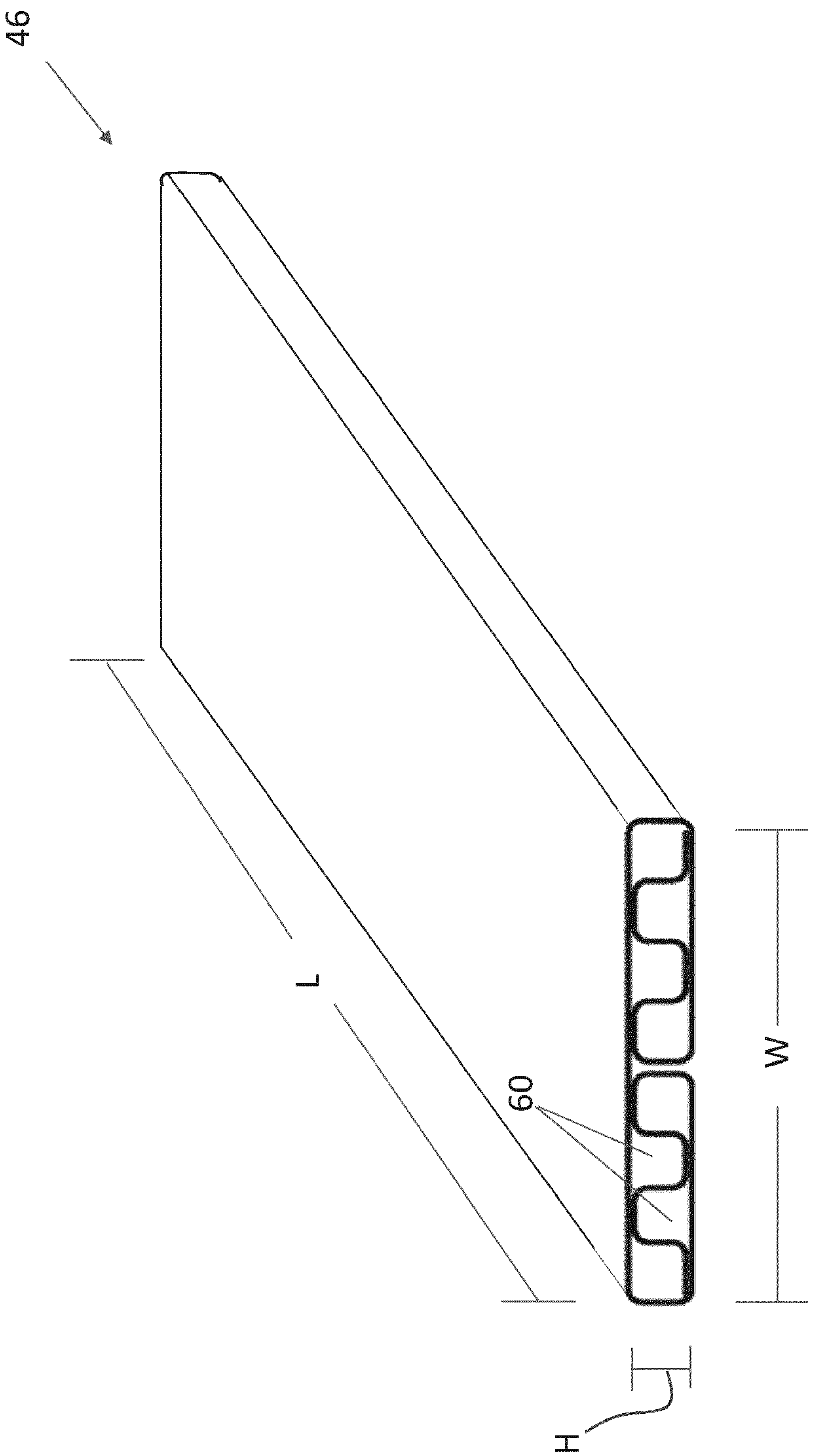


FIG. 7

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# EUROPEAN SEARCH REPORT

Application Number
EP 22 20 4917

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
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TECHNICAL FIELDS SEARCHED (IPC)
F28D

The present search report has been drawn up for all claims

1

| Place of search | Date of completion of the search | Examiner |
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| Munich | 15 February 2023 | Martínez Rico, Celia |

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

EP 22 20 4917

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15-02-2023

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