(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 995 773 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
**11.05.2022 Bulletin 2022/19**

(21) Application number: **21207242.5**

(22) Date of filing: **09.11.2021**

(51) International Patent Classification (IPC):
***F28F 1/00*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
**F28F 1/422; F28F 13/187;** F28F 2001/428

(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 MK MT NL NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
**BA ME**
Designated Validation States:
**KH MA MD TN**

(30) Priority: **09.11.2020 US 202063198724 P**

(71) Applicant: **Carrier Corporation**
**Palm Beach Gardens, FL 33418 (US)**

(72) Inventors:
- **ZHANG, Wei**
  **Shanghai, 201206 (CN)**
- **MOHANTA, Lokanath**
  **Syracuse, 13057 (US)**

(74) Representative: **Dehns**
**St. Bride's House**
**10 Salisbury Square**
**London EC4Y 8JD (GB)**

# (54) HEAT TRANSFER TUBE

(57) A finned tube (100) (e.g., for use in a flooded and falling film evaporator) is provided. The finned tube (100) includes a tube body (110) with an interior surface (110) and an exterior surface (111). The finned tube (100) may include a plurality of adjacent helical fins (120) (e.g., continuously or intermittently) protruding circumferentially around the exterior surface (111) of the tube body (110). At least one channel (130) is disposed between the plurality of adjacent helical fins (120). Each respective helical fin (120) includes at least one sidewall (122) and a fin top (121). Each channel (130) includes at least one channel enhancement (131) impressed radially into and transversely through at intervals around the circumference of the exterior surface (111) of the tube body (110). The finned tube (100) may also include at least one top enhancement (124) and/or sidewall enhancement (123) impressed radially into and transversely through at intervals around the circumference of the exterior surface (111) of the tube body (110).

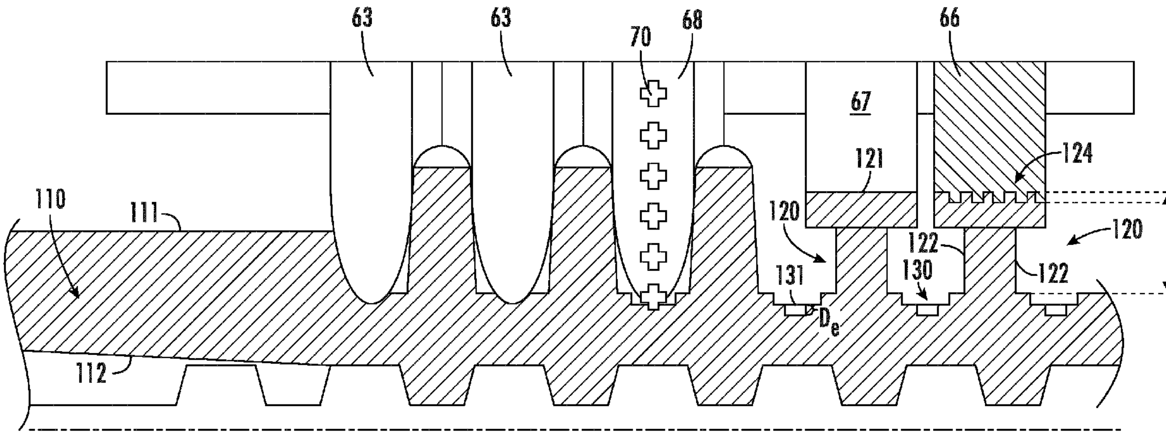



FIG. 2

EP 3 995 773 A1

## Description

### BACKGROUND

**[0001]** The invention relates generally to heat transfer tubes in flooded heat exchangers where nucleate boiling (e.g., on the external surface of the heat transfer tubes) is the dominant mode of heat transfer. In particular, the invention relates to the external surface configuration of a heat transfer tube that is used for evaporating a liquid in which the tube in submerged (e.g., either completely or partially).

**[0002]** Shell and tube type evaporators are used to transfer heat from one fluid to other in many air conditioning and refrigeration systems. A shell and tube evaporator is a heat exchanger in which multiple tubes are arranged in some patterns within a single shell. In refrigeration systems, typically a coolant is passed through the multiple parallel tubes arranged along the length of the shell. Refrigerant flows into the shell of the heat exchanger in liquid phase and forms a refrigerant pool in the shell. Due to heat transfer from the tubes, the refrigerant undergoes phase transformation and leaves the shell as a refrigerant vapor. The fluid is cooled by heat transfer through the walls of the tubes. The heat transfer capability of such an evaporator is largely determined by the efficiency of the heat transfer surface of the individual tubes which are customized based on the thermophysical properties of the refrigerant. The external surface enhancement configuration along with internal enhancement of an individual tube determines the overall heat transfer characteristics of the shell and tube heat exchanger.

**[0003]** Heat transfer performance of a heat transfer tube can be improved by following methods including (i) increasing the heat transfer surface area of the tube, (ii) promoting nucleate boiling on the surface of the tube that is in contact with the boiling fluid, and (iii) promoting external natural convection at the outer surface of the tube. In the nucleate boiling process, initially, a small quantity of entrapped vapor, embryo bubble, in the nucleation sites grows due to the heat transferred from the heated surface. When the bubble grows, it vaporizes more liquid in contact with the solid surface and also vaporizes at the liquid-vapor interface. Heat from the solid surface and from the surrounding superheated liquid superheats the vapor in a bubble and the bubble grows in size. When the bubble size is large enough, surface tension is overcome by the buoyancy force and the bubble detaches from the surface. As the bubble leaves the surface, liquid enters the volume vacated by the bubble. The bubble departure results in a convection current in the liquid. Usually, some traces of vapor remains in the volume, and becomes a source of additional liquid to vaporize to form another bubble. The periodic formation of bubbles at the surface, the release of the bubbles from the surface, and the rewetting of the surface together with the convective effect of the vapor bubbles rising through the liquid results in an improved heat transfer rate for the heat transfer surface.

**[0004]** It is generally known that the nucleate boiling process can be enhanced by configuring the heat transfer surface so that more nucleation sites can be created and sustained on the surface of the tube that provide locations for the entrapment of vapor and promote the bubble nucleation. For example, simply roughening a heat transfer surface will provide more nucleation sites that can improve the heat transfer performance of the surface over a similar smooth surface.

**[0005]** In nucleate boiling including liquid refrigerants, for example, in the evaporator of an air conditioning or refrigeration system, nucleation sites of the re-entrant type produce stable bubble columns, good surface heat transfer characteristics and also amount to more surface area. A re-entrant type nucleation site is a surface cavity in which the opening of the cavity is smaller than the subsurface volume of the cavity. An excessive influx of the surrounding liquid can flood a re-entrant type nucleation site and deactivate it. In the subsurface volumes, which are mostly filled with vapor with liquid films in the neighboring wall, thin film evaporation happens when the film becomes discontinuous. This thin film evaporation contributes to the steady nucleation process. By configurating the heat transfer surface so that it has relatively large communicating subsurface channels with relatively smaller openings to the surface, and it promotes the discontinuity in the thin film, the heat transfer performance of the surface improved. There are many different configurations of heat transfer tubes, each having their own take of which features to include so as to improve heat transfer. However, new heat transfer tube configurations that can further improve heat transfer are always welcome.

**[0006]** Accordingly, there remains an ongoing need for newly configured heat transfer tubes with improved heat transfer capabilities.

### BRIEF DESCRIPTION

**[0007]** According to a first aspect of the invention, a finned tube including a tube body, and a plurality of adjacent helical fins is provided. The tube body includes an interior surface and an exterior surface. The plurality of adjacent helical fins intermittently protrude circumferentially around the exterior surface of the tube body, at least one channel is disposed between the plurality of adjacent helical fins, each respective helical fin comprising at least one sidewall and a fin top, each channel including at least one channel enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body, each sidewall including at least one sidewall enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body.

**[0008]** Optionally, there are between thirteen (13) and twenty-eight (28) helical fins per centimeter (between thirty-three (33) and seventy (70) per inch) of tube length.

**[0009]** Optionally, a ratio ($H_f/D_o$) of a fin height ($H_f$) to an outer diameter ($D_o$) of the tube body is between 0.02 and 0.05.

**[0010]** Optionally, each respective channel enhancement includes a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

**[0011]** Optionally, each respective sidewall enhancement includes a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

**[0012]** Optionally, each fin top includes at least one top enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body.

**[0013]** Optionally, each respective top enhancement includes a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

**[0014]** Optionally, each respective sidewall is devoid of a protruding wing.

**[0015]** Optionally, each respective helical fin is approximately cross-sectionally symmetrical.

**[0016]** According to another aspect of the disclosure, a finned tube including a tube body and a plurality of adjacent helical fins is provided. The tube body includes an interior surface and an exterior surface. The plurality of adjacent helical fins continuously protrude circumferentially around the exterior surface of the tube body, at least one channel is disposed between the plurality of adjacent helical fins, each respective helical fin comprising at least one sidewall and a fin top, each channel including at least one channel enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body, each sidewall including at least one sidewall enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body.

**[0017]** Optionally, there are between thirteen (13) and twenty-eight (28) helical fins per centimeter (between thirty-three (33) and seventy (70) per inch) of tube length.

**[0018]** Optionally, a ratio ($H_f/D_o$) of a fin height ($H_f$) to an outer diameter ($D_o$) of the tube body is between 0.02 and 0.05.

**[0019]** Optionally, each respective channel enhancement includes a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

**[0020]** Optionally, each respective sidewall enhancement includes a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

**[0021]** Optionally, each fin top includes at least one top enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body.

**[0022]** Optionally, each respective top enhancement includes a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

**[0023]** Optionally, each respective sidewall is devoid of a protruding wing.

**[0024]** Optionally, each respective helical fin is approximately cross-sectionally symmetrical.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0025]** Certain exemplary embodiments will now be described in greater detail by way of example only. The following descriptions of the drawings should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

FIG. 1 is a schematic illustration of the manufacture of a finned tube using a tool arbor containing a plurality of finning disks, a channel marking disk, a flattening disk, and a notching disk.

FIG. 2 is a cross-sectional side view of a finned tube.

FIG. 3 is a cross-sectional side view of a finned tube.

FIG. 4 is a cross-sectional side view of a finned tube.

FIG. 5 is a cross-sectional side view of a finned tube.

FIG. 6 is a cross-sectional side view of a finned tube.

FIG. 7 is a perspective view of a section of a finned tube with the fins intermittently protruding circumferentially around the exterior surface of the tube body.

FIG. 8 is a perspective view of a section of a finned tube with the fins continuously protruding circumferentially around the exterior surface of the tube body

## DETAILED DESCRIPTION

**[0026]** As will be described below, a finned tube with unique features that enhance its heat transfer capabilities is provided. Specifically, the features of the finned tube described herein may improve the finned tube's heat transfer capabilities by (i) increasing the heat transfer area of the tube surface (e.g., by incorporating one or more enhancements in at least one of the channels between the fins, the sidewalls of the fins, and the top surface of the fins) and (ii) promoting nucleate boiling on the surface of the tube that is in contact with the boiling fluid (e.g., by creating nucleation sites and reentrant cavities at or near the enhancements that provide locations for the entrapment of vapor and promote the formation of vapor bubbles). In addition, promoting thin film evaporation of the thin film entrapped in the channel marks as will be described. The finned tube described herein may be particularly useful in an evaporator (e.g., flooded and/or falling film type evaporators) of a vapor compression system (e.g., which may utilize one or more refrigerant to transfer heat from a working fluid, such as air, water, glycol, etc.). For example, the finned tube described herein may be configured to allow the working fluid to pass through interior of the finned tube with the refrigerant located on the exterior of the finned tube, where heat is transferred from the working fluid to the refrigerant through the body of the finned tube. Although described as an independent tube, it should be appreciated that typically a plurality of finned tubes may be mounted in parallel and connected together to form a tube bundle within the evaporator. This tube bundle is typically is immersed (e.g., either completely or partially) in the refrigerant pool. It is envisioned that by utilizing the finned tube described herein the heat transfer characteristics of the evaporator may be improved.

**[0027]** With reference now to the Figures, a schematic illustration of the manufacture of an exemplary finned tube 100 using an exemplary tool arbor containing a plurality of finning disks 63, a channel marking disk 68, a flattening disk 67, and a notching disk 66 is shown in FIG. 1. It should be appreciated that the finning disks 63, the channel marking disk 68, the flattening disk 67, and the notching disk 66 may be collectively referred to as the tool gang 62. As shown in FIG. 1, the tube 100 may be viewed to include a tube body 110 with an exterior surface 111 and an interior surface 110. The finned tube 100 (e.g., as a results of the tool gang 62) includes a plurality of adjacent helical fins 120 protruding (e.g., intermittently or continuously) circumferentially around the exterior surface 111 of the tube body 110. At least one channel 130 (shown in FIGs. 2-8) may be disposed between the plurality of adjacent helical fins 120 (e.g., to separate the different rows $R_f$ (shown in FIGs. 7 and 8) of fins 120 from one another. It should be appreciated that each channel 130 may be viewed as a void between adjacent helical fins 120. As shown in FIGs. 2-6, each respective helical fin 120 may be viewed to include at least one sidewall 122 and a fin top 121. Each channel 130 may include at least one channel enhancement 131 impressed radially into and transversely through at intervals around the circumference of the exterior surface 111 of the tube body 110 (e.g., by the channel marking disk 68). This placement of the channel enhancements 131 at intervals may enhance the heat transfer characteristics of the finned tube 100. These intervals may be generated by spacing of the surface features 70 (shown in FIGs. 2-5) on the channel marking disk 68.

**[0028]** It is envisioned that the finned tube 100 described herein may be readily manufactured by a rolling process. This rolling process is illustrated in FIG. 1. As shown, the finning machine 60 may operate on a tube 10, made of a malleable metal such as copper or aluminum, to produce both interior ribs and exterior fins 120 on the tube 10. For example, the finned tube 100 described herein may, in certain instances, be viewed to be manufactured in a rolling process where the fins 120 are created through extrusion of the metal (e.g., copper or aluminum), instead of using an applied process where the fins are applied by winding an independent metal around the tube. It should be appreciated that the finning machine 60 may include one or more tool arbors 61, each containing one or more tool gangs 62. As shown in FIG. 1, extending into the tube 100 is the mandrel shaft 65 to which the mandrel 64 is attached. During manufacture, the tube body 110 is pressed between the mandrel 64 and the finning disks 63 as the tube 100 rotates. Under pressure, the metal, of which the tube 100 is made of, flows into the grooves between the finning disks 63, which forms the beginnings of the fins 120 (and the channels 130 therebetween, as shown in FIG. 2) on the exterior surface 111 of the tube 100. As the tube 100 continues to rotate the tube 100 advances between the mandrel 64 and the tool gang 62 (from left to right in FIG. 1) resulting in a number of rows $R_f$ of helical fins being formed on the tube 100. For purposes of clarify, FIGs. 2-5 may be viewed as cross-sectional side views of rows $R_f$ of helical fins (e.g., where each fin 120 represents a different row $R_f$). It should be appreciated that the number of rows $R_f$ generated may be a function of the number of finning disks 63 on the tool arbor 61 in use on the finning machine 60.

**[0029]** As shown in FIGs. 1 and 2, after the finning disks 63 form the beginnings of the fins 120 (and the channels 130 therebetween), a channel marking disk 68, which includes one or more surface features 70 (e.g., which may be configured as a star, rectangle, square, triangle, star, etc.), may be used to impress radially into and transversely through within the channels 130 so as to form the channel enhancements 131. It should be appreciated that the intervals at which the channel enhancements 131 are spaced within the channel 130 may be a function of the spacing of the surface features 70 on the channel marking disk 68. It is envisioned that all embodiments, as described below, include at least one channel enhancement 131 in each channel 130 (defined between adjacent helical fins 120). This channel enhancement 131, either alone or in combination with the designed density of the helical fins 120 (e.g., which may be viewed in terms of number of fins 120 per tube 100 length), may contribute to the improved heat transfer characteristics of the finned tube 100 described herein.

**[0030]** As shown in FIGs. 1 and 2, in the same pass and after the finning disks 63 and channel marking disk 68 form the fins 120 and the channel enhancements 131 on the tube 100, a flatting disk 67 may be used to flatten and spread the distal tips of the fins 120 (e.g., thereby closing the gaps 180 (shown in FIGs. 7 and 8), at least partially, between adjacent rows $R_f$ of fins 120. Once the fins 120 are flattened, a notching disk 66 may be used to generate at least one top enhancement 124 (shown in FIGs. 2-5) on the fins 120. It should be appreciated that notching disk 66 may be omitted or removed from the finning machine 60 when the finned tube 100 does not include top enhancements 124. In addition, although not shown, it should be appreciated that the notching disk may be combined with the flattening disk 67 in certain instances. As shown in FIG. 1, the mandrel 64 may be configured in such a way that it will impress some type of pattern into the interior surface 112 of the tube body 110. A typical pattern is of one or more helical rib convolutions, which can improve the efficiency of the heat transfer between the fluid flowing through the tube 100 and the tube body 110. It should be appreciated that any pattern, or no pattern at all, may be impressed by the mandrel 64 for the finned tube 100 described herein.

**[0031]** As shown FIGs. 2-6, the finned tube 100 described herein may be configured in various manners. For example, in certain embodiments, the finned tube 100 may include top enhancements 124, which may be absent in other embodiments. It should be appreciated that the various enhancements may be completed by modifying the finning machine 60. However, it is envisioned that in all embodiments, the finned tube 100 includes a plurality of adjacent helical fins 120 protruding (e.g., either intermittently or continuously) circumferentially around the exterior surface 111 of the tube body 110, where each channel 130 (e.g., disposed between adjacent fins 120) includes at least one channel enhancement 131 impressed radially into and transversely through at intervals (e.g., as compared to continuous, uninterrupted enhancements) around the exterior surface 111 of the tube body 110.

**[0032]** FIG. 2 illustrates a magnified cross-sectional side view of a portion of a first embodiment of a finned tube 100. As shown, the finned tube 100 includes a plurality of adjacent helical fins 120 (e.g., separated by a channel 130 with at least one channel enhancement 131 impressed radially into and transversely through at intervals around the exterior surface 111 of the tube body 110). It should be appreciated that although the channel enhancement 131 is depicted as a cross, any suitable configuration (e.g., such as a rectangle, square, triangle, star, etc.) may be utilized. In this embodiment, the finned tube 100 may further include a top enhancement 124 impressed radially into and transversely through (e.g., with the notching disk 66) at intervals around the circumference of the exterior surface 111 of the tube body 110. It is envisioned that each respective enhancement 131, 124 regardless of specific configuration or where located (e.g., in the channel 130 or in the fin top 121), may have a certain depth $D_e$, which may be defined in terms of the fin height $H_f$. The depth $D_e$ of the enhancement 131, 124 is between 0.05 and 0.2 of the fin height $H_f$ in certain instances. To achieve the desired heat transfer, each fin 120 may be designed to have a certain fin height $H_f$, which may be defined (e.g., as a ratio $H_f/D_o$) in terms of the outer diameter $D_o$ of the tube body 110 (shown in FIG. 1). This ratio $H_f/D_o$ may be between 0.02 and 0.05 in certain instances. It should be appreciated that the finned tube 100, as shown in FIG. 2, may be designed with manufacturability in mind. For example, as shown, each respective helical fin 120 may be approximately cross-sectionally symmetrical (e.g., along the vertical plane) and devoid of a protruding wing 141 (shown in FIG. 6).

**[0033]** FIG. 3 illustrates a magnified cross-sectional side view of a portion of a second embodiment of a finned tube 100. As shown, similar to the first embodiment (shown in

**[0034]** FIG. 2), this embodiment of the finned tube 100 includes a plurality of adjacent helical fins 120 (e.g., separated by a channel 130 with at least one channel enhancement 131 impressed radially into and transversely through at intervals around the exterior surface 111 of the tube body 110). It should be appreciated that although the channel enhancement 131 is depicted as a cross, any suitable configuration (e.g., such as a rectangle, square, triangle, star, etc.) may be utilized. In this embodiment, as with the first embodiment (shown in FIG. 2), the finned tube 100 may further include a top enhancement 124 impressed radially into and transversely through (e.g., with the notching disk 66) at intervals around the circumference of the exterior surface 111 of the tube body 110. In addition, this embodiment, unlike the first embodiment (shown in FIG. 2), the finned tube 100 may further include at least one sidewall enhancement 123 impressed radially into and transversely through (e.g., with the sidewall marking disk 69, which may be included in the finning machine 60) at intervals around the circumference of the exterior surface 111 of the tube body 110. These intervals may be generated by spacing of the surface features 71 (shown in FIGs. 3-5) on the sidewall marking disk 69. As with the channel enhancement 131, the sidewall enhancement 123 may be in any suitable configuration (e.g., rectangle, square, triangle, hatching, etc.). It is envisioned that each respective enhancement 131, 124, 123 regardless of specific configuration or where located (e.g., in the channel 130, in the fin top 121, or in the sidewall 122), may have a certain depth $D_e$, which may be defined in terms of the fin height $H_f$. The depth $D_e$ of the channel enhancement 131, 124, 123 is between 0.05 and 0.2 of the fin height $H_f$ in certain instances. As described above, to achieve the desired heat transfer, each fin 120 may be designed to have a certain fin height $H_f$, which may be defined (e.g., as a ratio $H_f/D_o$) in terms of the outer diameter $D_o$ of the tube body 110 (shown in FIG. 1). This ratio $H_f/D_o$ may be between 0.02 and 0.05 in certain instances. It should be appreciated that the finned tube 100, as shown in FIG. 3, may be designed with manufacturability in mind. For example, as shown, each respective helical fin 120 may be approximately cross-sectionally symmetrical (e.g., along the vertical plane) and devoid of a protruding wing 141 (shown in FIG. 6).

**[0035]** FIG. 4 illustrates a magnified cross-sectional side view of a portion of a third embodiment of a finned tube 100. As shown, similar to the first embodiment (shown in FIG. 2) and the second embodiment (shown in FIG. 3), this embodiment of the finned tube 100 includes a plurality of adjacent helical fins 120 (e.g., separated by a channel 130 with at least one channel enhancement 131 impressed radially into and transversely through at intervals around the exterior surface 111 of the tube body 110). It should be appreciated that although the channel enhancement 131 is depicted as a cross, any suitable configuration (e.g., such as a rectangle, square, triangle, star, etc.) may be utilized. In this embodiment, as with the first embodiment (shown in FIG. 2) and the second embodiment (shown in FIG. 3), the finned tube 100 may further include a top enhancement 124 impressed radially into and transversely through (e.g., with the notching disk 66) at intervals around the circumference of the exterior surface 111 of the tube body 110. In addition, this embodiment, like the second embodiment (shown in FIG. 3), the finned tube 100 may further include at least one sidewall enhancement 123 impressed radially into and transversely through (e.g., with the sidewall marking disk 69) at intervals around the circumference of the exterior surface 111 of the tube body 110. As shown in this embodiment, a single sidewall 122 may include multiple sidewall enhancements 123. As with the channel enhancement 131, each sidewall enhancement 123 may be in any suitable configuration (e.g., rectangle, square, triangle, hatching, etc.). It is envisioned that each respective enhancement 131, 124, 123 regardless of specific configuration or where located (e.g., in the channel 130, in the fin top 121, or in the sidewall 122), may have a certain depth $D_e$, which may be defined in terms of the fin height $H_f$. The depth $D_e$ of the channel enhancement 131, 124, 123 is between 0.05 and 0.2 of the fin height $H_f$ in certain instances. As described above, to achieve the desired heat transfer, each fin 120 may be designed to have a certain fin height $H_f$, which may be defined (e.g., as a ratio $H_f/D_o$) in terms of the outer diameter $D_o$ of the tube body 110 (shown in FIG. 1). This ratio $H_f/D_o$ may be between 0.02 and 0.05 in certain instances. It should be appreciated that the finned tube 100, as shown in FIG. 4, may be designed with manufacturability in mind. For example, as shown, each respective helical fin 120 may be approximately cross-sectionally symmetrical (e.g., along the vertical plane) and devoid of a protruding wing 141 (shown in FIG. 6).

**[0036]** FIG. 5 illustrates a magnified cross-sectional side view of a portion of a fourth embodiment of a finned tube 100. As shown, similar to the first embodiment (shown in FIG. 2), the second embodiment (shown in FIG. 3), and the third embodiment (shown in FIG. 4), this embodiment of the finned tube 100 includes a plurality of adjacent helical fins 120 (e.g., separated by a channel 130 with at least one channel enhancement 131 impressed radially into and transversely through at intervals around the exterior surface 111 of the tube body 110). Unlike the prior embodiments, in this embodiment, the channel enhancement 131 is depicted as a triangle, which, as shown, may be formed alongside the sidewall enhancements 123 (which, as shown, may have the same triangular configuration) using a plurality of unitary enhancement disks 80 (which may be included in the finning machine 60). As shown, the unitary enhancement disks 80 may serve the combined functions of the finning disks 63 (by extruding the metal away from the exterior surface 111 of the tube body 110), the channel marking disk 68 (by impressing the channel enhancements 131 in the channels 130), and the sidewall marking disk 69 (by impressing the sidewall enhancements 123 in the sidewalls 122). It should be appreciated that although the channel enhancement 131 and sidewall enhancements 123 are depicted as a triangular, any suitable configuration (e.g., such as a rectangle, square, star, etc.) may be utilized. In this embodiment, as with previously described embodiments (shown in FIGs. 2-4), the finned tube 100 may further include a top enhancement 124 impressed radially into and transversely through (e.g., with the notching disk 66) at intervals around the circumference of the exterior surface 111 of the tube body 110. It is envisioned that each respective enhancement 131, 124, 123 regardless of specific configuration or where located (e.g., in the channel 130, in the fin top 121, or in the sidewall 122) or how formed (e.g., whether through individual disks or a unitary enhancement disk 80, may have a certain depth $D_e$, which may be defined in terms of the fin height $H_f$. The depth $D_e$ of the channel enhancement 131, 124, 123 is between 0.05 and 0.2 of the fin height $H_f$ in certain instances. As described above, to achieve the desired heat transfer, each fin 120 may be designed to have a certain fin height $H_f$, which may be defined (e.g., as a ratio $H_f/D_o$) in terms of the outer diameter $D_o$ of the tube body 110 (shown in FIG. 1). This ratio $H_f/D_o$ may be between 0.02 and 0.05 in certain instances. It should be appreciated that the finned tube 100, as shown in FIG. 5, may be designed with manufacturability in mind. For example, as shown, each respective helical fin 120 may be approximately cross-sectionally symmetrical (e.g., along the vertical plane) and devoid of a protruding wing 141 (shown in FIG. 6).

**[0037]** FIG. 6 illustrates a magnified cross-sectional side view of a portion of a fifth embodiment of a finned tube 100. As shown, similar to the previous embodiments (shown in FIGs. 2-4), this embodiment of the finned tube 100 includes a plurality of adjacent helical fins 120 (e.g., separated by a channel 130 with at least one channel enhancement 131 impressed radially into and transversely through at intervals around the exterior surface 111 of the tube body 110). Unlike the prior embodiments, in this embodiment, the helical fins 120 are not symmetrical (e.g., along the vertical plane), the sidewalls 122 include protruding wings 140, and the fin tops 121 do not include enhancements. In particular, the lack of symmetry may be created by the configuration of the sidewall enhancements 123 shown in FIG. 6, which may be viewed as non-uniformly distributed in the cross-section of the fin 120. This non-uniform distribution of the sidewall enhancement 123 may be created during manufacture. For example, as the tube 100 is rotated and advanced, the notching disk 66 with oblique notches and the flattening disk 67 may cause the top of the fin 120 to twist slightly from the base (from the exterior surface 111) to its tip (toward the fin top 121) such that the sidewall enhancement 123 has a twisted, non-uniform asymmetrical configuration. In addition, while creating a notch, material will be pushed down in a perpendicular to the channel length 130 forming the wings 140.

**[0038]** It is envisioned that each of the above-described embodiments (shown in FIGs. 2-6) of the finned tube 100 may have a certain designed density of the helical fins 120 (e.g., which, as mentioned above, may be viewed in terms of number of fins 120 per tube 100 length). Regardless of the specific configuration of the finned tube 100 the finned tube 100 may have between thirteen (13) and twenty-eight (28) helical fins 120 per centimeter (between thirty-three (33) and seventy (70) helical fins 120 per inch) of tube length. It is envisioned that this density in combination with the specific enhancements may contribute to the improved heat transfer characteristics of the finned tube 100 described herein.

**[0039]** In addition, it is envisioned that each of the above-described embodiments (shown in FIGs. 2-6) of the finned tube 100 may be configured with the plurality of adjacent helical fins 120 being either intermittently (as shown in FIG. 7) or continuously (as shown in FIG. 8) protruding circumferentially around the exterior surface 111 of the tube body 110. When intermittently protruding, as shown in FIG. 7, each fin 120 within each respective row $R_f$ may be separated by a void 170 (i.e., a space). This void 170 may be generated by the finning machine 60 by intermittently pressing in between the fins 120 (e.g., after the fins 120 are extruded by the finning disk 63). When continuously protruding, as shown in FIG. 8, each fin 120 within each respective row $R_f$ may not be separated (i.e., there is no void 170 generated by the finning machine 60). As shown in FIGs. 7 and 8, regardless of whether the fins 120 are intermittently or continuously protruding, the finned tube 100 includes openings 180 (i.e., spaces) at the upper end of the fins 120 (e.g., between each respective helical fin 120) so as to allow refrigerant vapor to rise through the fin 120 and liquid refrigerant to go to the inner wall either in one opening 180 or alternative openings. As shown, these openings 180 may be viewed to align with the respective fin 120 columns $C_f$, which are configured in a helical fashion.

**[0040]** The use of the terms "a" and "and" and "the" and similar referents, in the context of describing the invention, are to be construed to cover both the singular and the plural, unless otherwise indicated herein or cleared contradicted by context. The use of any and all example, or exemplary language (e.g., "such as", "e.g.", "for example", etc.) provided herein is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed elements as essential to the practice of the invention.

**[0041]** While the 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 thereof without departing from the scope of the invention as set out in the appended claims. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims.

**[0042]** The following clauses set out aspects of the invention which may or may not be presently claimed but which may form basis for future amendments and/or a divisional application.

1. A finned tube comprising:

    a tube body comprising an interior surface and an exterior surface;

    a plurality of adjacent helical fins intermittently protruding circumferentially around the exterior surface of the tube body, at least one channel disposed between the plurality of adjacent helical fins, each respective helical fin comprising at least one sidewall and a fin top, each channel comprising at least one channel enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body, each sidewall comprising at least one sidewall enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body.

2. The finned tube of clause 1, wherein there are between thirteen (13) and twenty-eight (28) helical fins per centimeter (between thirty-three (33) and seventy (70) per inch) of tube length.

3. The finned tube of clause 1, wherein a ratio ($H_f/D_o$) of a fin height ($H_f$) to an outer diameter ($D_o$) of the tube body is between 0.02 and 0.05.

4. The finned tube of clause 1, wherein each respective channel enhancement comprises a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

5. The finned tube of clause 1, wherein each respective sidewall enhancement comprises a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

6. The finned tube of clause 1, wherein each fin top comprises at least one top enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body.

7. The finned tube of clause 6, wherein each respec-

tive top enhancement comprises a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

8. The finned tube of clause 1, wherein each respective sidewall is devoid of a protruding wing.

9. The finned tube of clause 1, wherein each respective helical fin is approximately cross-sectionally symmetrical.

10. A finned tube comprising:

a tube body comprising an interior surface and an exterior surface;

a plurality of adjacent helical fins continuously protruding circumferentially around the exterior surface of the tube body, at least one channel disposed between the plurality of adjacent helical fins, each respective helical fin comprising at least one sidewall and a fin top, each channel comprising at least one channel enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body, each sidewall comprising at least one sidewall enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body.

11. The finned tube of clause 10, wherein there are between thirteen (13) and twenty-eight (28) helical fins per centimeter (between thirty-three (33) and seventy (70) per inch) of tube length.

12. The finned tube of clause 10, wherein a ratio ($H_f/D_o$) of a fin height ($H_f$) to an outer diameter ($D_o$) of the tube body is between 0.02 and 0.05.

13. The finned tube of clause 10, wherein each respective channel enhancement comprises a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

14. The finned tube of clause 10, wherein each respective sidewall enhancement comprises a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

15. The finned tube of clause 10, wherein each fin top comprises at least one top enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body.

16. The finned tube of clause 15, wherein each respective top enhancement comprises a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

17. The finned tube of clause 10, wherein each respective sidewall is devoid of a protruding wing.

18. The finned tube of clause 10, wherein each respective helical fin is approximately cross-sectionally symmetrical.

## Claims

**1.** A finned tube comprising:

a tube body comprising an interior surface and an exterior surface;
a plurality of adjacent helical fins protruding circumferentially around the exterior surface of the tube body, at least one channel being disposed between the plurality of adjacent helical fins, each respective helical fin comprising at least one sidewall and a fin top, each channel comprising at least one channel enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body, each sidewall comprising at least one sidewall enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body, wherein:

the plurality of adjacent helical fins intermittently protrude circumferentially around the exterior surface of the tube body; or
the plurality of adjacent helical fins continuously protrude circumferentially around the exterior surface of the tube body.

**2.** The finned tube of claim 1, wherein there are between thirteen (13) and twenty-eight (28) helical fins per centimeter (between thirty-three (33) and seventy (70) per inch) of tube length.

**3.** The finned tube of claim 1 or 2, wherein a ratio ($H_f/D_o$) of a fin height ($H_f$) to an outer diameter ($D_o$) of the tube body is between 0.02 and 0.05.

**4.** The finned tube of claim 1, 2 or 3, wherein each respective channel enhancement comprises a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

**5.** The finned tube of any preceding claim, wherein each respective sidewall enhancement comprises a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

**6.** The finned tube of any preceding claim, wherein each fin top comprises at least one top enhancement impressed radially into and transversely through at intervals around the circumference of the exterior surface of the tube body.

**7.** The finned tube of claim 6, wherein each respective top enhancement comprises a depth ($D_e$) between 0.05 and 0.2 of a fin height ($H_f$).

**8.** The finned tube of claim any preceding claim, wherein each respective sidewall is devoid of a protruding wing.

**9.** The finned tube of any preceding claim, wherein each respective helical fin is approximately cross-sectionally symmetrical.

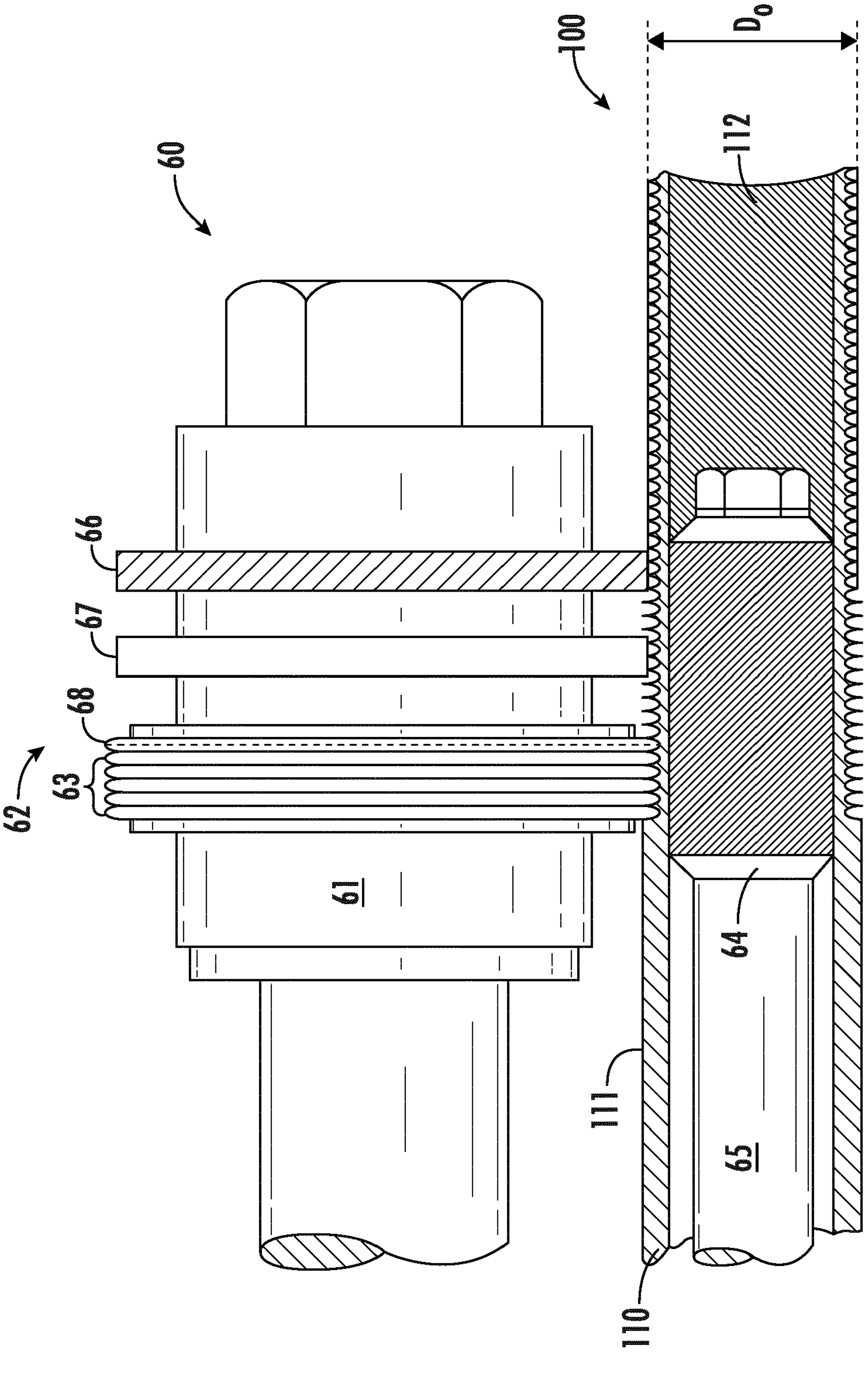
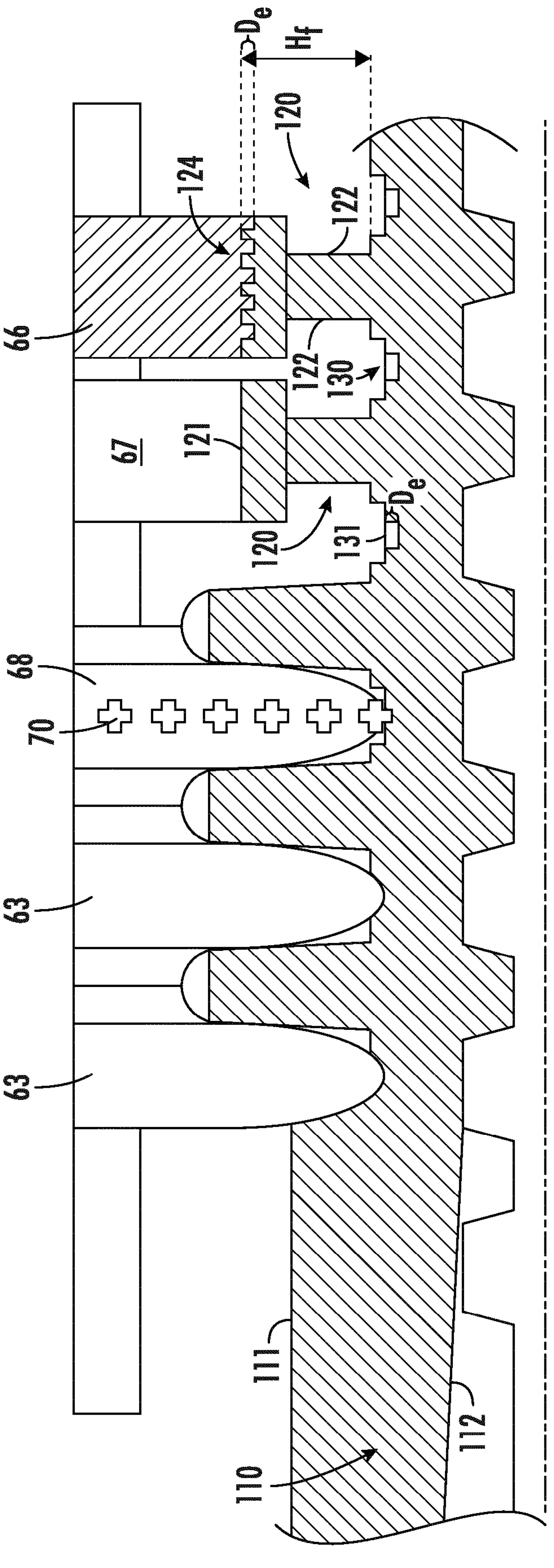
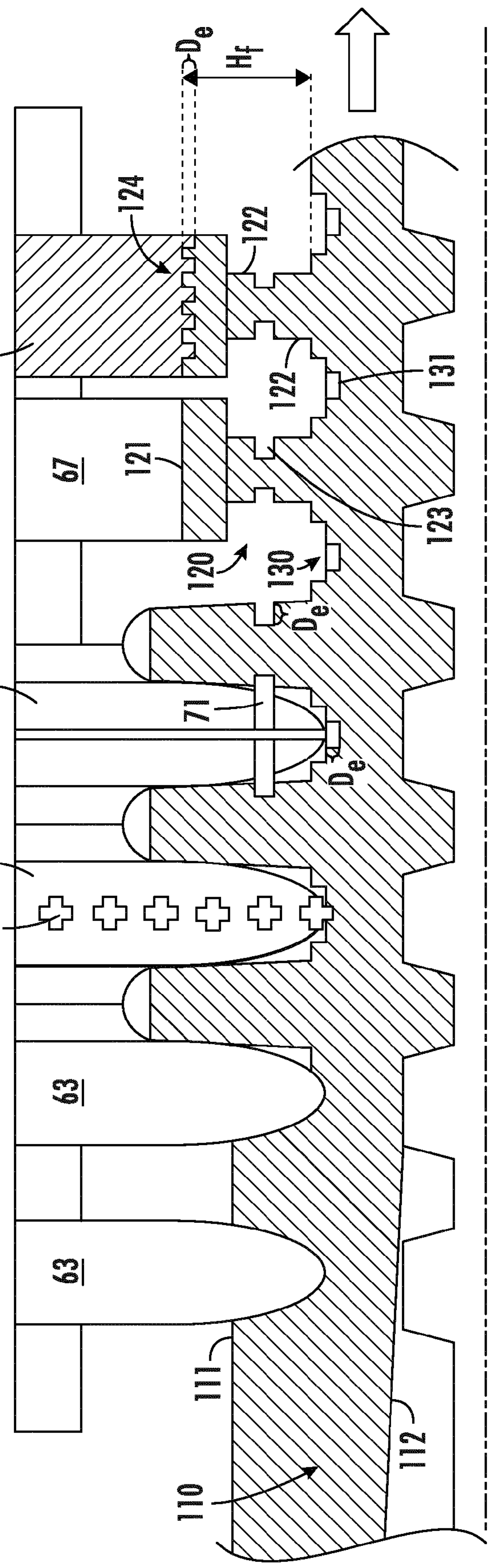



FIG. 1



$D_e$
$H_f$
120
124
122
66
122
130
67
121
$D_e$
120
131
68
70
63
63
111
112
110


FIG. 2



66
124
122
D_e
H_f
67
121
122
131
123
120
130
D_e
69
71
D_e
68
70
63
63
111
112
110


FIG. 3

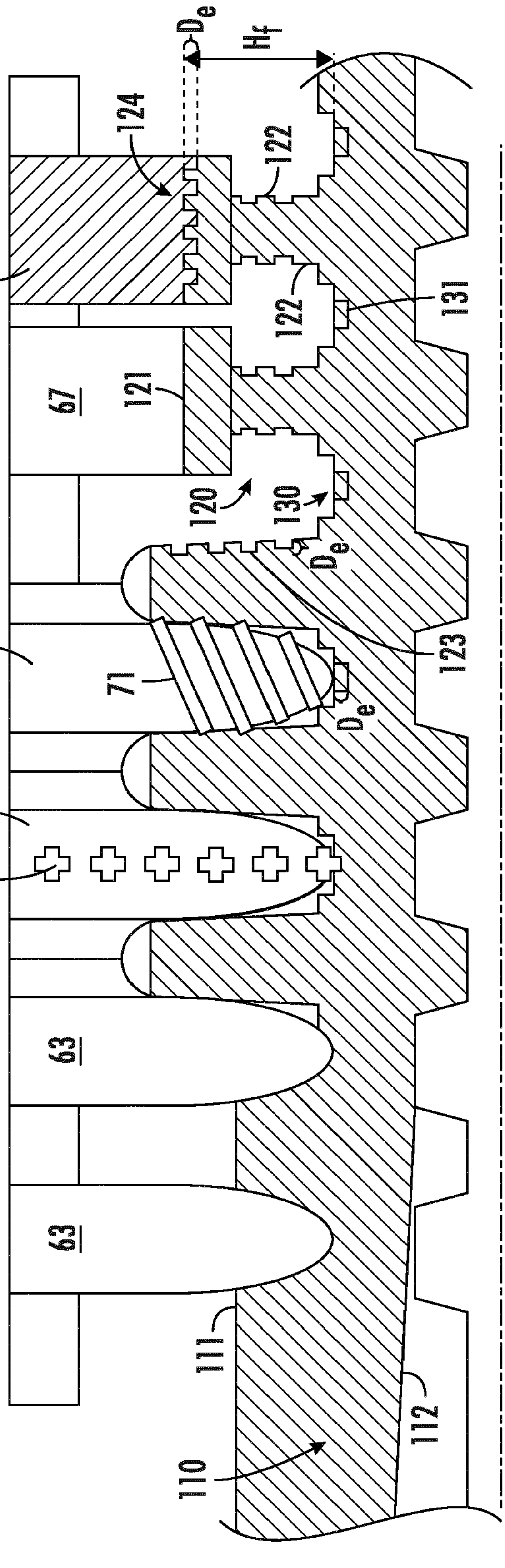

$D_e$
$H_f$
124
122
66
122
131
67
121
120
130
$D_e$
69
123
71
$D_e$
68
70
63
63
111
110
112

FIG. 4

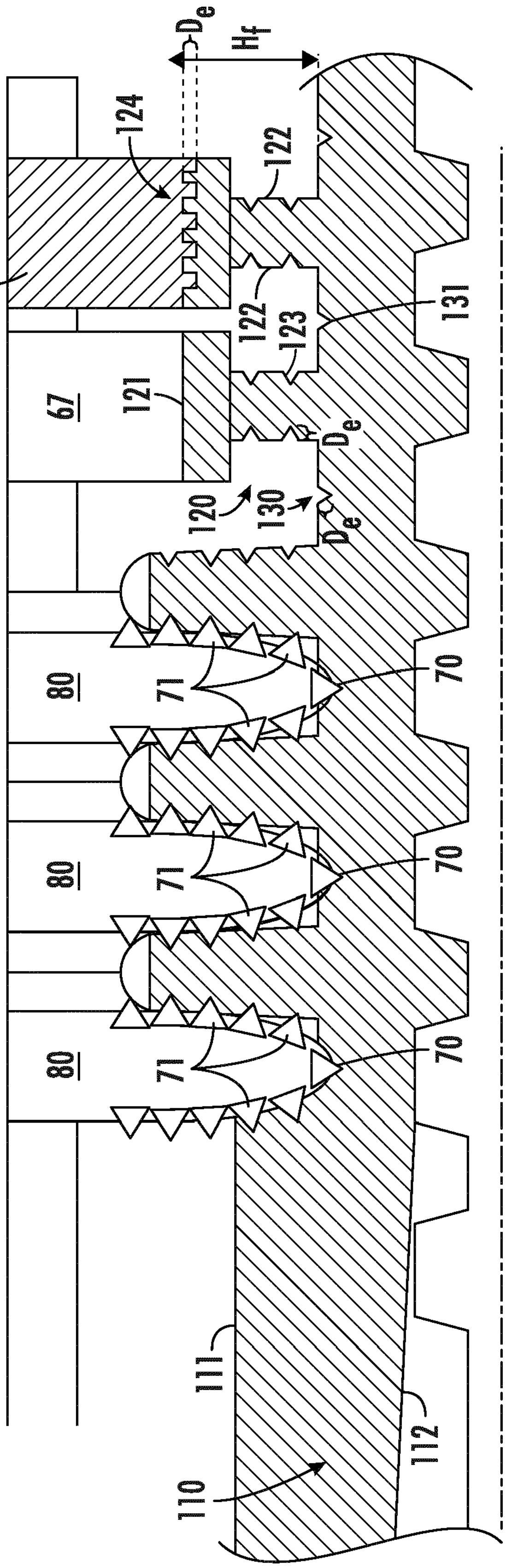

$D_e$
$H_f$
124
122
66
122
123
131
67
121
$D_e$
120
130
$D_e$
80
71
70
80
71
70
80
71
70
111
112
110

FIG. 5

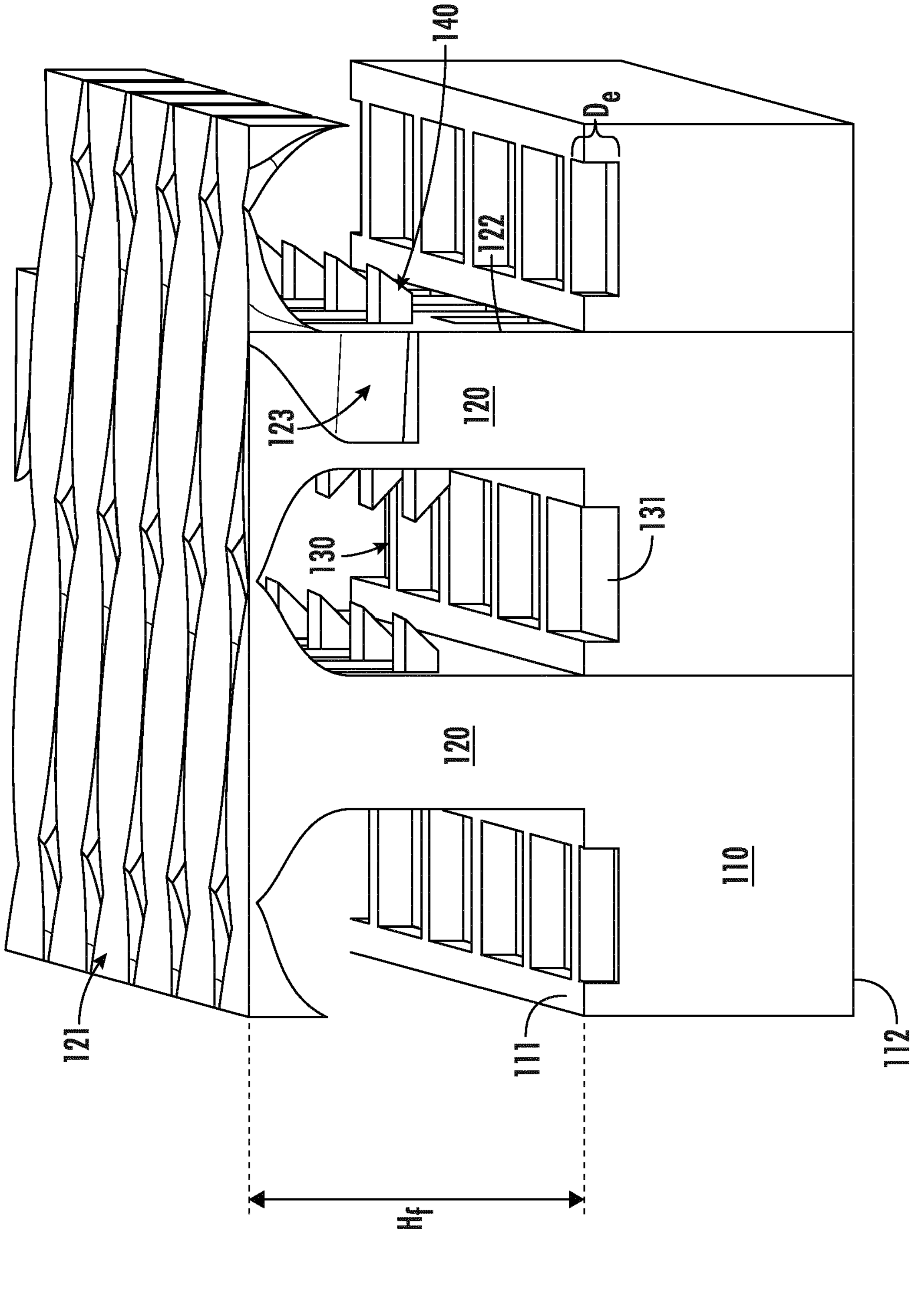



FIG. 6

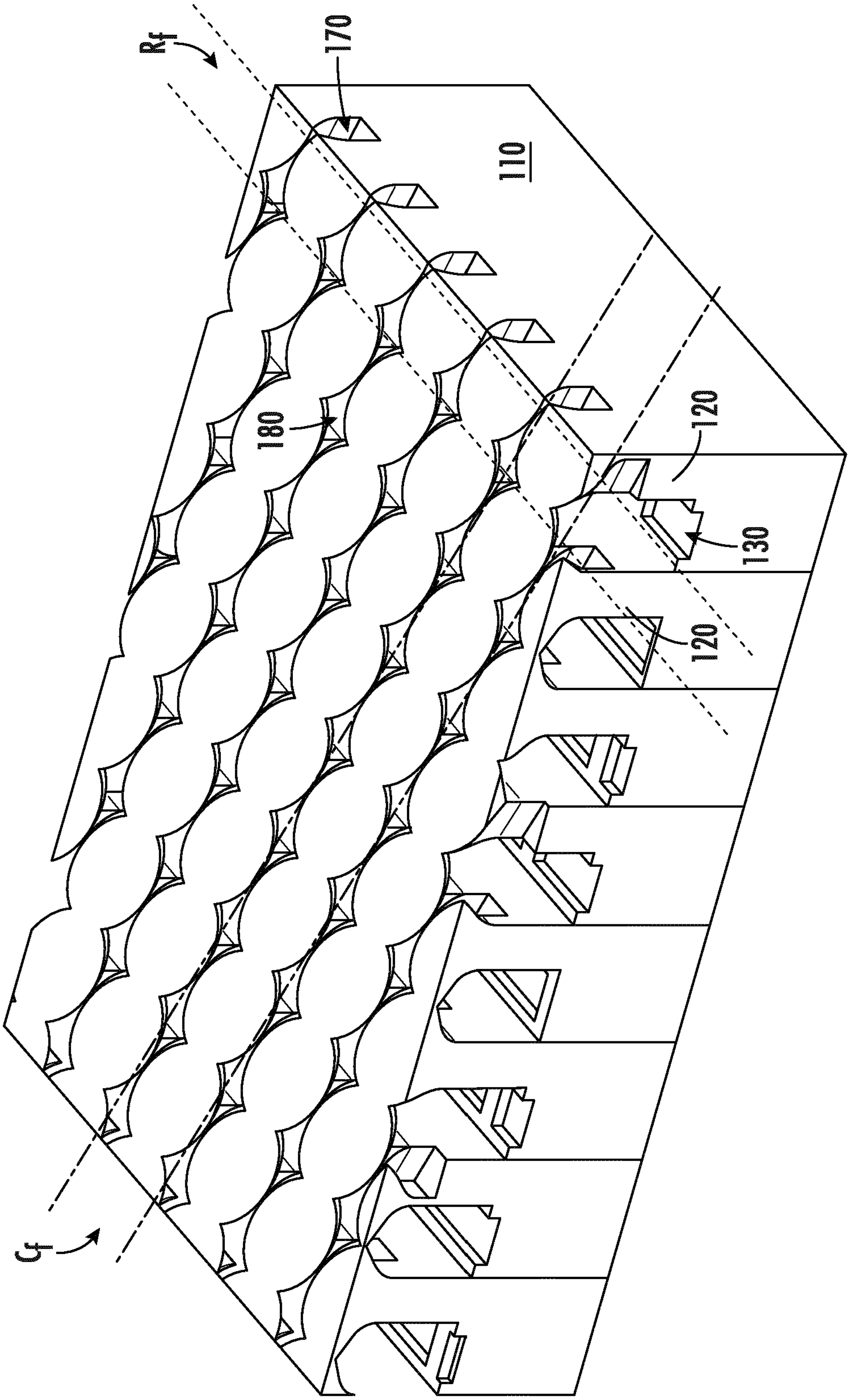



FIG. 7

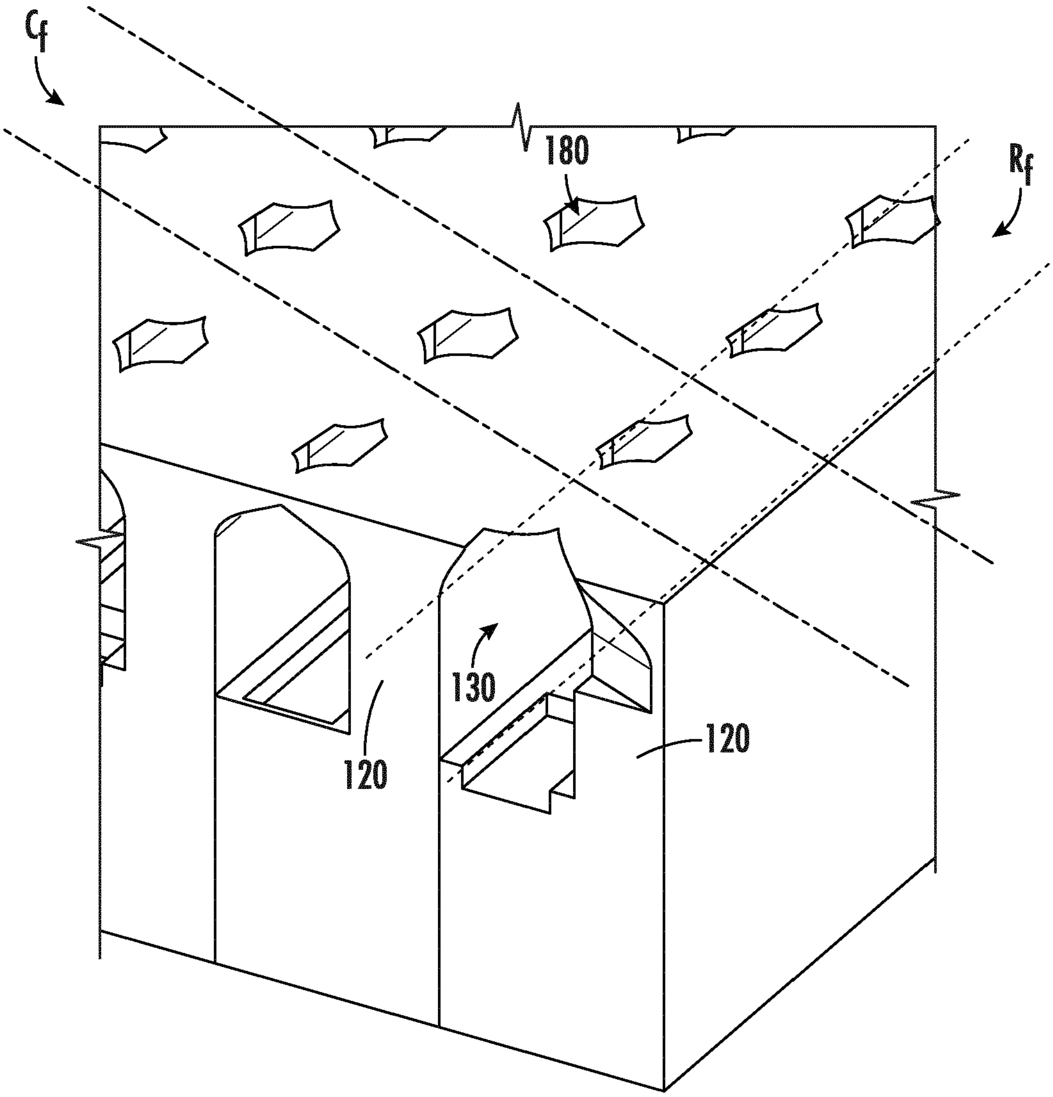



FIG. 8

Europäisches Patentamt
European Patent Office
Office européen des brevets

# EUROPEAN SEARCH REPORT

Application Number
EP 21 20 7242

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| X | EP 2 917 675 B1 (WIELAND WERKE AG [DE]) 1 May 2019 (2019-05-01) * figure 4 * ----- | 1-9 | INV. F28F1/00 |
| X | US 2003/024121 A1 (BEUTLER ANDREAS [DE] ET AL) 6 February 2003 (2003-02-06) * figure 5 * ----- | 1-9 | |
| A | US 5 775 411 A (SCHUEZ GERHARD [DE] ET AL) 7 July 1998 (1998-07-07) * figure 2 * ----- | 1-9 | |
| A | US 4 796 693 A (KASTNER HANS-WERNER [DE] ET AL) 10 January 1989 (1989-01-10) * figure 1 * ----- | 1-9 | |

TECHNICAL FIELDS SEARCHED (IPC)

F28F

The present search report has been drawn up for all claims

1

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 16 March 2022 | Bain, David |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

# ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 21 20 7242

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

16-03-2022

| Patent document cited in search report | | Publication date | Patent family member(s) | | | Publication date |
|---|---|---|---|---|---|---|
| EP 2917675 | B1 | 01-05-2019 | CN | 102980431 | A | 20-03-2013 |
| | | | CN | 103217045 | A | 24-07-2013 |
| | | | CN | 104903673 | A | 09-09-2015 |
| | | | EP | 2917675 | A1 | 16-09-2015 |
| | | | HU | E045431 | T2 | 30-12-2019 |
| | | | KR | 20150084761 | A | 22-07-2015 |
| | | | PL | 2917675 | T3 | 30-09-2019 |
| | | | PT | 2917675 | T | 02-08-2019 |
| | | | US | 2015247681 | A1 | 03-09-2015 |
| | | | WO | 2014072047 | A1 | 15-05-2014 |
| US 2003024121 | A1 | 06-02-2003 | AT | 356966 | T | 15-04-2007 |
| | | | CN | 1366170 | A | 28-08-2002 |
| | | | DE | 10101589 | C1 | 08-08-2002 |
| | | | EP | 1223400 | A2 | 17-07-2002 |
| | | | ES | 2283470 | T3 | 01-11-2007 |
| | | | JP | 3935348 | B2 | 20-06-2007 |
| | | | JP | 2002277188 | A | 25-09-2002 |
| | | | PT | 1223400 | E | 31-05-2007 |
| | | | US | 2002092644 | A1 | 18-07-2002 |
| | | | US | 2003024121 | A1 | 06-02-2003 |
| US 5775411 | A | 07-07-1998 | DE | 4404357 | C1 | 09-03-1995 |
| | | | EP | 0667504 | A1 | 16-08-1995 |
| | | | JP | 3547199 | B2 | 28-07-2004 |
| | | | JP | H07270088 | A | 20-10-1995 |
| | | | US | 5775411 | A | 07-07-1998 |
| US 4796693 | A | 10-01-1989 | EP | 0222100 | A2 | 20-05-1987 |
| | | | US | 4796693 | A | 10-01-1989 |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82