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(54) **FLUID DISTRIBUTOR FOR MICROCHANNEL HEAT EXCHANGER**

(57) A fluid distributor (100) for a heat exchanger comprises a header (102) having compartments (104-1... 104-N). A plurality of MCHX tubes (108) associated with a heat exchange section of the heat exchanger are fluidically connected to at least one of the compartments (104-1... 104-N). The fluid distributor (100) further comprises a distribution tube (110) extending longitudinally along the compartments (104-1... 104-N) through the walls (106-1... 106-N). The distribution tube (110) comprises a plurality of cavities (112-1... 112-8) extending longitudinally along the length of the distribution tube (110) and configured radially around a central axis (A-A') of the distribution tube (110). Each cavity (112-1... 112-8) comprises ports (P) opening in a compartment (104-1... 104-N). Further, the fluid distributor (100) comprises a supply tube (114) fluidically connected to the distribution tube (110) or to a supply tube compartment (104-1) of header (102) and configured to supply a fluid into the distribution tube (110).

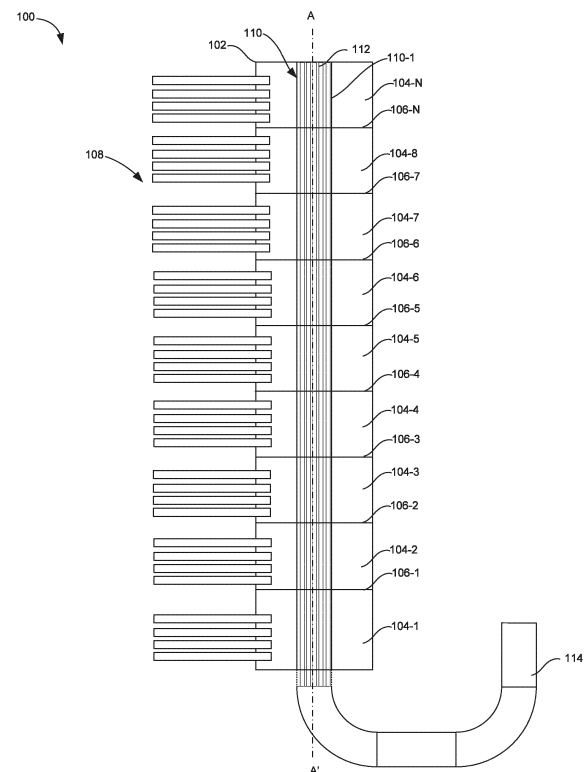


FIG. 1A

Description

BACKGROUND

[0001] This invention relates to the field of heat exchangers, and more particularly, a fluid distributor for heat exchangers.

SUMMARY

[0002] According to a first aspect of the invention there is provided a fluid distributor for a heat exchanger. The fluid distributor comprises a header comprising of compartments separated by walls, wherein a plurality of tubes associated with a heat exchange section of the heat exchanger are fluidically connected to at least one of the compartments. The fluid distributor further comprises a distribution tube extending longitudinally along the compartments of the header through the walls. The distribution tube comprises a plurality of cavities extending longitudinally along a length of the distribution tube and configured radially around a central axis of the distribution tube, wherein each of the cavities comprises one or more ports opening in the compartments. Further, the fluid distributor comprises a supply tube fluidically connected to the distribution tube or to a supply tube compartment of the header and configured to supply a working fluid into the distribution tube.

[0003] Optionally, the fluid distributor comprises a flow restrictor configured within the supply tube or between the supply tube and the distribution tube, wherein the flow restrictor is an annular member having a central opening that is configured in line with the distribution tube and having a predefined gap therebetween.

[0004] Optionally, the central opening of the flow restrictor and the distribution tube have equal diameters. Optionally, the central opening of the flow restrictor is in a range of 10 to 80% of an orifice of the distribution tube.

[0005] Optionally, the fluid distributor comprises a swirl generator configured upstream of the distribution tube or within the supply tube, wherein the swirl generator is configured to cause the working fluid, supplied by the supply tube, to move in a swirl motion.

[0006] Optionally, the swirl generator comprises a housing having a plurality of grooves with curved profiles being configured on an inner wall surface of the housing, the grooves extending radially and circumferentially along the inner wall surface.

[0007] Optionally, the swirl generator comprises a housing and a plurality of blades extending radially from a central longitudinal axis of the housing and oriented at predefined angles from a radial plane.

[0008] Optionally, the swirl generator comprises a housing, and a plurality of blades extending radially from a central longitudinal axis of the housing, wherein each of the blades comprises a first section and a second section with a slit extending at a predefined angle from the first section.

[0009] Optionally, the swirl generator comprises a housing, and a plurality of swirl-generating elements having a predefined shape and at least one curved surface, protruding from or configured on an inner wall surface of the housing.

[0010] Optionally, the swirl generator comprises a ring protruding from or configured on the inner wall surface of the housing, the ring is configured coaxially within the housing with the plurality of swirl-generating elements configured above and/or below the ring.

[0011] Optionally, the supply tube is axially connected to the supply tube compartment or the distribution tube.

[0012] Optionally, the supply tube is radially connected to the supply tube compartment or the distribution tube.

[0013] Optionally, the supply tube is configured off-centered from the central axis of the distribution tube.

[0014] Optionally, the supply tube is directly connected to the distributor tube, wherein the distributor tube and the supply tube have equal diameters.

[0015] Optionally, the header is a vertical header of the heat exchanger and the supply tube is fluidically connected to terminal supply tube compartment.

[0016] Optionally, the fluid distributor comprises one or more swirl-generating elements being configured within or on an inner wall surface of the supply tube compartment, the supply tube, or both.

[0017] Optionally, the supply tube is radially connected at a predefined position on the supply tube compartment of the header, such that the orifice of the distribution tube opens below, above, or at a same level of the predefined position or the supply tube.

[0018] Optionally, the supply tube compartment comprises a baffle having a central opening and a plurality of openings configured radially around the central opening. The baffle is coaxially configured within the supply tube compartment such that a bottom end or the orifice of the distribution tube remains connected to the central opening and the supply tube is connected radially to the supply tube compartment above the baffle.

[0019] Optionally, the supply tube compartment comprises a baffle having a plurality of openings. The baffle is coaxially configured within the supply tube compartment of the header with the distribution tube extending longitudinally through the baffle such that a bottom end or the orifice of the distribution tube opens below the baffle and the supply tube is radially connected to the supply tube compartment above the baffle.

[0020] Optionally, the supply tube is configured off-centered from the central axis of the distribution tube.

[0021] According to a second aspect of the invention there is provided a heat exchanger comprising the fluid distributor according to the first aspect of the invention.

[0022] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, features, and techniques of the invention will become more apparent from the following description taken in conjunction

with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The accompanying drawings are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification. The drawings illustrate exemplary embodiments of the invention and, together with the description, serve to explain the principles of the invention.

[0024] In the drawings, similar components and/or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label with a second label that distinguishes among the similar components. If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label. Certain exemplary embodiments will now be described in greater detail by way of example only and with reference to the accompanying drawings.

FIGs. 1A to 1D illustrate exemplary views of a fluid distributor of a heat exchanger.

FIGs. 2A and 2B illustrate exemplary views of the fluid distributor having a flow restrictor.

FIG. 3A illustrates an exemplary view of the fluid distributor having a swirl generator.

FIG. 3B illustrates an exemplary view of the swirl generator having a plurality of curved grooves along an inner wall of a housing of the swirl generator.

FIG. 3C illustrates an exemplary front view, top view, and perspective view respectively of the swirl generator having a plurality of blades extending radially from a central longitudinal axis of the housing of the swirl generator.

FIG. 3D illustrates an exemplary front view and top view respectively of the swirl generator having a plurality of blades with split sections extending radially from a central longitudinal axis of the housing of the swirl generator.

FIG. 3E illustrates an exemplary top view and front view respectively of the swirl generator having a plurality of swirl-generating elements disposed on an inner wall surface of the housing of the swirl generator.

FIG. 3F illustrates an exemplary top view and front view respectively of the swirl generator having a plurality of swirl-generating elements and a ring configured on an inner wall surface of the housing of the swirl generator.

FIGs. 4A and 4B illustrate exemplary views of the fluid distributor having the supply tube off-center from a central axis of the distributor tube.

FIGs. 5A and 5B illustrate exemplary views of the fluid distributor having a baffle with openings and the supply tube off-center from the central axis of the

distributor tube.

FIG. 6A illustrates an exemplary plot depicting the fluid flow rate in different cavities of the distributor tube with 4 openings when 25% orifice of the distributor tube of FIG. 2A is open.

FIG. 6B illustrates an exemplary plot depicting the fluid flow rate in different cavities of the distributor tube when 25% orifice of the distributor tube of FIG. 2B is open.

FIG. 6C illustrates an exemplary plot depicting the fluid flow rate in different cavities of the distributor tube when the swirl generator of FIG. 3B is configured with the distribution tube.

FIG. 6D illustrates an exemplary plot depicting the fluid flow rate in different cavities of the distributor tube in the flow distributor of FIGs. 4A and 4B.

FIG. 6E illustrates an exemplary plot depicting the fluid flow rate in different cavities of the distributor tube in the flow distributor of FIGs. 5A and 5B.

DETAILED DESCRIPTION

[0025] The following is a detailed description of embodiments depicted in the accompanying drawings. The embodiments are in such detail as to clearly communicate the invention. However, the amount of detail offered is not intended to limit the anticipated variations of embodiments; on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the scope of the invention as defined by the appended claims.

[0026] Various terms are used herein. To the extent a term used in a claim is not defined below, it should be given the broadest definition persons in the pertinent art have given that term as reflected in printed publications and issued patents at the time of filing.

[0027] In the specification, reference may be made to the spatial relationships between various components and to the spatial orientation of various aspects of components as the devices are depicted in the attached drawings. However, as will be recognized by those skilled in the art after a complete reading of the specification, the components of this invention described herein may be positioned in any desired orientation. Thus, the use of terms such as "above," "below," "upper," "lower," "first," "second" or other like terms to describe a spatial relationship between various components or to describe the spatial orientation of aspects of such components should be understood to describe a relative relationship between the components or a spatial orientation of aspects of such components, respectively, as the header, distribution tube, refrigerant distributor, multichannel tubes, heat exchanger, supply tube, and corresponding components, described herein may be oriented in any desired direction.

[0028] Microchannel heat exchangers (MCHX) employing microchannel tubes are important components in heat pump systems, facilitating efficient heat transfer

between different fluid streams. These heat exchangers are employed in a wide range of applications, including residential and commercial heating, ventilation, and air conditioning (HVAC) systems. An important challenge in the design and operation of MCHX is the effective distribution of the working fluid (refrigerant) across the microchannel tubes to ensure optimal heat transfer performance and capacity. The working fluid may be in two phases, vapor and liquid. When two phases are present, the two phases must be mixed to facilitate effective distribution.

[0029] Mal-distribution of the working fluid within MCHX can lead to significant imbalances in thermal characteristics and a reduction in overall heat transfer efficiency. One of the primary concerns associated with mal-distribution is the varying heat transfer coefficient between the vapor and liquid phases. Due to the lower heat transfer coefficient of the vapor phase, an uneven distribution can result in localized areas of reduced heat transfer, leading to decreased capacity and overall performance of the heat pump system.

[0030] Furthermore, the problem of mal-distribution becomes exacerbated when MCHX is configured with vertical headers. In such configurations, the influence of gravity plays a role in causing separation between the vapor and liquid phases due to the differing densities of these phases. This vapor-liquid separation may lead to increased mal-distribution of fluid across the microchannel tubes and compromise the overall heat transfer efficiency of the system.

[0031] There is a need for a solution to address the challenges posed by mal-distribution in MCHX, particularly in MCHX having vertical headers, by providing an improved and effective fluid distribution system that helps the MCHX achieve a more uniform distribution of the working fluid phases across all the microchannel tubes, thereby enhancing the overall thermal performance of the MCHX.

[0032] The header (or manifold) forms a conduit to deliver working fluid to the heat exchange tubes. The header may be vertical, horizontal or some intermediate angle between vertical and horizontal. Additionally, the flow of the working fluid may be in any direction (bottom to top, top to bottom or side to side). The header includes compartments dedicated to a group of heat exchange tubes which is a subset of the total number of heat exchange tubes. A distribution tube located within the header provides working fluid to the compartments. The distribution tube has cavities extending longitudinally. Each distribution tube cavity provides working fluid to one or more compartments of the header.

[0033] A supply tube provides the working fluid to the header. The supply tube may be directly connected to the distribution tube or may be fluidly connected to a supply tube compartment in the header. The supply tube compartment may be located at one end of the header (a terminal supply tube compartment) or may be located at some intermediate point of the header (an intermediate

supply tube compartment). When the supply tube compartment is a terminal supply tube compartment, the distribution tube has one or more orifices to allow the working fluid to enter the distribution tube. When the supply tube compartment is an intermediate supply tube compartment, the distribution tube has two or more orifices to allow the working fluid to enter the distribution tube. The supply tube compartment may provide a space to mix the phases of the working fluid. Mixing the phases of the working fluid can be achieved by placement of the supply tube outlet relative to the distribution tube orifice(s), the structure of the distribution tube orifice, the structure of the supply tube compartment, or a combination thereof.

[0034] When the supply tube is directly connected to the distribution tube, the distribution tube and the supply tube may have equal internal diameters or may have different internal diameters. Further, the distribution tube has one or more orifices opening in or located within the supply tube. The orifice(s) may be before or after a bend in the supply tube. The terminal end of the supply tube or the distribution tube orifice may include a mixing element such as a swirl generator as described below.

[0035] When the supply tube connects to the header the working fluid enters a supply tube compartment. The supply tube compartment may be terminal or intermediate as described above. When the supply tube is a terminal supply tube compartment the location of the supply tube relative to the distribution tube orifice and the distribution tube axis can affect working fluid phase mixing. Additionally, the supply tube compartment structure can be used to enhance working fluid phase mixing. When the supply tube compartment is intermediate the structure of the supply tube compartment as well as the placement of the supply tube outlet can be used to enhance the working fluid phase mixing.

[0036] Referring to FIGs. 1A to 1D, the fluid distributor 100 for a heat exchanger is disclosed. The fluid distributor 100 or the heat exchanger can include a header 102 comprising one or more hollow compartments 104-1 to 104-N (collectively designated as compartments 104, herein) being partitioned by one or more walls 106-1 to 106-N (collectively referred to as walls or partition walls 106, herein). The header 102 can be a hollow member having parallelly placed walls 106 separated by a pre-defined distance to create the compartments 104 there-within. The compartments 104 may have equal volumes or the volumes may vary. When the compartment volumes vary the number of microchannel tubes associated with the compartments may vary as well. The header 102 may have a cylindrical profile or a substantially curved profile with flat bases at the two opposite ends but is not limited to the like. Further, a plurality of microchannel tubes (collectively designated as MCHX tubes 108, herein) associated with a heat exchange section or coils of the heat exchanger can be fluidically connected to at least one of the compartments 104-1 to 104-N.

[0037] In addition, the header includes a distribution

tube 110 extending longitudinally along the compartments 104 of the header 102 through the partition walls 106. The distribution tube 110 can include a plurality of cavities 112-1 to 112-8 (collectively designated as cavities, 112, herein) extending longitudinally along a length of the distribution tube 110 and configured radially around a central axis (A-A') of the distribution tube 110 in a distribution tube casing 110-1. The cavities may be pie-shaped as shown in the Figures or may form concentric rings. Further, as shown in FIGs. 2A, 2B, 3A, 4A, and 5B, each of the cavities 112 can include one or more ports (P) opening in at least one of the partitioned compartments 104 of the header 102. When the cavities form concentric rings the exterior of the distribution tube may have a stepped shape resulting from the termination of the ring after the one or more ports opening in the destination compartment.

[0038] The distribution tube 110 can be a rod-shaped member 110-1 having a plurality of axial hollow passages 112 extending longitudinally along the length and configured radially around a central axis (A-A') of the rod member to form the plurality of cavities 112. Further, additional hollow passages can extend radially from the vertical passages 112 and open into the interior of the header 102 to form the ports (P) of the cavities 112.

[0039] Further, the flow distributor includes a supply tube 114 fluidically connected to distribution tube 110 or to the header 102 and configured to supply a fluid into the distribution tube 110 such that the fluid is more uniformly mixed and supplied into the cavities 112 and further into the MCHX tubes 108 of the heat exchange section via the ports (P) of the corresponding cavities 112.

[0040] An exemplary header 102 is a vertical header 102 of the heat exchanger but, as discussed above, is not limited thereto. In one or more embodiments, the supply tube 114 can be directly fluidically connected to the distribution tube 110. The distribution tube 110 can include one or more orifices opening in or located within the supply tube 114, such that the fluid supplied by the supply tube 114 may directly enter into each of the cavities 112 (or orifice) of the distribution tube 110. Further, in one or more embodiments, the orifice(s) of the distribution tube 110 may be before or after a bend in the supply tube 114 to axially supply the fluid into the distribution tube 110. Furthermore, in one or more embodiments, the supply tube 114 can be fluidically connected to a bottom-most compartment 104-1, as the supply tube compartment, among the compartments 104 of the header 102, with an orifice (O) of the distribution tube 110 opening in the bottom-most compartment 104-1. The top end of the distribution tube 110 (or the cavities 112) may be closed and the orifice (O) at the bottom end of the distribution tube 110 may open in the supply tube compartment 104-1, such that the fluid supplied by the supply tube 114 may enter into each of the cavities 112 (or orifice) of the distribution tube 110 via the supply tube compartment 104-1 and further flow into the MCHX tubes 108 via the corresponding compartments 104 and the ports (P) of the

cavities 112.

[0041] In one or more embodiments, the number of cavities 112 in the distribution tube 110 can be equal to the number of compartments 104 having the MCHX tubes 108 such that ports (P) associated with one of the cavities 112 can open in one of the partitioned compartments 104 of the header 102, however, one of the cavities 112 can open in more than one compartment 104, without any limitation. In an example, but not limited to the like, the distribution tube 110 can include 8 cavities 112-1 to 112-8 for 8 compartments 104 (excluding the bottom-most compartment 104-1) of the header 102 as shown in FIG. 1B. Further, in another example, the distribution tube 110 can include 4 cavities 112-1 to 112-4 for 4 compartments 104 (excluding the bottom-most compartment 104-1) of the header 102 as shown in FIG. 1C. In one or more embodiments, the size and number of the cavities 112 of the distribution tube 110, and the size and number of ports (P) in each of the cavities 112 can be selected based on the flow rate of the fluid to be supplied to the MCHX tubes 108 in each compartment 104 of the header 102.

[0042] In one or more embodiments, as shown in FIGs. 1C and 1D, the supply tube 114 can be axially connected to the header 102 or the distribution tube 110. Further, in some embodiments, the supply tube 114 can be directly connected to the distribution tube 110, with the distribution tube 110 and the supply tube 114 having equal diameters, however, the distribution tube 110 and the supply tube 114 can also have different diameters. In one or more embodiments, the supply tube 114 can be perpendicular to the header 102 such that the supply tube compartment 104-1, the distribution tube 110, and the cavities 112 of the distribution tube 110 remain axial to the supply tube 114.

[0043] In one or more embodiments, as shown in FIGs. 1A and 1B, the supply tube 114 can also be radially connected to and off-centered from the header 102. Further, in some embodiments, the supply tube 114 can be configured off-centered from the central axis (A-A') of the distribution tube 110, such that the fluid supplied by the supply tube 114 may flow in a swirl motion within the bottom-most compartment 104-1 of the header 102 to get more uniformly mixed and then flow into each of the cavities 112 of the distribution tube 110.

[0044] Referring to FIGs. 2A and 2B, in one or more embodiments, the fluid distributor 100 can include a flow restrictor 202 configured in the supply tube 114 of the heat exchanger. In one or more embodiments, as shown in FIG. 2A, the flow restrictor 202 can be an annular member (also designated as 202, herein) having an opening 204 that can be configured in line with the orifice (O) of the distribution tube 110 such that a predefined gap remains between the orifice (O) and the flow restrictor 202. In one or more embodiments, as shown in FIG. 2B, the fluid distributor 100 can further include a truncated cone 206 configured at the orifice (O) of the distribution tube 110 such that fluid supplied by the supply tube 114 can flow

around the truncated cone 206 and further enter into the distribution tube 110.

[00445] A truncated cone 206 can be configured along with the annular member 202, however, the truncated cone 206 can also be directly connected to the orifice (O) of the distribution tube 110 without the annular member 204. Further, the opening 204 of the flow annular member 202 and the orifice (O) of the distribution tube 110 can also have equal diameters. However, the opening 204 of the flow annular member 202 can also be in a range of 10 to 80% of the orifice (O) of the distribution tube 110. Accordingly, when the fluid is supplied into distribution tube 110 by the supply tube 114, the rim (around the opening 204) of the flow restrictor 202 can cause turbulence in the fluid (or provide resistance to the fluid), thereby more uniformly mixing the fluid and allowing approximately equal volume of the fluid to flow into each cavity 112 of the distribution tube 110. Thus, the more uniformly mixed fluid can flow into the MCHX tubes 108 or the compartments 104 of the header 102 via the ports (P) of the corresponding cavities 112.

[00446] Referring to FIG. 6A, an exemplary plot depicting the fluid flow rate in different cavities of the distributor tube is disclosed when 25% orifice of the distribution tube is open in the fluid distributor of FIG. 2A. The computation fluid dynamics (CFD) simulations were performed on the distribution tube 110 having four cavities 112-1 to 112-4 with the flow restrictor (annular member) 202 configured within the supply tube 114, at the orifice (O) of the distribution tube 110. As illustrated, the results confirmed a more uniform flow of fluid in each of the cavities 112-1 to 112-4.

[00447] Referring to FIG. 6B, an exemplary plot depicting the fluid flow rate in different cavities of the distributor tube is disclosed when 25% orifice of the distribution tube is open in the fluid distributor of FIG. 2B. The CFD simulations were performed on the distribution tube 110 having four cavities 112-1 to 112-4 with the annular member 202 and truncated cone 206 configured at the orifice (O) of the distribution tube 110. As illustrated, the results confirmed a more uniform flow of fluid in each of the cavities 112-1 to 112-4.

[00448] Referring to FIGs. 3A to 3F, in one or more embodiments, the fluid distributor 100 can include a swirl generator 300 configured within the supply tube 114 or between an orifice of the distribution tube 110 and the supply tube 114. Further, the supply tube 114 can be directly connected to the distribution tube 110 such that the swirl generator 300 remains upstream of the orifice (O) of the distribution tube 110. The swirl generator 300 can be configured to cause the fluid, supplied by or flowing through the supply tube 114, to move in a swirl motion to more uniformly mix the fluid and further supply an approximately equal volume of the mixed fluid into each of the cavities 112 of the distribution tube 110.

[00449] Referring to FIG. 3B, in a first embodiment, the swirl generator 300 can include a housing 302 configured to be fitted at the orifice (O) of the distribution tube 110.

The housing 302 can further include a plurality of grooves 304 having curved profiles configured on an inner wall surface of the housing 302. The grooves 304 can extend radially and circumferentially along the inner wall surface of the swirl generator 300, such that the fluid (supplied by the supply tube 114) can move in a swirl motion while flowing through the housing 302 to more uniformly mix the liquid and vapor, especially makes the liquid film more uniform around the wall of the tube, which can further supply an approximately equal volume of the mixed fluid into each of the cavities 112 of the distribution tube 110. Thus, the more uniformly mixed fluid can flow into the MCHX tubes 108 via the compartments 104 of the header 102 and the ports (P) of the corresponding cavities 112.

[0050] Referring to FIG. 6C, an exemplary plot depicting the fluid flow rate in different cavities of the distributor tube is disclosed when the swirl generator of FIG. 3B is configured with the distribution tube. The CFD simulations were performed on the distribution tube having eight cavities 112-1 to 112-8 with the swirl generator 300 of FIG. 3B configured upstream of the distribution tube 110 and the supply tube 114 directly connected to the swirl generator 300. As illustrated, the results confirmed a more uniform flow of fluid in each of the cavities 112-1 to 112-8.

[0051] Referring to FIG. 3C, in a second embodiment, the swirl generator 300 can include a housing 302 configured to be fitted at the orifice (O) of the distribution tube 110 and a plurality of blades 306 extending radially from a central longitudinal axis of the housing 302. The blades 306 can radially extend from the central axis (A-A') of the housing 302 towards an inner wall 106 of the housing 302 with a first angle between adjacent blades 306. Further, each of the blades 306 can be oriented at a second angle from a radial (sectional) plane of the housing 302. In an example, as shown in FIG. 3B, but not limited to the like, the swirl generator 300 can include four blades 306 with the first angle of 90° between the adjacent blades, however, the swirl generator 300 can have any number of blades 306 with equal or unequal angles between the adjacent blades 306. Accordingly, when the fluid is supplied into the distribution tube 110, the blades 306 of the swirl generator 300 being oriented at the second angle from the radial plane can cause the fluid to flow in a swirl motion while flowing through the swirl generator 300, thereby more uniformly mixing the fluid and allowing an approximately equal volume of the fluid to flow into each cavity 112 of the distribution tube 110. Thus, the more uniformly mixed fluid can flow into the MCHX tubes 108 via the compartments 104 of the header 102 and the ports (P) of the corresponding cavities 112.

[0052] Referring to FIG. 3D, in a third embodiment, the swirl generator 300 can include a housing 302 configured to be fitted at the orifice (O) of the distribution tube 110 and a plurality of blades 306 extending radially from a central longitudinal axis of the housing 302. Each of the blades 306 can include a first section 306-1, and a second section 306-2 extending at a predefined angle from the

first section 306-1. Further, each of the second sections 306-2 can have a slit or cut-out portion. The first section 306-1 and the second section 306-2 can be having a planar profile; however, they can also have a curved profile. The blades 306 can radially extend from the central axis (A-A') of the housing 302 towards an inner wall of the housing 302 with a first angle between the adjacent blades 306. Further, the first section 306-1 of the blades 306 can be oriented at a second angle from a radial (sectional) plane of the housing 302 and the second section 306-2 can extend at a third angle from the first section 306-1. Accordingly, when the fluid is supplied into the distribution tube 110, the slits and the profile (angle) of the first section 306-1 and second section 306-2 of the blades 306 can cause the fluid to flow in a swirl motion while flowing through the swirl generator 300, thereby more uniformly mixing the fluid and allowing an approximately equal volume of the fluid to flow into each cavity 112 of the distribution tube 110. Thus, the more uniformly mixed fluid can flow into the MCHX tubes 108 via the compartments 104 of the header 102 and the ports (P) of the corresponding cavities 112.

[0053] Referring to FIG. 3E, in a fourth embodiment, the swirl generator 300 can include a housing 302 configured to be fitted at the orifice (O) of the distribution tube 110 and a plurality of swirl-generating elements 308 having a predefined shape and at least one curved surface, protruding from or configured at second predefined positions on an inner wall 106 surface of the housing 302. Further, referring to FIG. 3F, in a fifth embodiment, the swirl generator 300 of FIG. 3E can include a ring 310 protruding from or configured on the inner wall 106 surface of the housing 302. The ring 310 can be configured coaxially within the housing 302 with the swirl-generating elements 308 configured above and/or below the ring 310.

[0054] In one or more embodiments, the swirl-generating elements 308 can be rectangular-shaped members that can be machined to give a curved profile. Further, one of the sides of the swirl-generating elements 308 can then be attached to the inner wall 106 of the housing 302, such that the curved profile of the elements can cause the fluid to flow in a swirl motion while flowing through the swirl generator 300.

[0055] Further, in one or more embodiments, the swirl-generating elements 308 can be substantially triangular-shaped members that can be machined to form a curved profile. Further, one of the non-inclined sides of the swirl-generating elements 308 can then be attached to the inner wall of the housing 302, such that the curved profile and inclined side of the swirl elements 308 can cause the fluid to flow in a swirl motion while flowing through the swirl generator 300.

[0056] In addition, in one or more embodiments (not shown), the fluid distributor 100 can also include one or more swirl-generating elements (308) being configured within or on an inner wall surface of the supply tube compartment 104-1 of the header 102 and/or the supply

tube 114 to facilitate the fluid to flow in a swirl motion while entering the distribution tube 110.

[0057] Referring to FIGs. 4A and 4B, in one or more embodiments, the supply tube 114 can be radially connected to a curved lateral surface of the bottom-most compartment 104-1 such that the supply tube 114 remains off-centered or off-set from a central axis (A-A') of the distribution tube 110 or the header 102. Accordingly, the off-centered position of the supply tube 114 can cause the fluid (supplied by the supply tube 114) to flow in a swirl motion within the bottom-most compartment 104-1 of the header 102 to get more uniformly mixed, further allowing an approximately equal volume of the mixed fluid to flow into each cavity 112 of the distribution tube 110. Accordingly, the more uniformly mixed fluid can flow into the MCHX tubes 108 via the compartments 104 of the header 102 and the ports (P) of the corresponding cavities 112.

[0058] Referring to FIG. 6D, an exemplary plot depicting the fluid flow rate in different cavities of the distributor tube in the flow distributor of FIGs. 4A and 4B are disclosed. The CFD simulations were performed on the distribution tube 110 having eight cavities 112-1 to 112-8 with the supply tube 114 radially connected to a curved lateral surface of the bottom-most compartment 104-1 such that the supply tube 114 remains off-centered from a central axis (A-A') of the distribution tube. As illustrated, the results confirmed a more uniform flow of fluid in each of the cavities 112-1 to 112-8.

[0059] Referring to FIGs. 5A and 5B, in one or more embodiments, the fluid distributor 100 having a baffle 502 with openings 504 and the supply tube 114 being off-centered from the central axis (A-A') of the distribution tube 110 is disclosed. The baffle 502 can be coaxially configured within the bottom-most compartment 104-1 of the header 102 with the distribution tube 110 extending longitudinally through the baffle 502 such that a bottom end of the distribution tube 110 remains below the baffle 502 and the supply tube 114 remains radially connected to the bottom-most compartment 104-1 above the baffle 502.

[0060] The supply tube 114 can be radially connected to a curved lateral surface of the bottom-most compartment 104-1 such that the supply tube 114 remains off-centered or off-set from a central axis (A-A') of the distribution tube 110 or the header 102 and a bottom end of the distribution tube 110 remains below the baffle 502. Accordingly, the off-centered position of the supply tube 114 can cause the fluid (supplied by the supply tube 114) to flow in a swirl motion within the bottom-most compartment 104-1 of the header 102 and flow into the distribution tube 110 via the openings 504 of the baffle 502. In addition, the openings 504 of the baffle 502 can further cause turbulence to the fluid flow, thereby more uniformly mixing the fluid and further allowing an approximately equal volume of the mixed fluid to flow into each cavity 112 of the distribution tube 110. Accordingly, the more uniformly mixed fluid can flow into the MCHX tubes 108 or the compartments 104 of the header 102 via the ports (P)

of the corresponding cavities 112. In one or more embodiments, the size and number of the openings in the baffle can be selected based on the flow rate of the fluid to be supplied to distribution tube 110.

[0061] Referring to FIG. 6E, an exemplary plot depicting the fluid flow rate in different cavities of the distributor tube in the flow distributor of FIGs. 5A and 5B are disclosed. The CFD simulations were performed on the distribution tube 110 having eight cavities 112-1 to 112-8 with the supply tube 114 radially connected to the bottom-most compartment 104-1 above the baffle 502 and off-centered from a central axis (A-A') of the distribution tube 110 and a bottom end of the distribution tube 110 remaining below the baffle 502. As illustrated, the results confirmed a more uniform flow of fluid in each of the cavities 112-1 to 112-8.

[0062] It should be obvious to a person skilled in the art that while various embodiments of this invention have been elaborated for a vertical header having a specific number of compartments and a specific number of cavities in the distribution tube for the sake of simplicity and better explanation purpose, however, the teachings of this specification are equally applicable for other heat exchanger having a different configuration and including a different number of compartments and cavities, and all such embodiments are well within the scope of this invention, as defined by the appended claims.

[0063] Thus, this invention (fluid distributor) overcomes the drawbacks, limitations, and shortcomings associated with existing MCHX and corresponding fluid distributors by providing an improved and effective solution that helps the MCHX achieve more uniform distribution of the working fluid across all the cavities of the distribution tube and further into the microchannel tubes, thereby enhancing the overall thermal performance of the MCHX.

[0064] While the invention has been described with reference to exemplary 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 defined by the appended claims. Modifications may be made to adopt a particular situation or material to the teachings of the invention without departing from the scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed, but that the invention includes all embodiments falling within the scope of the invention as defined by the appended claims.

[0065] In interpreting the specification, all terms should be interpreted in the broadest possible manner consistent with the context. In particular, the terms "comprises" and "comprising" should be interpreted as referring to elements, components, or steps in a non-exclusive manner, indicating that the referenced elements, components, or steps may be present, or utilized, or combined with other elements, components, or steps that are not expressly referenced. Where the specification claims

refer to at least one of something selected from the group consisting of A, B, C and N, the text should be interpreted as requiring only one element from the group, not A plus N, or B plus N, etc.

[0066] The following clauses set out embodiments of the invention which may or may not presently be claimed, but which may form the basis for future amendment or a divisional application.

1. A fluid distributor for a heat exchanger, the fluid distributor comprising of:

a header comprising of compartments separated by walls, wherein a plurality of tubes associated with a heat exchange section of the heat exchanger are fluidically connected to at least one of the compartments;

a distribution tube extending longitudinally along the compartments of the header through the walls, the distribution tube comprising a plurality of cavities extending longitudinally along a length of the distribution tube and configured radially around a central axis of the distribution tube, wherein each of the cavities comprises one or more ports opening in the compartments; and

a supply tube fluidically connected to the distribution tube or to a supply tube compartment of the header and configured to supply a working fluid into the distribution tube.

2. The fluid distributor of clause 1, wherein the fluid distributor comprises a flow restrictor configured within the supply tube or between the supply tube and the distribution tube, wherein the flow restrictor is an annular member having a central opening that is configured in line with the distribution tube and having a predefined gap therebetween.

3. The fluid distributor of clause 2, wherein the central opening of the flow restrictor and the distribution tube have equal diameters.

4. The fluid distributor of clause 2, wherein the central opening of the flow restrictor is in a range of 10 to 80% of an orifice of the distribution tube.

5. The fluid distributor of any one of clauses 1 to 4, wherein the fluid distributor comprises a swirl generator configured upstream of the distribution tube or within the supply tube, wherein the swirl generator is configured to cause the working fluid, supplied by the supply tube, to move in a swirl motion.

6. The fluid distributor of clause 5, wherein the swirl generator comprises a housing having a plurality of grooves with curved profiles being configured on an inner wall surface of the housing, the grooves extending radially and circumferentially along the inner wall surface.

7. The fluid distributor of clause 5, wherein the swirl generator comprises a housing and a plurality of

blades extending radially from a central longitudinal axis of the housing and oriented at predefined angles from a radial plane.

8. The fluid distributor of clause 5, wherein the swirl generator comprises a housing, and a plurality of blades extending radially from a central longitudinal axis of the housing, wherein each of the blades comprises a first section and a second section with a slit extending at a predefined angle from the first section.

9. The fluid distributor of clause 5, wherein the swirl generator comprises a housing, and a plurality of swirl-generating elements having a predefined shape and at least one curved surface, protruding from or configured on an inner wall surface of the housing.

10. The fluid distributor of clause 9, wherein the swirl generator comprises a ring protruding from or configured on the inner wall surface of the housing, the ring is configured coaxially within the housing with the plurality of swirl generating elements configured above and/or below the ring.

11. The fluid distributor of any one of clauses 1 to 10, wherein the supply tube is axially connected to the supply tube compartment or the distribution tube.

12. The fluid distributor of any one of clauses 1 to 10, wherein the supply tube is radially connected to the supply tube compartment or the distribution tube.

13. The fluid distributor of any one of clauses 1 to 12, wherein the supply tube is configured off-centered from the central axis of the distribution tube.

14. The fluid distributor of any one of clauses 1 to 10, wherein the supply tube is directly connected to the distributor tube, wherein the distributor tube and the supply tube have equal diameter.

15. The fluid distributor of any one of clauses 1 to 13, wherein the header is a vertical header of the heat exchanger and the supply tube is fluidically connected to a terminal supply tube compartment.

16. The fluid distributor of any one of clauses 1 to 15, wherein the fluid distributor comprises one or more swirl-generating elements being configured within or on an inner wall surface of the supply tube compartment, the supply tube or both.

17. The fluid distributor of any one of clauses 15 to 16, wherein the supply tube is radially connected at a predefined position on the supply tube compartment of the header, such that the orifice of the distribution tube opens below, above, or at a same level of the predefined position or the supply tube.

18. The fluid distributor of any one of clauses 15 to 17, wherein the supply tube compartment comprises a baffle having a central opening and a plurality of openings configured radially around the central opening, the baffle is coaxially configured within the supply tube compartment such that a bottom end or the orifice of the distribution tube remains connected to the central opening and the supply tube

is connected radially to the supply tube compartment above the baffle.

19. The fluid distributor of any one of clauses 15 to 17, wherein the supply tube compartment comprises a baffle having a plurality of openings, the baffle is coaxially configured within the supply tube compartment of the header with the distribution tube extending longitudinally through the baffle such that a bottom end or the orifice of the distribution tube opens below the baffle and the supply tube is radially connected to the supply tube compartment above the baffle.

20. The fluid distributor of any one of clauses 15 to 19, wherein the supply tube is configured off-centered from the central axis of the distribution tube.

21. A heat exchanger comprising a fluid distributor according to any one of clauses 1-20.

Claims

1. A fluid distributor (100) for a heat exchanger, the fluid distributor comprising of:

a header (102) comprising compartments (104-1... 104-N) separated by walls (106-1... 106-N), wherein a plurality of tubes (108) associated with a heat exchange section of the heat exchanger are fluidically connected to at least one of the compartments;

a distribution tube (110) extending longitudinally along the compartments of the header through the walls, the distribution tube comprising a plurality of cavities (112-1... 112-8) extending longitudinally along a length of the distribution tube and configured radially around a central axis (A-A') of the distribution tube, wherein each of the cavities comprises one or more ports (P) opening in the compartments; and

a supply tube (114) fluidically connected to the distribution tube or to a supply tube compartment (104-1) of the header and configured to supply a working fluid into the distribution tube.

2. The fluid distributor of claim 1, wherein the fluid distributor (100) comprises a flow restrictor (202) configured within the supply tube (114) or between the supply tube and the distribution tube (110), wherein the flow restrictor is an annular member having a central opening (204) that is configured in line with the distribution tube and having a predefined gap therebetween.

3. The fluid distributor of claim 2, wherein the central opening (204) of the flow restrictor (202) and the distribution tube (110) have equal diameters, or wherein the central opening of the flow restrictor is in a range of 10 to 80% of an orifice (O) of the

distribution tube.

4. The fluid distributor of any of claims 1 to 3, wherein the fluid distributor (100) comprises a swirl generator (300) configured upstream of the distribution tube (110) or within the supply tube (114), wherein the swirl generator is configured to cause the working fluid, supplied by the supply tube, to move in a swirl motion.

5. The fluid distributor of claim 4, wherein the swirl generator (300) comprises a housing (302) having a plurality of grooves (304) with curved profiles being configured on an inner wall surface (106) of the housing, the grooves extending radially and circumferentially along the inner wall surface,

or wherein the swirl generator (300) comprises a housing (302) and a plurality of blades (306) extending radially from a central longitudinal axis (A-A') of the housing and oriented at pre-defined angles from a radial plane,

or wherein the swirl generator (300) comprises a housing (302), and a plurality of blades (306) extending radially from a central longitudinal axis of the housing, wherein each of the blades comprises a first section (306-1) and a second section (306-2) with a slit extending at a pre-defined angle from the first section.

6. The fluid distributor of claim 4, wherein the swirl generator (300) comprises a housing (302), and a plurality of swirl-generating elements (308) having a predefined shape and at least one curved surface, protruding from or configured on an inner wall (106) surface of the housing, optionally wherein the swirl generator (300) comprises a ring (310) protruding from or configured on the inner wall (106) surface of the housing (302), the ring is configured coaxially within the housing with the plurality of swirl generating elements (308) configured above and/or below the ring.

7. The fluid distributor of any of claims 1 to 6, wherein the supply tube (114) is radially connected to the supply tube compartment (104-1) or the distribution tube (110), and/or wherein the supply tube (114) is configured off-centered from the central axis (A-A') of the distribution tube (110).

8. The fluid distributor of any of claims 1 to 7, wherein the header (102) is a vertical header of the heat exchanger and the supply tube (114) is fluidically connected to a terminal supply tube compartment.

9. The fluid distributor of any of claims 1 to 8, wherein the fluid distributor (100) comprises one or more

swirl-generating elements (308) being configured within or on an inner wall surface of the supply tube compartment (104-1), the supply tube (114) or both.

10. The fluid distributor of any of claims 1 to 9, wherein the supply tube (114) is radially connected at a pre-defined position on the supply tube compartment (104-1) of the header (102), such that an orifice (O) of the distribution tube (110) opens below, above, or at a same level of the predefined position or the supply tube.

11. The fluid distributor of any of claims 1 to 10, wherein the supply tube compartment (104-1) comprises a baffle (502) having a central opening and a plurality of openings (504) configured radially around the central opening, the baffle is coaxially configured within the supply tube compartment such that a bottom end or the orifice (O) of the distribution tube (110) remains connected to the central opening and the supply tube is connected radially to the supply tube compartment above the baffle,

or wherein the supply tube compartment (104-1) comprises a baffle (502) having a plurality of openings (504), the baffle is coaxially configured within the supply tube compartment of the header (102) with the distribution tube (110) extending longitudinally through the baffle such that a bottom end or the orifice (O) of the distribution tube opens below the baffle and the supply tube is radially connected to the supply tube compartment above the baffle.

12. The fluid distributor of any of claims 1 to 6 or claim 9 when not dependent from claim 7 or 8, wherein the supply tube (114) is axially connected to the supply tube compartment (104-1) or the distribution tube (110),

13. The fluid distributor of any of claims 1 to 6 or claim 9 when not dependent from claim 7 or 8, wherein the supply tube (114) is directly connected to the distribution tube (110), wherein the distribution tube and the supply tube have equal diameter.

14. The fluid distributor of claim 12 or 13, wherein the supply tube (114) is configured off-centered from the central axis (A-A') of the distribution tube (110).

15. A heat exchanger comprising a fluid distributor (100) according to any preceding claim.

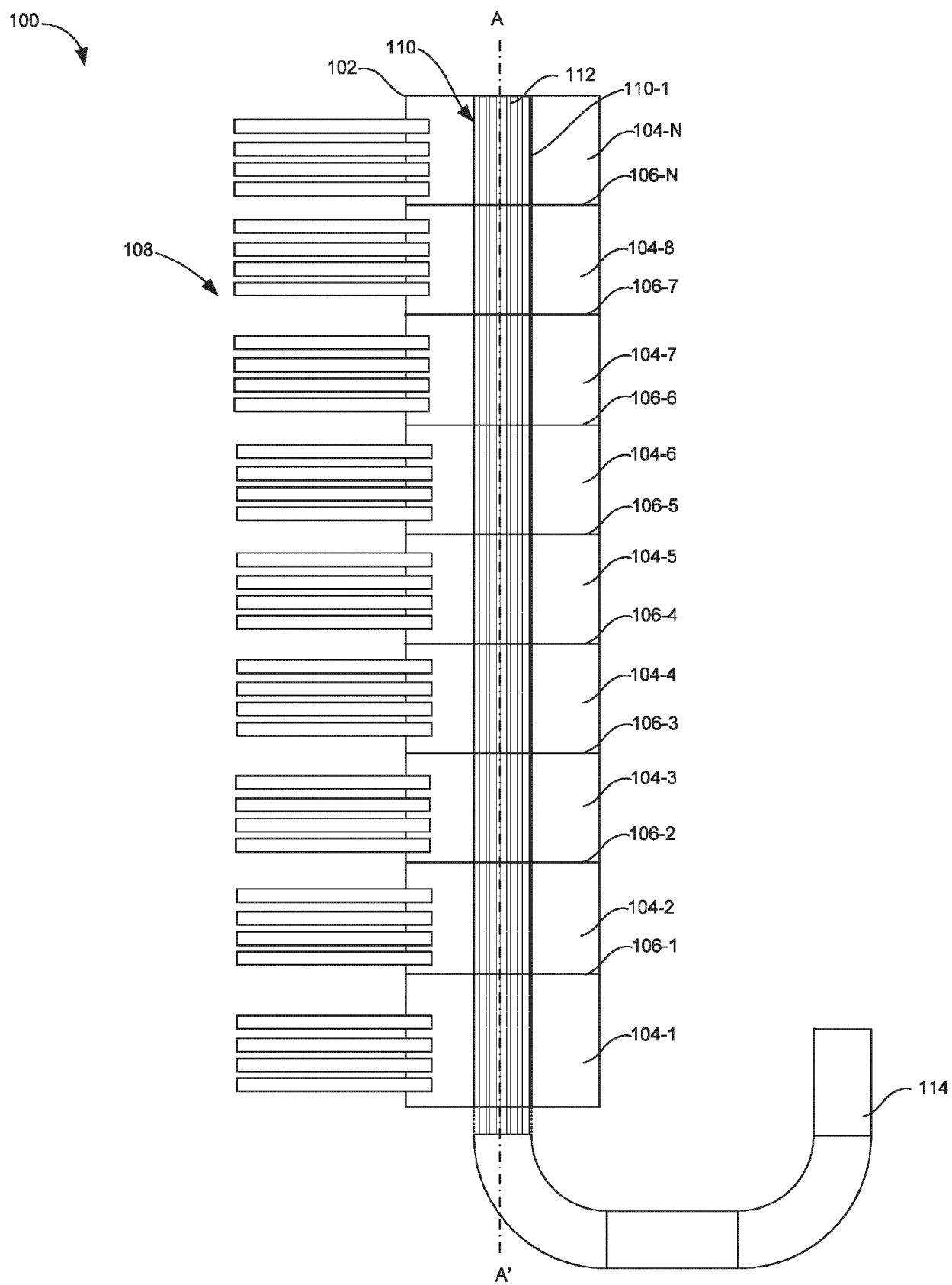


FIG. 1A

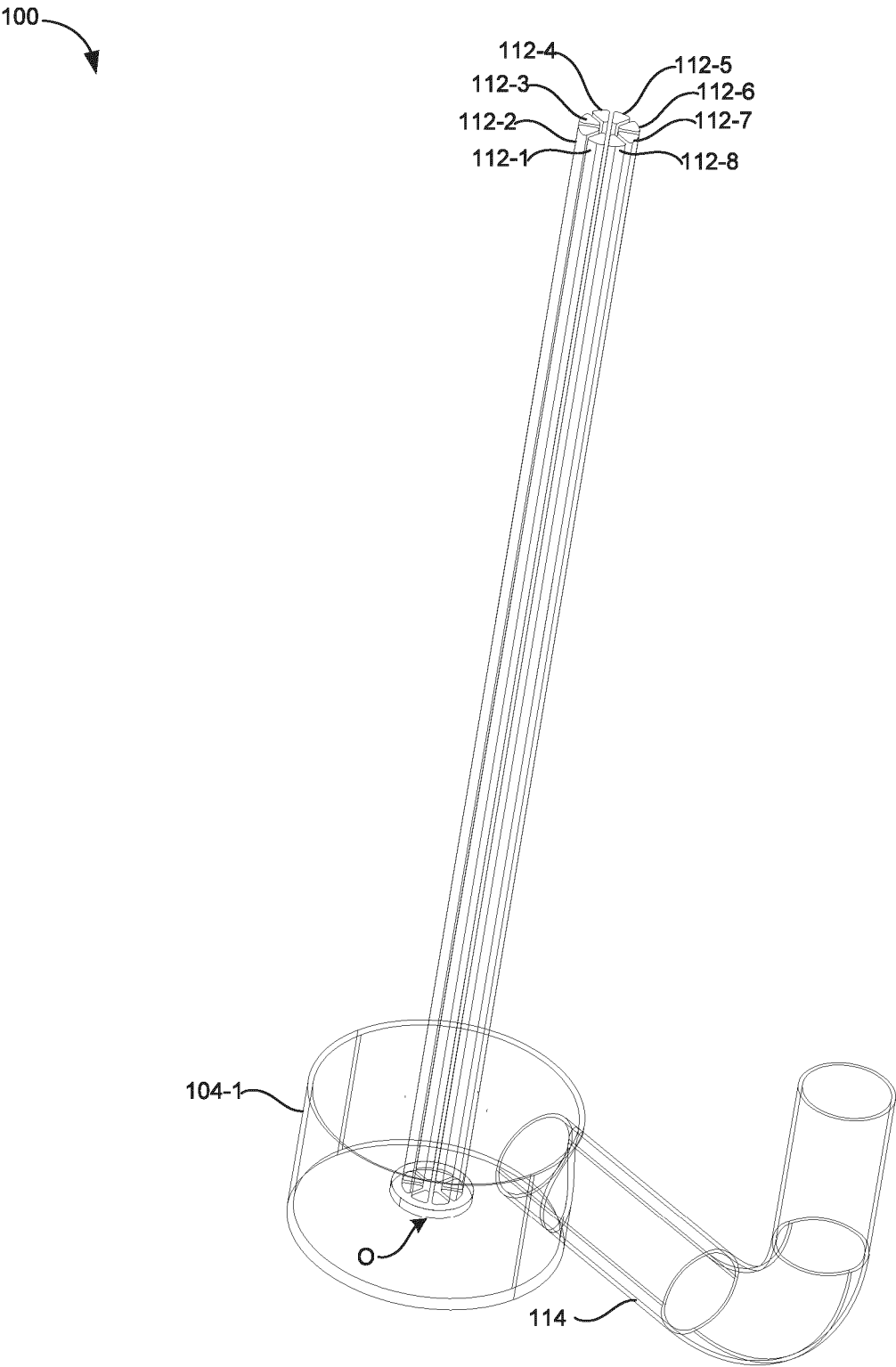


FIG. 1B

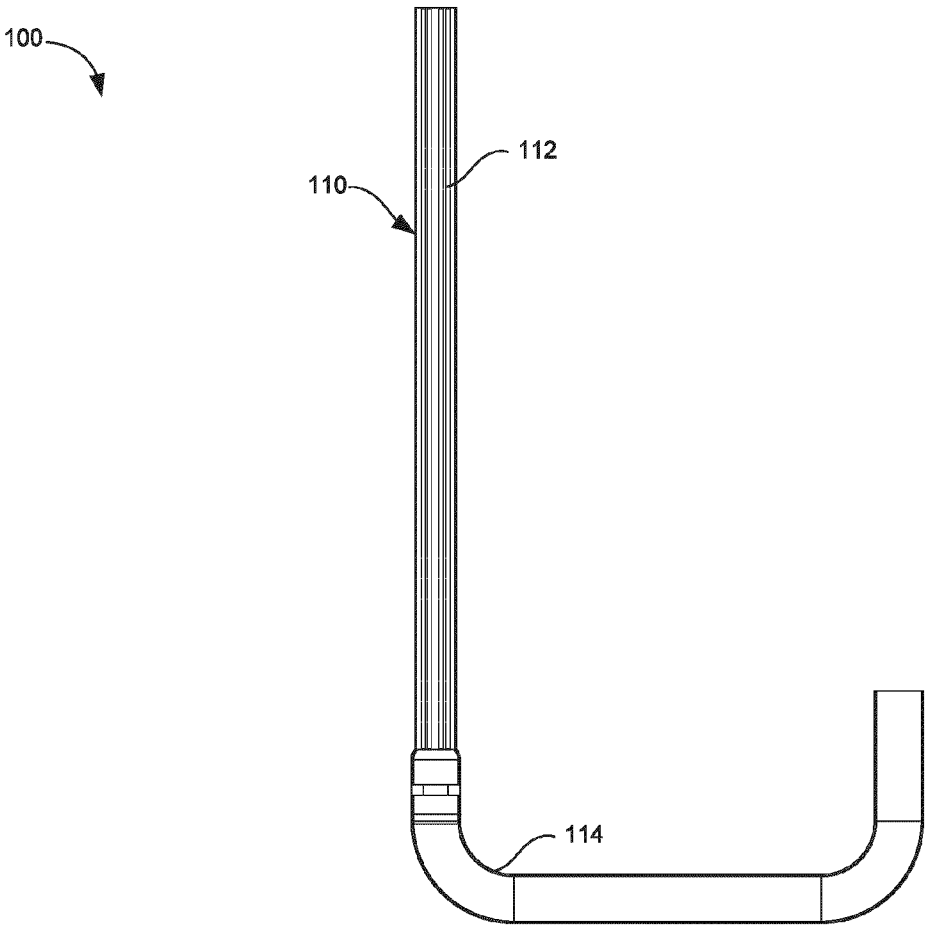


FIG. 1C

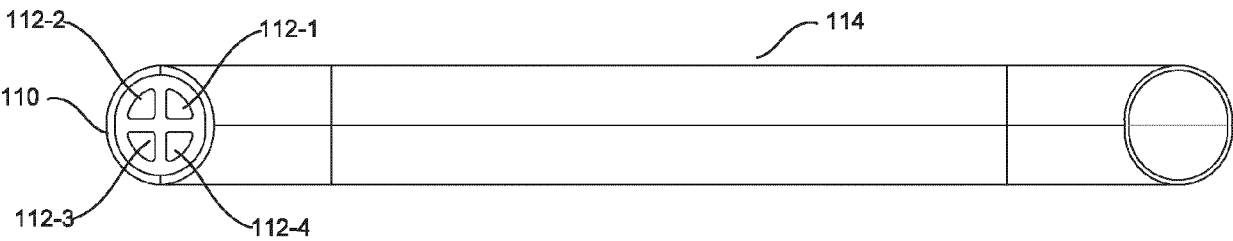


FIG. 1D

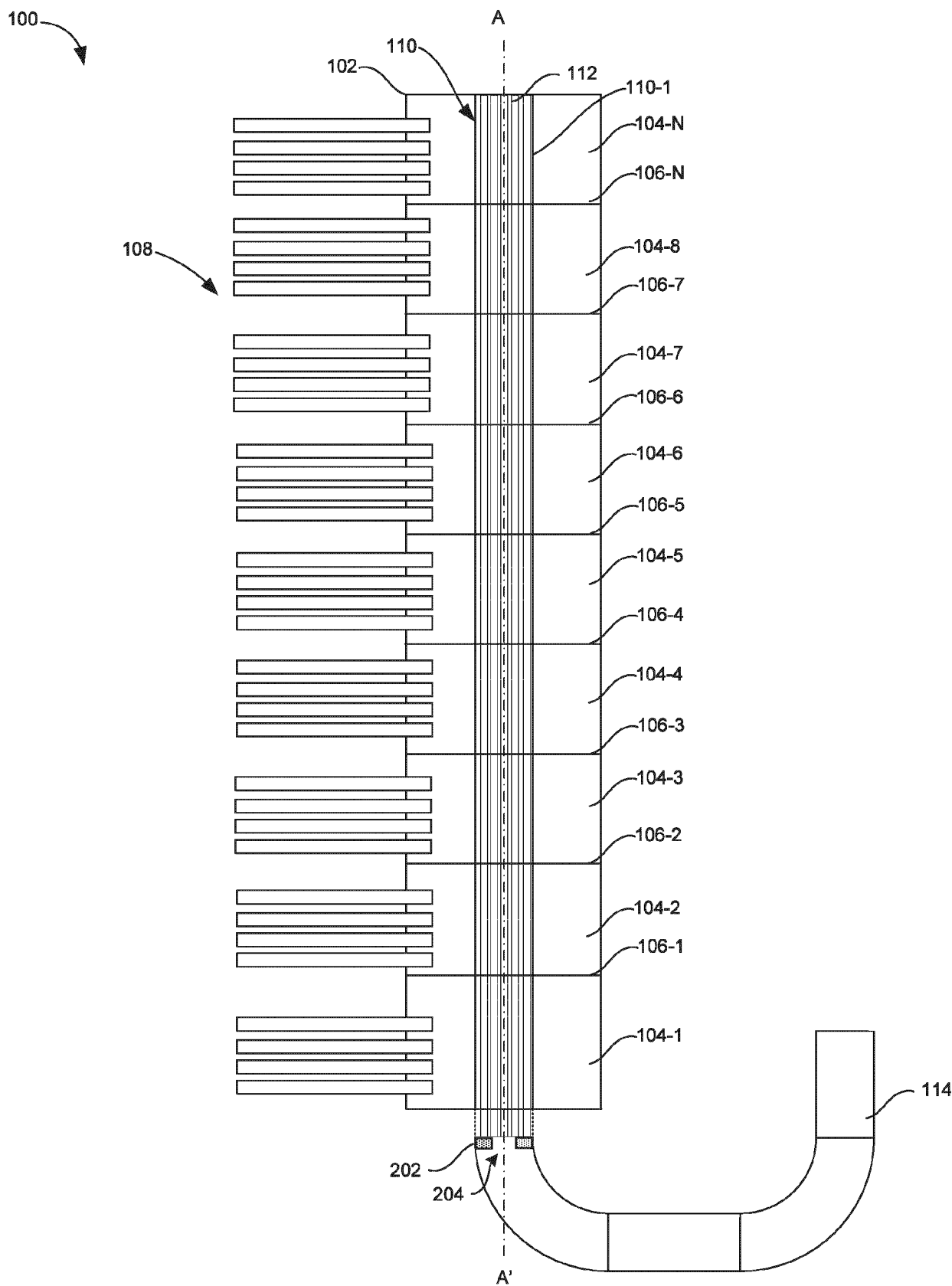


FIG. 2A

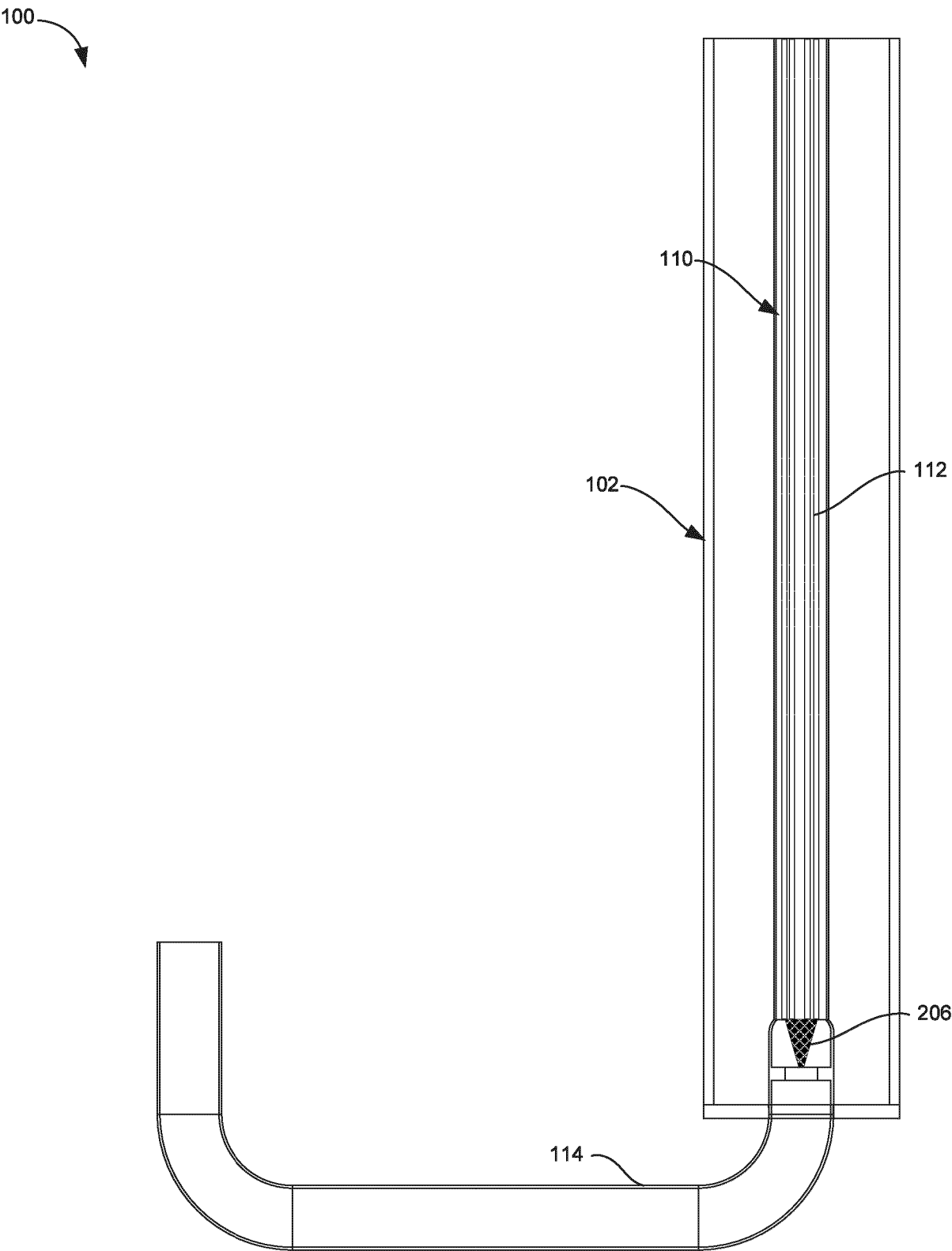


FIG. 2B

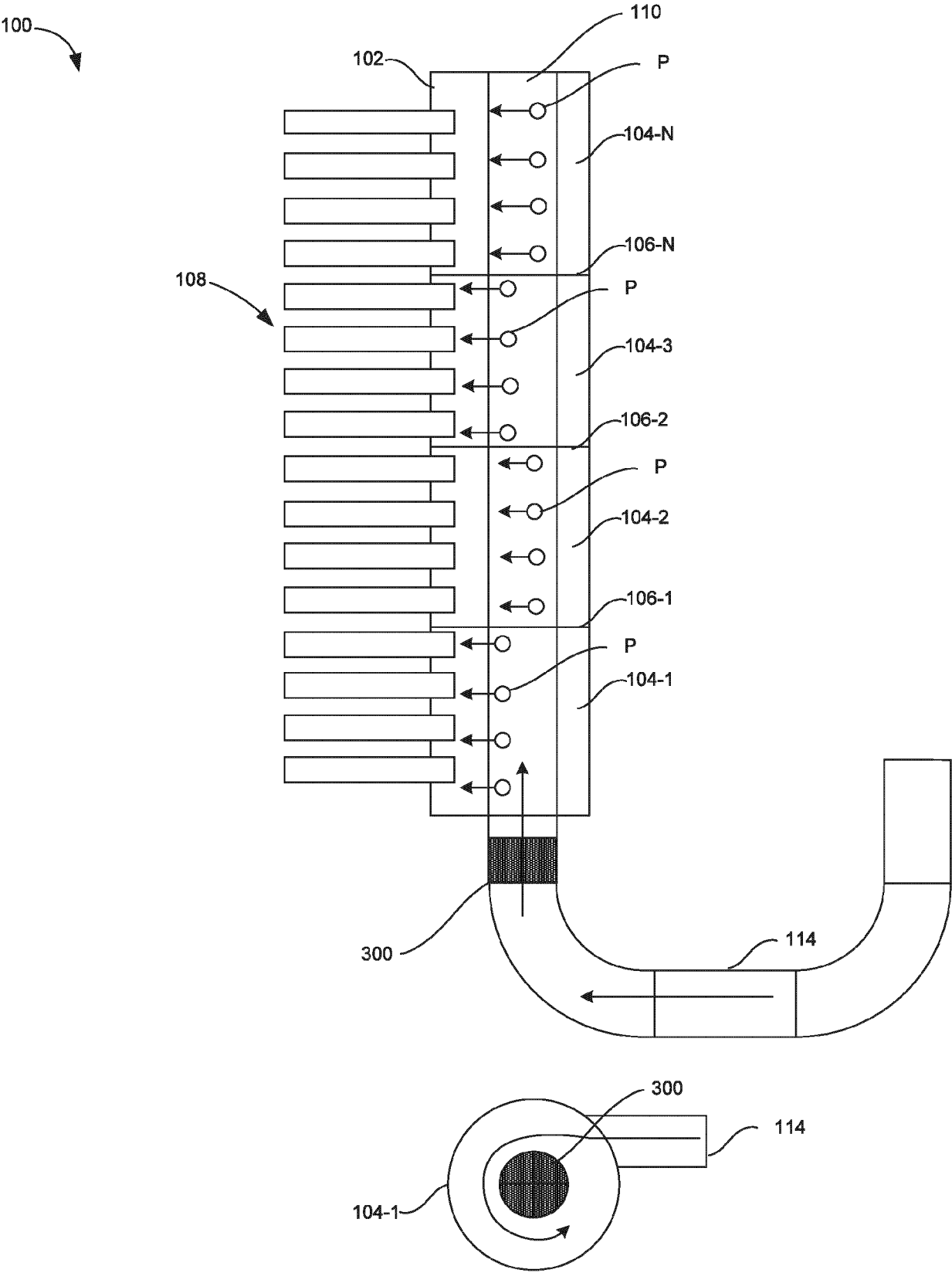


FIG. 3A

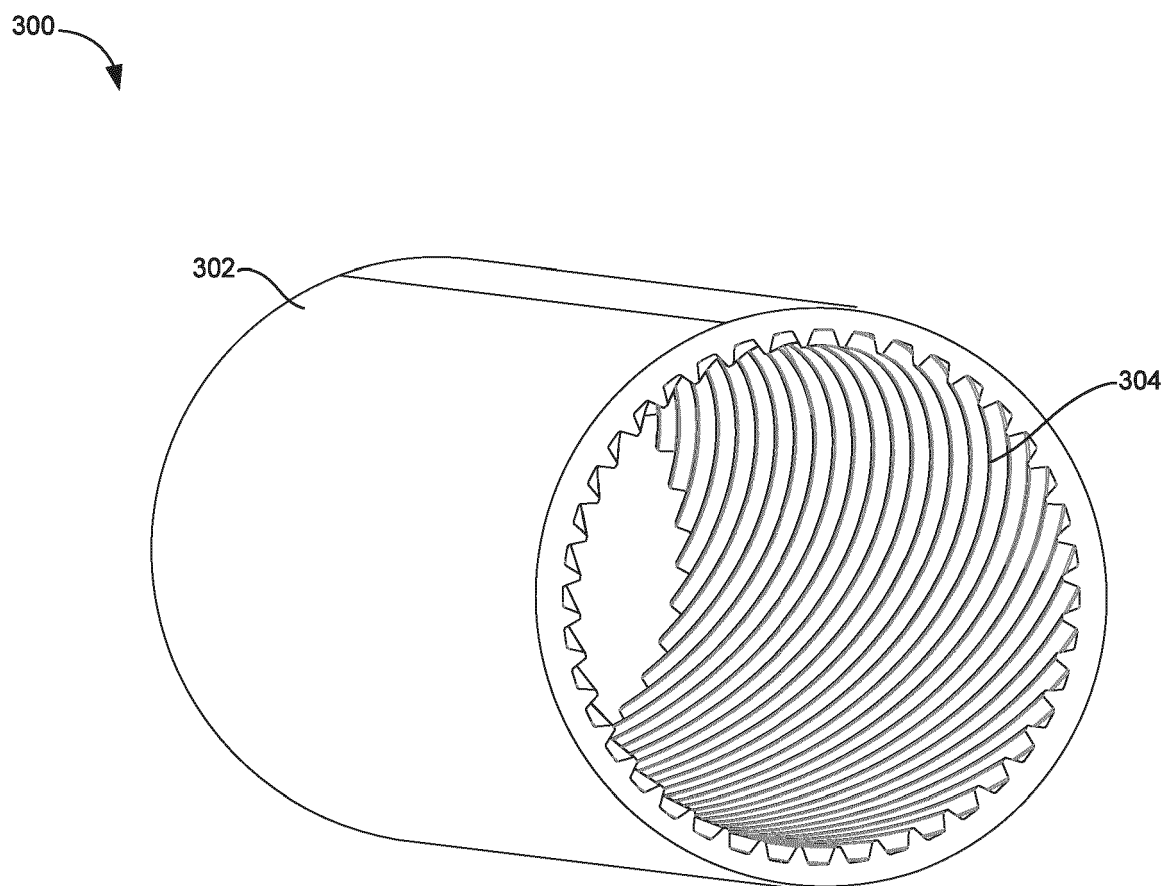


FIG. 3B

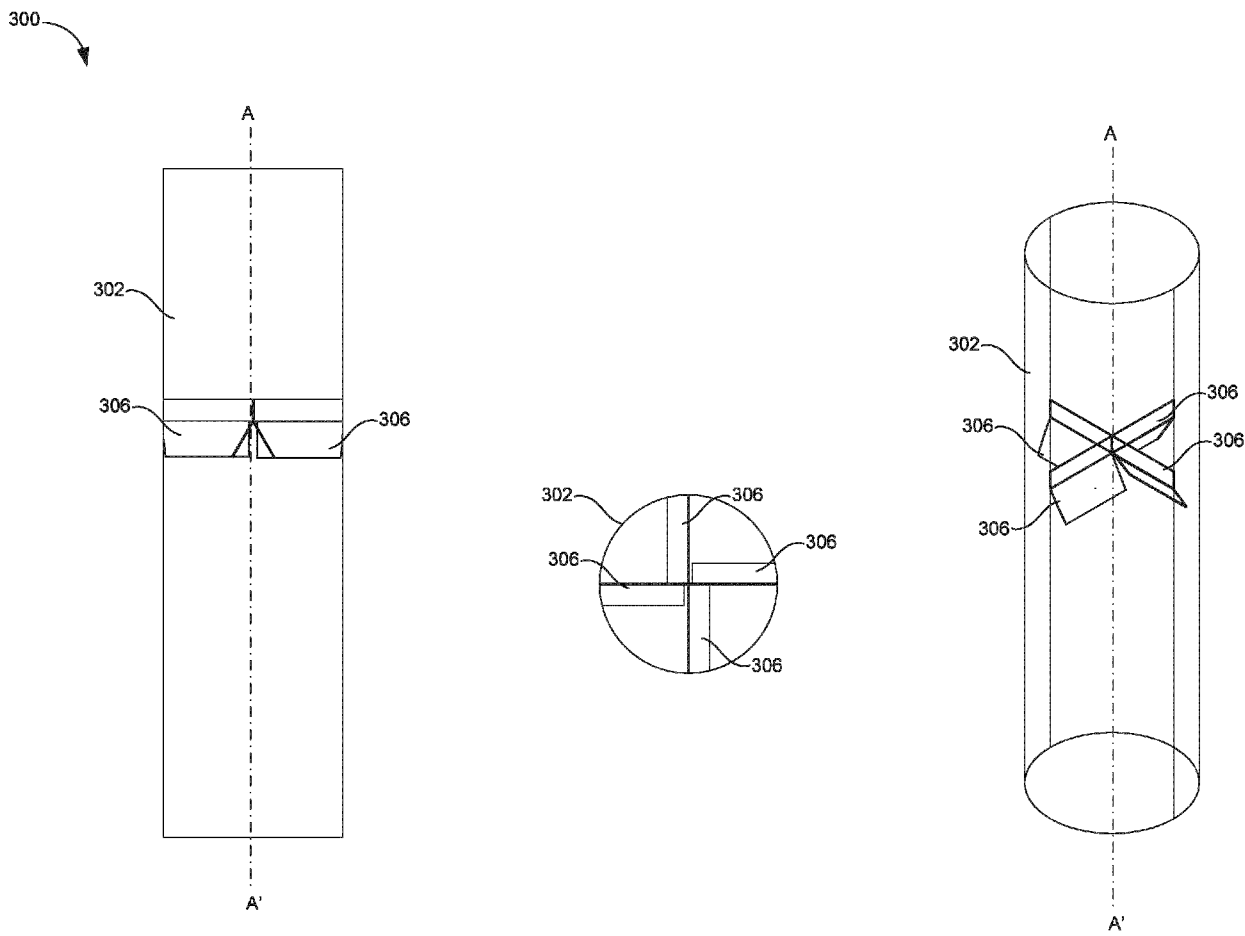


FIG. 3C

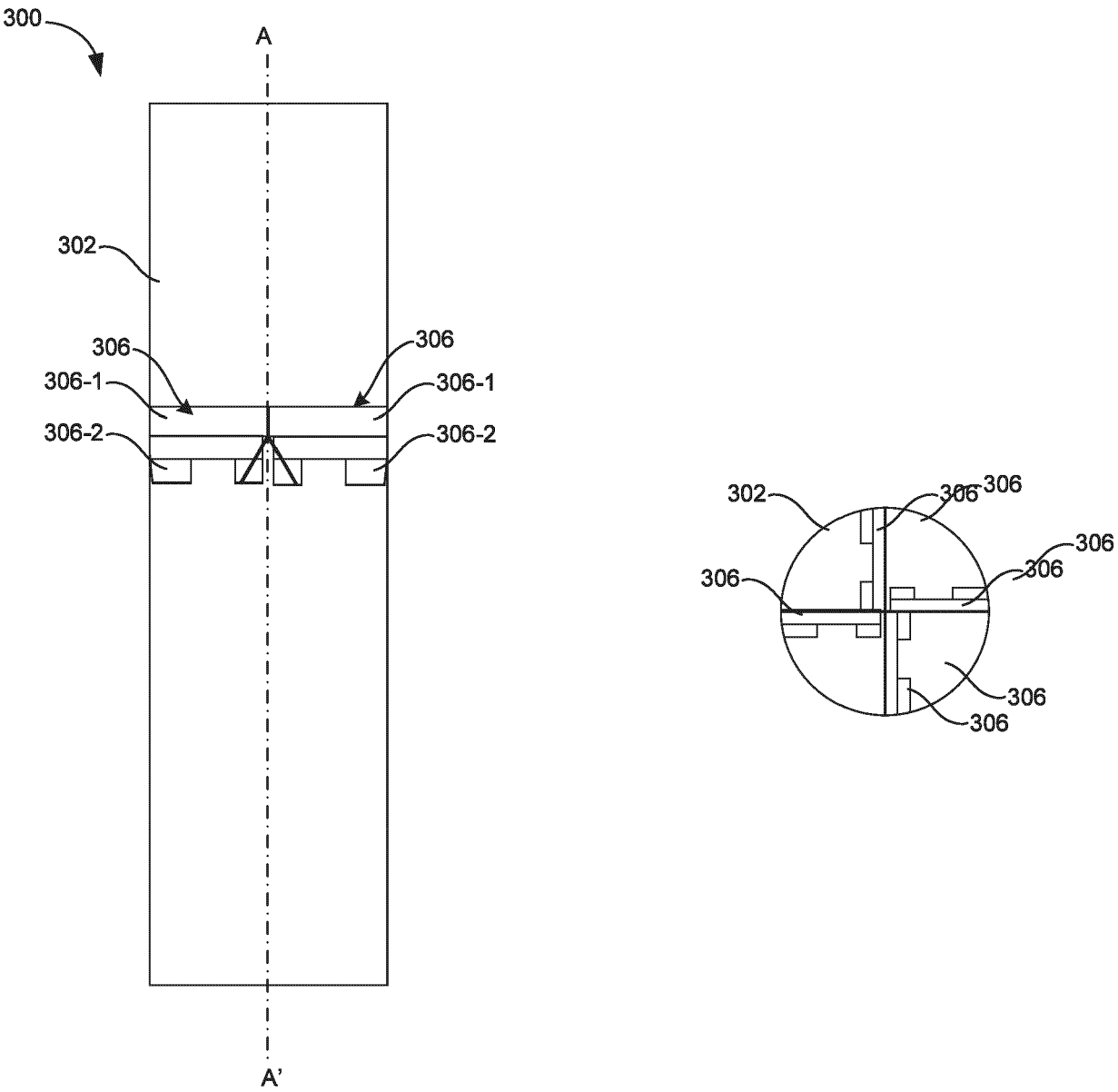


FIG. 3D

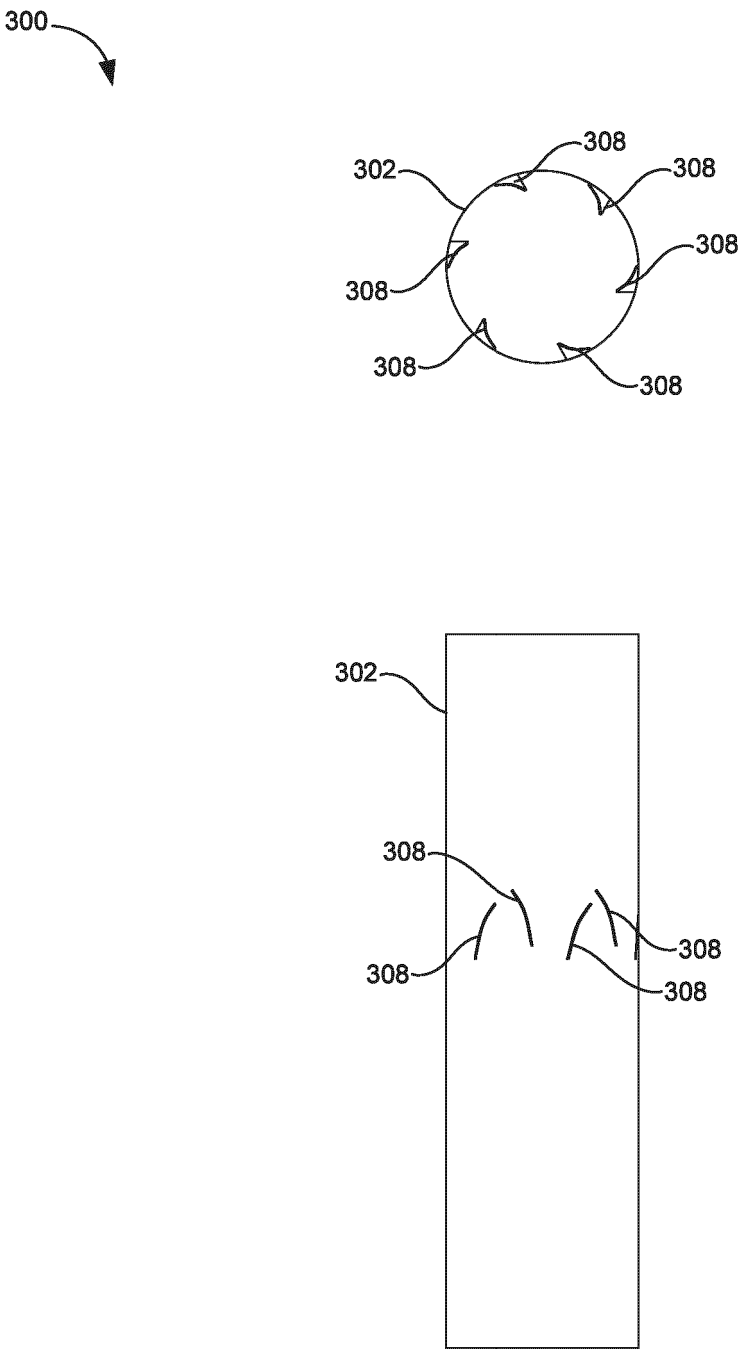


FIG. 3E

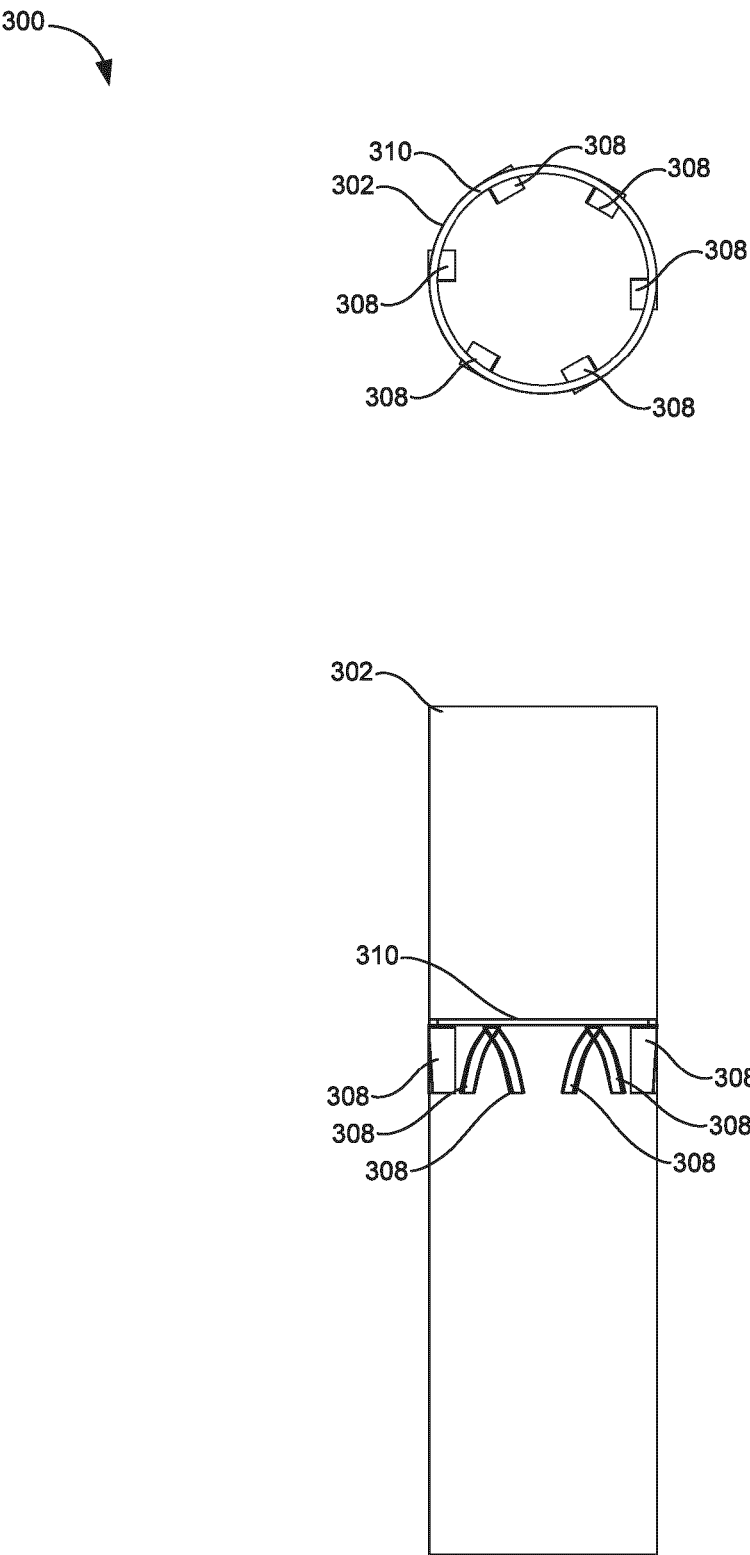


FIG. 3F

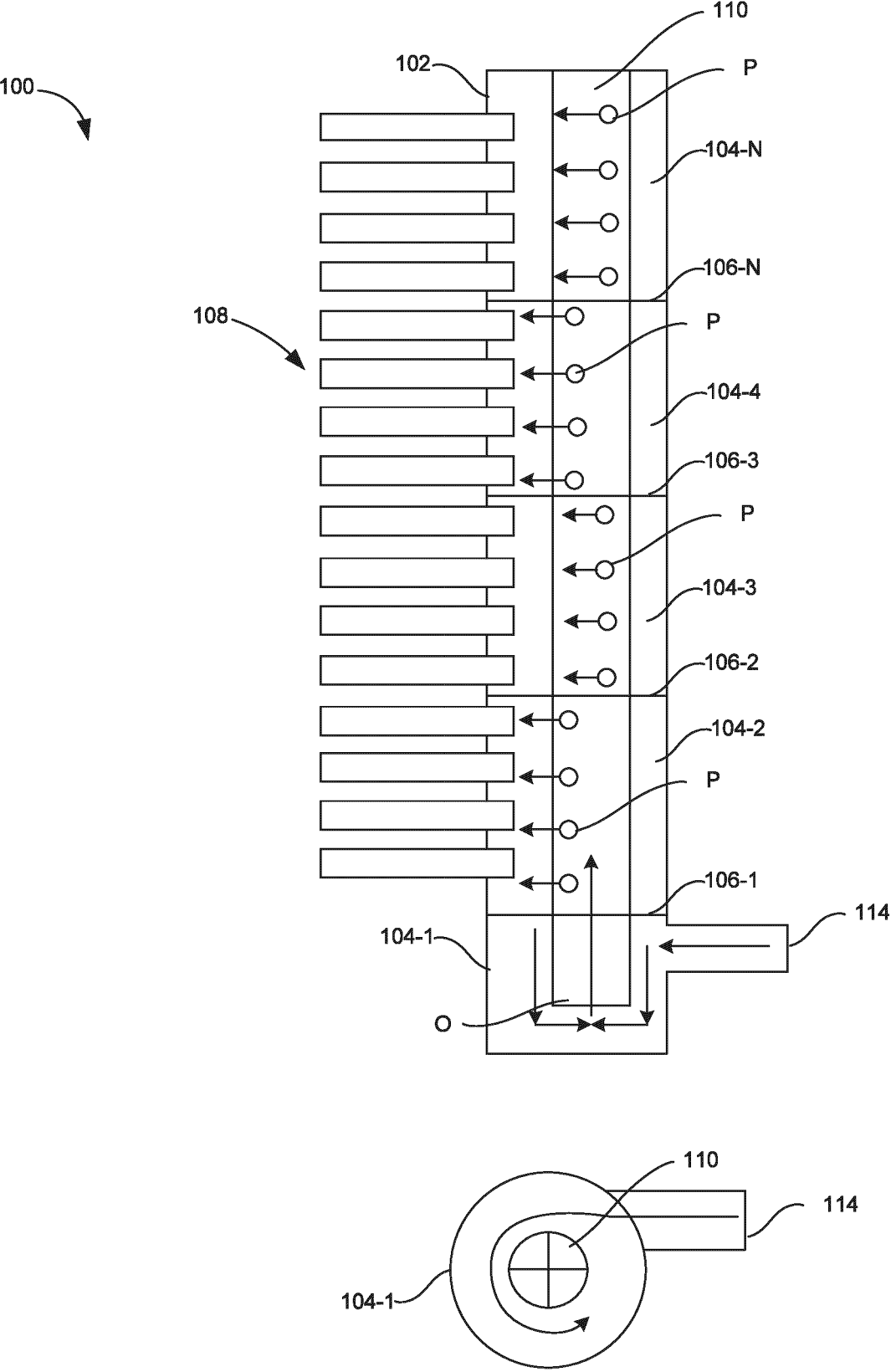


FIG. 4A

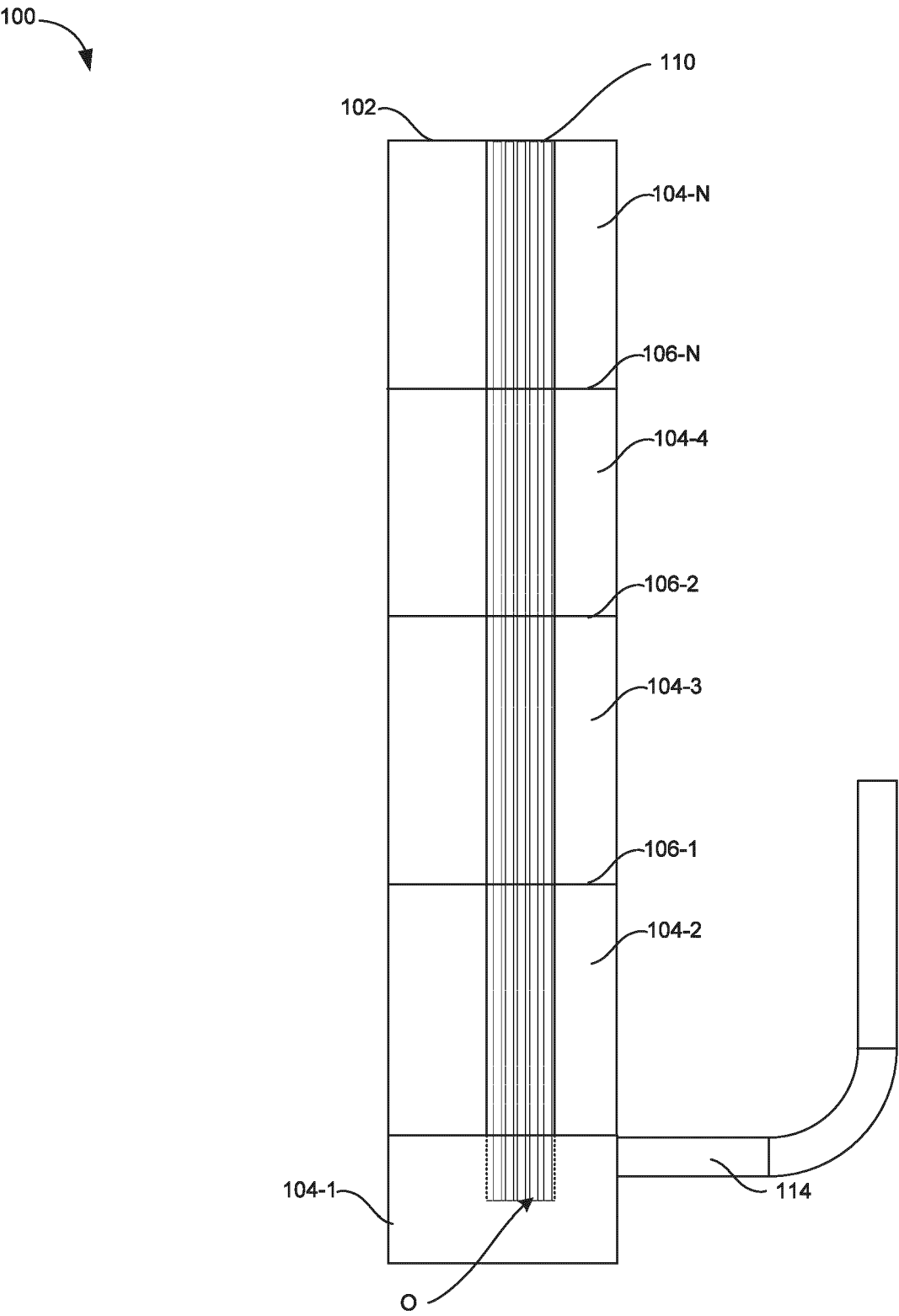


FIG. 4B

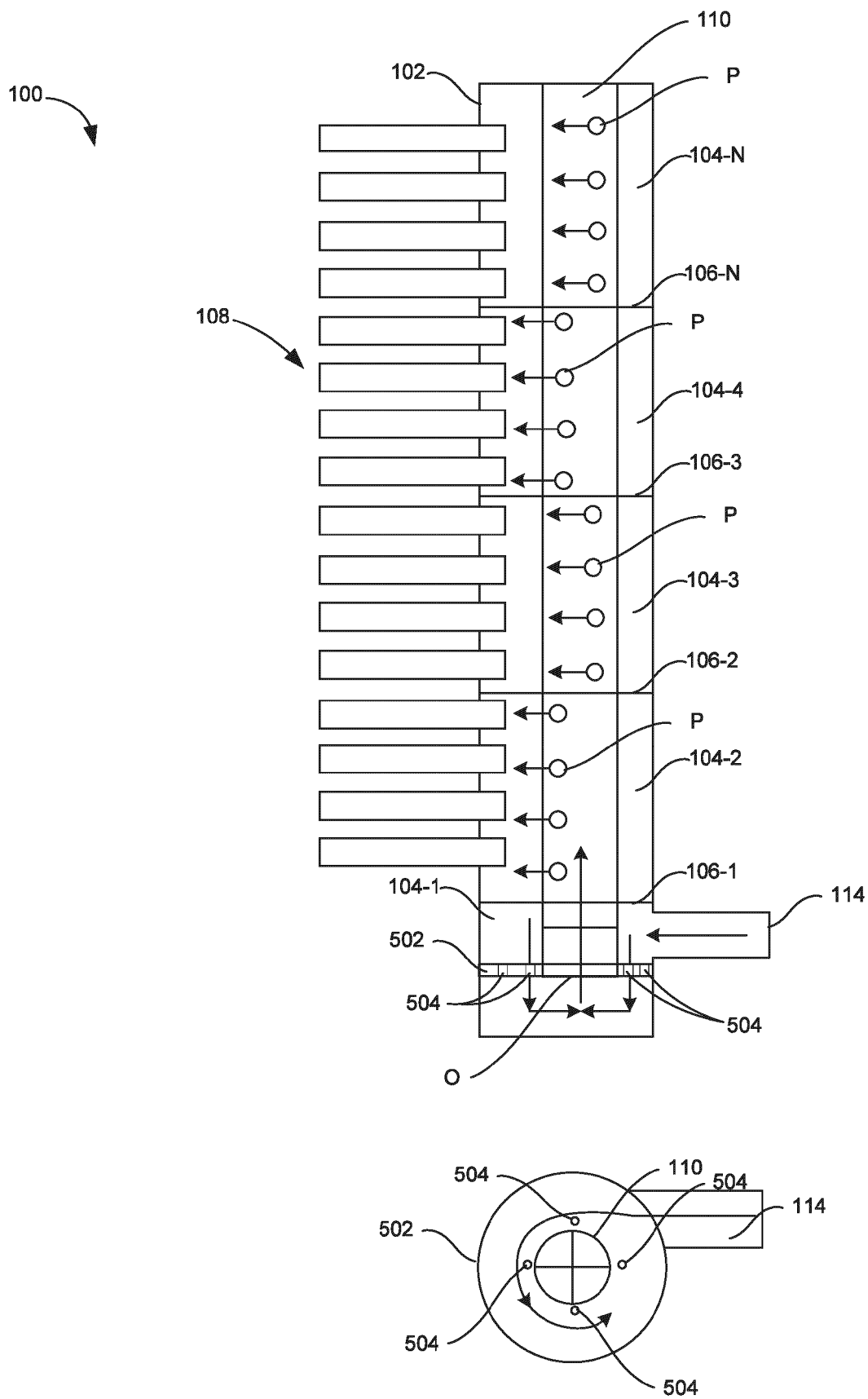


FIG. 5A

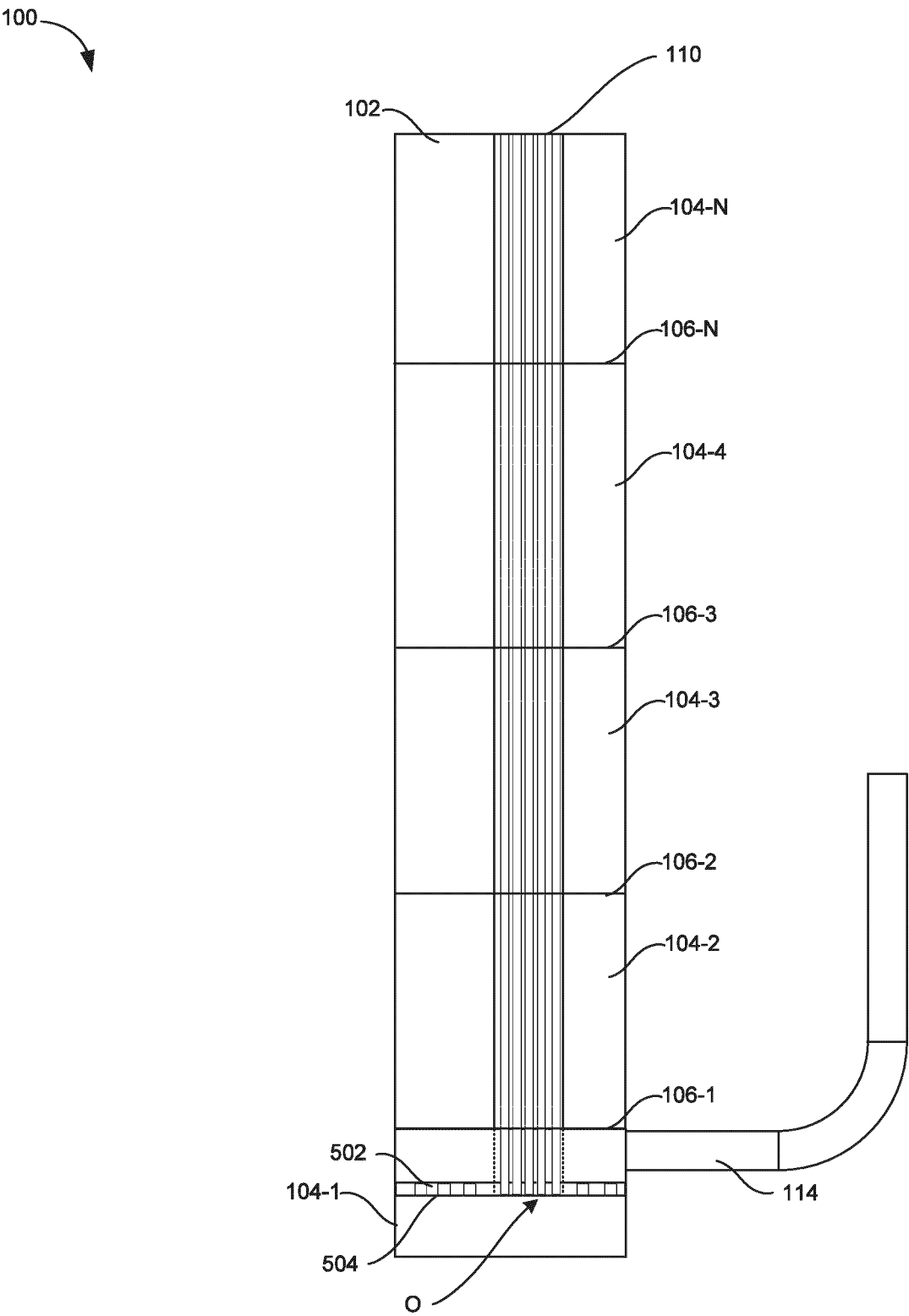


FIG. 5B

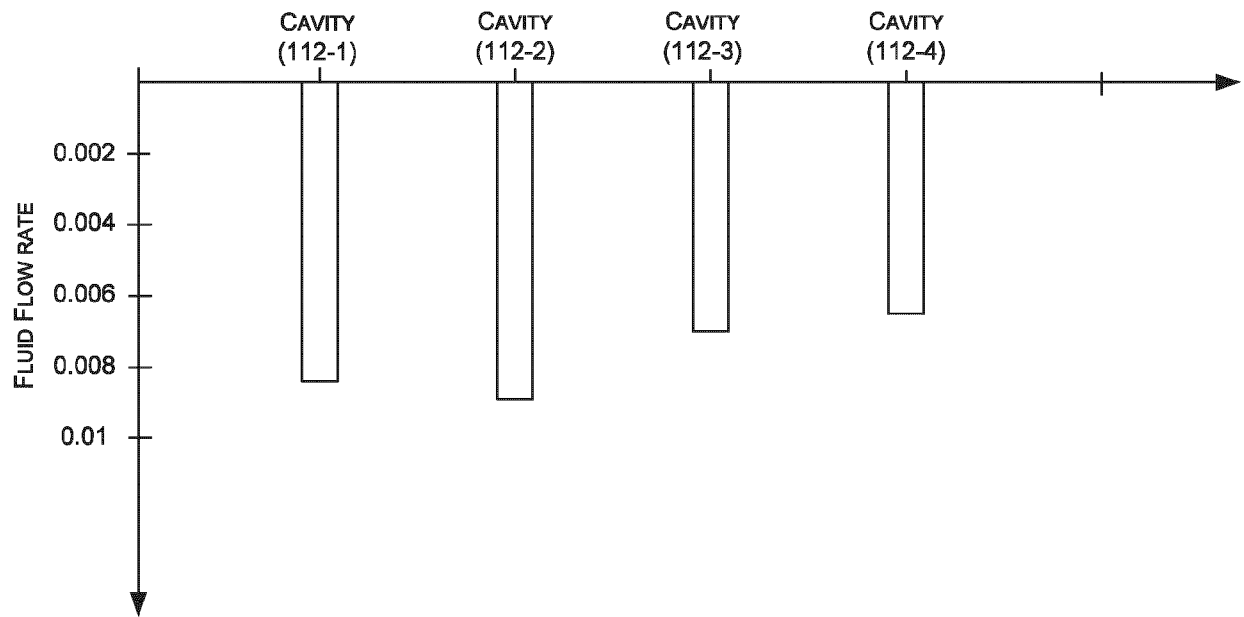


FIG. 6A

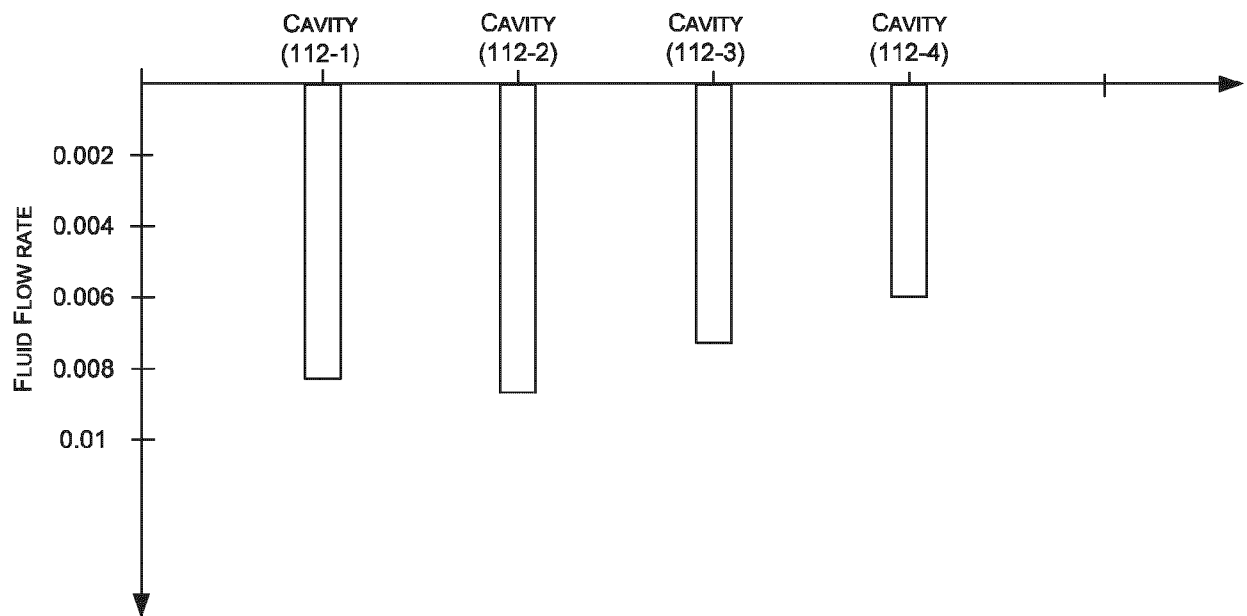


FIG. 6B

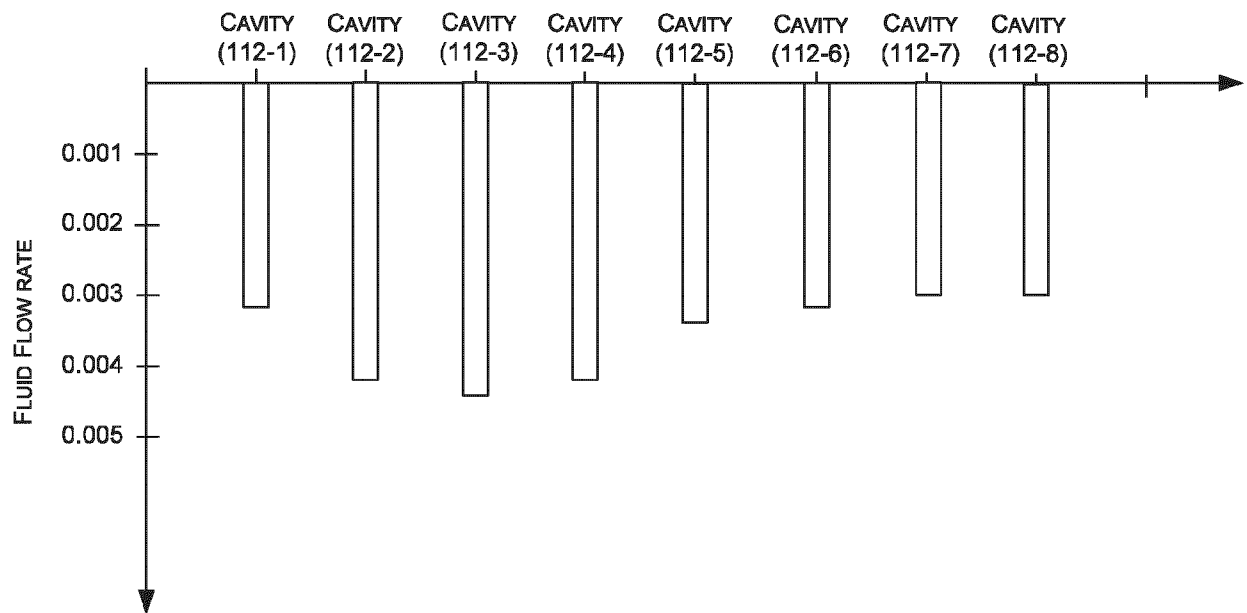


FIG. 6C

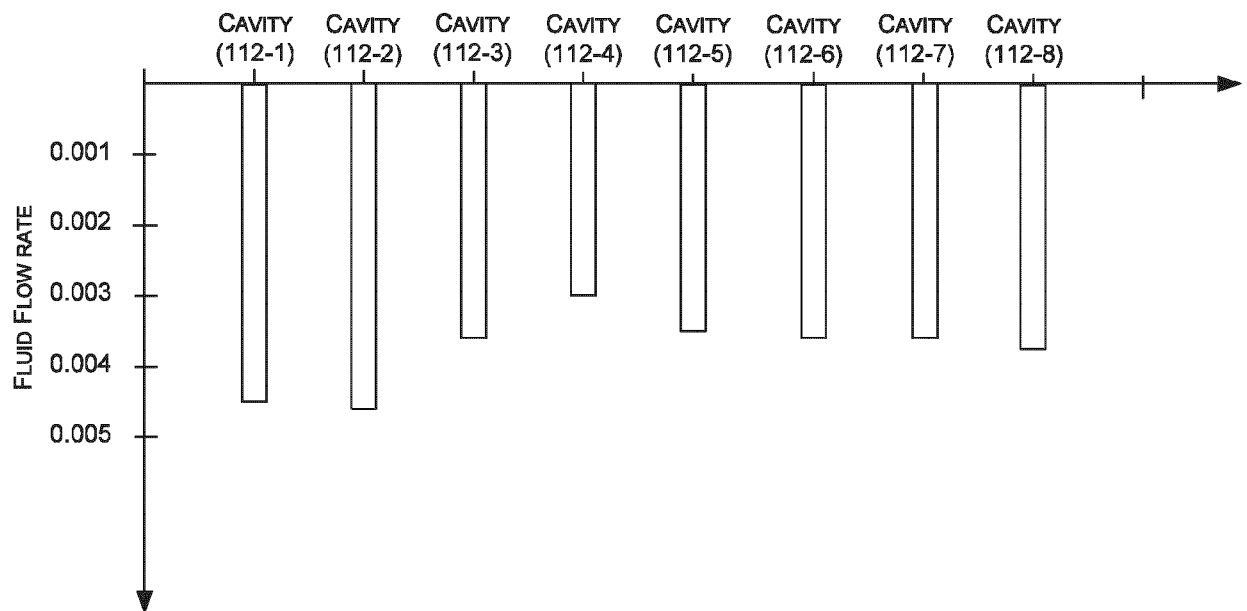


FIG. 6D

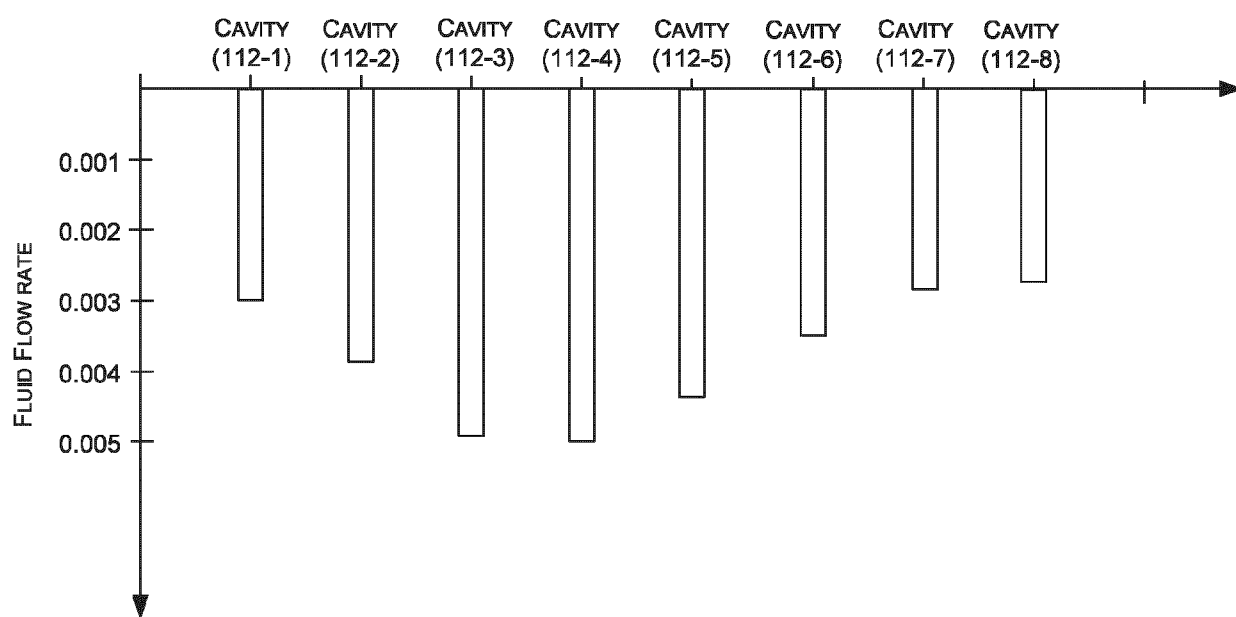


FIG. 6E



EUROPEAN SEARCH REPORT

Application Number

EP 24 19 6216

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			TECHNICAL FIELDS SEARCHED (IPC)
			F28F
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		9 January 2025	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	

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09 - 01 - 2025

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