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(54) **Titre : REMPLISSAGE DIRECT D'ECHANGE DE CHALEUR**
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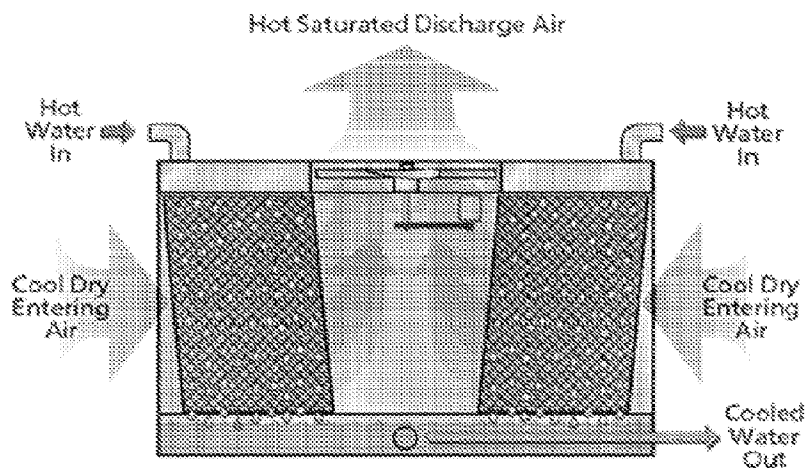


FIG. 1

(57) **Abrégé/Abstract:**

A fill sheet and a fill pack manufactured from a plurality of fill sheets for cooling a cooling medium in a cooling tower, each fill sheet optionally having microstructures, the fill sheet's having pairs of elliptically-shaped projections and depressions that act as spacers when the sheets are stacked on one-another to form a fill pack; and/or a fill sheet defining a continuous wave parallel to the longitudinal axes of the flutes.

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Abstract:

A fill sheet and a fill pack manufactured from a plurality of fill sheets for cooling a cooling medium in a cooling tower, each fill sheet optionally having microstructures, the fill sheet's having pairs of elliptically-shaped projections and depressions that act as spacers when the sheets are stacked on one-another to form a fill pack; and/or a fill sheet defining a continuous wave parallel to the longitudinal axes of the flutes.

DIRECT HEAT EXCHANGE FILL

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] The present invention relates to direct heat exchange fill and fill packs.

DESCRIPTION OF THE BACKGROUND

[0002] Heat exchangers are well known in industry and are designed to efficiently transfer heat from one medium to another. There are many types and sizes of heat exchangers and a particular type of heat exchanger is typically selected depending upon its use such as for refrigeration, air conditioning, chemical plants, petroleum refineries and power plants.

[0003] Cooling towers are used to transfer waste heat into the atmosphere. This cooling causes the evaporation of water to remove waste heat and cool water to near the wet-bulb air temperature. One type of cooling tower used to remove waste heat from warm water received from a heat source is represented in FIG. 1. Warm water from a heat source is pumped to a water distribution system at the top of the tower which may be a pressurized water distribution system or a gravity-fed water basin system. The water is distributed over a water dispersion media or “fill,” typically by large orifice nozzles. Simultaneously, air is drawn through air inlet louvers at the sides of the tower and travels horizontally through the fill in a crossflow arrangement with the falling water. The warm moist air is drawn to the top of the cooling tower by the fan and discharged to the atmosphere. The cooled water drains to a basin at the bottom of the tower and is returned to the heat source.

[0004] The water dispersion media or “fill” typically comprises a plurality of sheets that may be installed individually as hanging fill, or bonded together to produce hanging fill packs, or fill packs supported from below. For hanging fill, holes are punched near the top of the fill sheets to

accept rails or for mounting on rails where the fill sheets are spaced along the length of the rails. This causes the individual fill sheets to be under tensile loading under the holes, but under compressive loading at the rail-sheet interface. For bottom supported fill, sheets are secured together into rigid blocks of fill (“fill packs”), then placed on top of a support structure in the tower. In a cross-flow cooling tower of the type shown in Figure 1, each fill sheet is a generally flat sheet of thermoplastic material impressed with various types of surface features to enhance water/air mixing. These heat exchanger sheets are fabricated by thermoforming sheets of thermoplastic material under vacuum. Adjacent fill sheets are separated from one-another to form water and air passages by integrally formed nubs or “spacers.”

[0005] The performance of a cooling tower can be characterized by the quantity of water or other cooling fluid that can be cooled to a specified operating temperature for a certain set of ambient conditions. In order to achieve this cooling, water is sprayed onto the cooling tower fill and is exposed to an air flow, thereby causing evaporation of a small portion of water into the air, which cools the remaining water. By increasing the amount of evaporation occurring within the cooling tower, the overall performance of the tower may also be increased or improved. Since most of this evaporation occurs within the fill, changes to the fill design can significantly impact the amount of cooling a tower can achieve during operation. Specifically, changes to a cooling tower fill that reduce the pressure drop across a fill for a given air flow or otherwise improve the thermal performance of the fill, will result in a better performing cooling tower. By reducing the pressure drop across a fill, the resistance to airflow through the tower is decreased, allowing more air to pass over the water film for the same fan power, thereby causing the amount of evaporation to increase. To improve the thermal performance of a fill, increased mixing of the air and water can increase the amount of evaporation of water into the air by improving the

conditions at the air-water interface. Generating mixing of the air, however, typically requires changes to the fill which also increases the pressure drop across the fill, indicating the need for fill designs which can either reduce pressure drop over existing designs with minimal impact to mixing or improved strategies for mixing which require equal or less pressure drop.

[0006] For film fills used in cross-flow towers, all fills contain a dedicated heat transfer area, while some also contain an integral drift eliminator near the air outlet of the fill and/or an integral louver section near the air inlet of the fill. The heat transfer area of the fill is responsible for the thermal performance of the fill by providing a large surface area for water to spread out on the surfaces of the fill to increase contact with the air, mixing the air as it flows through the fill and mixing the water film as it flows over the sheets, while maintaining a low pressure drop across the fill.

[0007] Although most of the bulk water adheres to the surface of a film fill, some of the water forms small droplets and escapes the fill through the air outlet, otherwise known as drift. Drift is undesirable, as the drift represents a loss of water or other cooling fluid from the system and the loss of water or other cooling fluid has a cost to replenish, both itself and any treatment chemicals contained within the cooling fluid. The drift may also have a deleterious impact on surrounding equipment and environments since the drift may contain chemicals, salts and bacteria present in the circulating water or fluid. For cross-flow tower film fills, drift elimination features are sometimes included on the air outlet side of the sheet to capture these drift droplets and prevent them from escaping the cooling tower, which are referred to as drift eliminators and may be comprised of integral drift eliminators (“IDs”). For cross-flow film fills, there are typically two different types of drift eliminators which may be integrated, including the tube drift eliminator and the blade drift eliminator. Generally, tube drift eliminators are angled tubes

formed into the ID section of the fill by aligning drift corrugations of adjacent sheets. As water droplets enter the tubes entrained in the air stream, the momentum of the droplets causes them to impact the tube wall as the airflow changes direction while following the angled tube of the ID. A vertical channel is typically included at the inlet of the integral drift eliminator tubes to allow water collected on the surface of the integral drift eliminator to drain out of the fill into a lower catch basin, and to provide vertical structural support for bottom supported fills. Integral blade drift eliminator designs accomplish drift removal by creating a large vertically oriented ridge, near the air outlet of the fill to change the direction of airflow. The momentum of the water droplets at the integral drift eliminator inlet causes an impact with the ridge walls, eliminating the drift from the airstream. Other structural features such as ribs or spacers may be included before or after the eliminator ridge to ensure the sheets remain separated during operation and to stiffen the fill and/or sheet, as well as the assembled fill pack.

[0008] At the air inlet of the fill, integral louvers are sometimes included into the fill design to prevent water from splashing out of the front of the fill. These integral louvers are usually comprised of corrugations which are angled downward as they protrude into the fill, to provide a sloped surface for the water to run down, thereby preventing water or other cooling fluid from reaching the front of the fill. The corrugations on each sheet may be assembled together to form tubes or remain parallel to adjacent sheet corrugations with additional sheet spacer features added to the design.

SUMMARY OF THE INVENTION

[0009] Two inventive improvements to cross-flow fill are presented herein which may be used separately or in combination with one-another for improved heat exchange in cross-flow cooling towers. The first invention presented herein is an improvement to (but incorporates the basic

structure, manufacture, and assembly of) the aforementioned fill structure which uses spacers to separate the stacked fill sheets from one-another, but in which the integrally formed spacers are elliptically shaped. According to a preferred embodiment, the elliptically shaped spacers are arranged in pairs, with pairs spaced across the fill sheet in a plurality of spacer rows. Each pair of elliptically shaped spacers includes one spacer formed in one direction perpendicular to the plane of the fill sheet, and the other spacer of a pair formed in the opposite direction perpendicular to the plane of the fill sheet, with the result that no matter the perspective, one spacer of a pair is pressed into the fill sheet, “the female spacer,” and the other spacer of the pair extends out of the fill sheet, the “male spacer.”

[0010] When the sheets are stacked against one-another, they are arranged so that the male spacers of facing surfaces of adjacent sheets align with and contact one-another to create a space between the fill sheets that is equivalent to the height of two male spacers.

[0011] According to various embodiments of the elliptical spacer invention, a) the major axes of the elliptically shaped spacers may all be arranged horizontally, in which case the air passes generally straight through the sheets of fill; b) the major axes of the elliptically shaped spacers on one side of a fill sheet may alternate in upwardly tilting and downwardly tilting directions, in which case the air on one side of a fill sheet is forced up, then down, then up, then down, and so on, and air on the opposite side of the same fill sheet is alternatively forced down, then up, then down, then up, and so on; c) the major axes of the elliptically shaped spacers on one side of a fill sheet may all be tilted d) upwardly, in which case the air is continuously forced upward as it crosses the fill sheet; or e) downwardly; in which case the air is continuously forced downward as it crosses the fill sheet.

[0012] The second invention presented herein is an improvement to (but incorporates the basic structure, manufacture, and assembly of) the aforementioned fill structure in which the fill sheet features an underlying wave parallel to the direction of airflow. The wavy fill sheets of this invention increase the structural performance of a mechanically bonded pack when supported from the bottom. Compared to a cross-flow fill sheet characterized with microfeatures pressed into a flat sheet, the wavy fill sheets of the invention enhance the bending stiffness and buckling load of the fill sheet. The wave-shaped sheets maintain a constant spacing between adjacent sheets via spacers, which may be prior art spacers or the elliptical spacers according to the first invention herein, but the wavy shape induces turbulence to increase air water contact and thermal efficiency. The period and the amplitude of the wave shape may be optimized to balance increased pressure drop vs. increased thermal efficiency. According to a preferred embodiment the period of the wave form is 4-5" and more preferably 4.7" and the amplitude is 0.1"-0.3", more preferably 0.2"

[0013] Accordingly, there is provided according to the invention a fill sheet for assembly into a fill pack for cooling a cooling medium in a cooling tower, the fill sheet comprising a first end; a second end; a first side; a second side; the second end extending substantially parallel to the first end and generally perpendicularly relative to a vertical axis (with respect to water travel), the first and second ends extending substantially parallel to a lateral axis of the fill sheet; the first second side extending substantially parallel to the first side and generally parallel to the vertical axis, the first and second sides connecting the first and second ends; the first end, second end, first side and second side defining a first face and a second face that are mirror images of one-another; the first face of the fill sheet comprising a plurality of first-face elliptically-shaped projections and depressions arranged in a plurality of rows across the fill sheet, each of the first-

face elliptically shaped projections corresponding to a second-face elliptically shaped depression on the second face, each of the first-face elliptically shaped depressions corresponding to a second-face elliptically shaped projection on the second face.

[0014] There is further provided according to the invention a fill sheet in which the first-face elliptically-shaped projections and depressions are arranged in pairs, each of the pairs having a single first-face elliptically shaped projection and a single first-face elliptically shaped depression.

[0015] There is further provided according to the invention a fill sheet in which each of the first-face elliptically-shaped projections and depressions has a major axis that is parallel to a direction of air travel across the fill sheet.

[0016] There is further provided according to the invention a fill sheet in which all of the first-face elliptically-shaped projections and depressions have a major axis that is aligned at a same angle that is equal to or less than + 15 degrees from horizontal.

[0017] There is further provided according to the invention a fill sheet in which all of the first-face elliptically-shaped projections and depressions have a major axis that is aligned at a same angle that is equal to or less than – (negative) 15 degrees from horizontal.

[0018] There is further provided according to the invention a fill pack assembly for cooling a fluid flowing through the pack with a gas flowing through the pack in a substantially horizontal direction, the fill pack assembly comprising a plurality of identical fill sheets according to any of the above-referenced configurations, wherein the plurality of fill sheets are arranged so that elliptically-shaped projections on adjacent faces of adjacent sheets contact one-another.

[0019] There is further provided according to the invention a fill sheet for assembly into a fill pack for cooling a cooling medium in a cooling tower, the fill sheet comprising: a first end; a

second end; a first side; a second side; the second end extending substantially parallel to the first end and generally perpendicularly relative to a vertical axis (with respect to water travel), the first and second ends extending substantially parallel to a lateral axis of the fill sheet; the first second side extending substantially parallel to the first side and generally parallel to the vertical axis, the first and second sides connecting the first and second ends; the first end, second end, first side and second side defining a first face and a second face, the first and second faces mirror images of one-another; the fill sheet further defining a continuous wave extending in a direction parallel to a direction of air flow.

[0020] There is further provided according the invention a fill sheet wherein the continuous wave has a period of 3 inches to 6 inches and an amplitude of 0.05 inches to 0.5 inches.

[0021] There is further provided according the invention a fill sheet, wherein the continuous wave has a period of 4 inches to 5.5 inches and an amplitude of 0.1 inches to 0.35 inches

[0022] There is further provided according the invention a fill sheet, wherein the continuous wave has a period of 4.7 inches and an amplitude of 0.2 inches.

[0023] There is further provided according the invention a fill sheet having elliptically-shaped spacers formed thereon.

[0024] There is further provided according the invention a fill pack assembly for cooling a fluid flowing through the pack with a gas flowing through the pack in a substantially horizontal direction, the fill pack assembly comprising a plurality of identical fill sheets having the continuous wave described above.

[0025] There is further provided according the invention a fill pack assembly made of fill sheets characterized by a wave in which the plurality of fill sheets are arranged so that elliptically-shaped projections on adjacent faces of adjacent sheets contact one-another.

[0026] There is further provided according to the invention a fill sheet as described herein having integrally formed drift eliminators and/or integrally formed air inlet louvers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] Figure 1 is a side schematic view of a cross flow cooling tower.

[0028] Figure 2 is an elevational front view of a single fill sheet according to an embodiment of the invention.

[0029] Figure 3 is a perspective view of a single fill sheet according to an embodiment of the invention.

[0030] Figure 4 is a closeup perspective view of the embodiment of Figure 3.

[0031] Figure 5 is a further closeup perspective view of the embodiment of Figure 3.

[0032] Figure 6 is a perspective view of the top left corner of a stack of fill sheets according to an embodiment of the invention.

[0033] Figure 7 is a perspective view of the top right corner of the stack of fill sheets shown in Figure 6.

[0034] Figure 8 is a perspective view of a stack of fill sheets according to an embodiment of the invention.

[0035] Figure 9 is a close-up perspective view of the embodiment of Figure 8.

[0036] Figure 10 is a further closeup perspective view of the embodiment of Figure 8.

[0037] Figure 11 is a schematic representing a first embodiment of the invention in which the spacers are all oriented horizontally and parallel to the air flow.

[0038] Figure 12 is a schematic representing a second embodiment of the invention.

[0039] Figure 13 is a schematic representing a third embodiment of the invention.

[0040] Figure 14 is a schematic representing a fourth embodiment of the invention.

[0041] Figure 15 is a schematic representing a fifth embodiment of the invention.

[0042] Figure 16 is a front elevational view of a single fill sheet according to another invention.

[0043] Figure 17 is a perspective view of the top left corner of a single fill sheet according to the invention of Figure 16.

[0044] Figure 18 is a side view of the embodiment of Figure 17.

[0045] Figure 19 is a perspective view of a stack of fill sheets according to the invention of Figure 16.

[0046] Figure 20 is a side view of the embodiment of Figure 19.

[0047] Features in the attached drawings are numbered with the following reference numerals:

200 Fill Pack	210 Surface features
202 Fill Sheet	212 Spacer
204 Vertical Axis	212a Female Spacer
206 Horizontal Axis	212b Male Spacer
208a First End	214 Wave Shape
208b Second End	216 Air Inlet Louvers
208c First Side	218 Drift Eliminators
208d Second Side	

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0048] Referring to FIGS. 2-10, for example, the invention is directed to a cross flow water dispersion media in the form of individually hanging fill sheets 202, or fill pack 200 comprised of a plurality of identical stacked and engaged fill sheets 202. Each of the sheets 202 defines a vertical axis 204 extending generally vertically and a horizontal axis 206 extending generally horizontally relative to the fill sheets 202. It will be understood that use of the terms “vertical”

and “horizontal” with respect to the axes 204 and 206 is arbitrary for the purposes of description of the structure of the invention and are not intended to limit the orientation of the invention hereof in use. That said, and without limiting the invention or the use thereof, the fill pack 200 of the invention would generally be oriented in a standard cross-flow cooling tower so that vertical axis 204 is generally parallel to the direction of the water travel in a standard cross-flow cooling tower and horizontal axis is generally parallel to the direction of air travel.

[0049] Continuing the description of the invention from the standpoint a standard cross-flow cooling tower, the water flows through the fill pack 200 generally along the vertical axis 204 between first and second ends 208a, 208b of the sheets 202. First and second ends 208a and 208b of the fill sheets 202 are joined by first and second sides 208c and 208d. The air passes through the fill pack 200 generally along the horizontal axis 206 between the first and second sides 208c and 208d. The first end 208a extends substantially parallel to the second end 208b and generally perpendicular relative to the longitudinal axis 204. The first and second ends 208a, 208b extend substantially parallel to the lateral axis 206. Each fill sheet is preferably manufactured from thermoplastic material, for example, PVC, CPVC, HPVC or polypropylene, and preferably has a thickness of 0.010 to 0.025 inches (10 mils to 25 mils) and more preferably of 0.012 to 0.020 inches (12 mils to 20 mils).

[0050] The surface of the fill sheets may be smooth and/or featureless, or it may include surface feature 210 such as micro-ridges and valleys extending in a zigzag (e.g., herringbone) pattern across the surface of the sheet. By way of non-limiting example, the embodiments shown in the figures have microstructures in the form of alternating diagonal mini-corrugations that traverse the faces of the sheets. The fill sheets of the invention may include integrally formed air inlet

louvers 216 on the air inlet side and/or integrally formed drift eliminators 218 at the air outlet side.

[0051] Each fill sheet 202 has formed thereon a plurality of integrally formed spacers 212 in the form of elliptically-shaped protrusions extending out of the primary plane of the sheet (the plane defined by first end 208a, second end 208b, first side 208c and second side 208d). The elliptically shaped spacers are preferably arranged in pairs, with pairs spaced across the fill sheet in a plurality of rows. Each pair of elliptically shaped spacers includes one spacer formed in one direction perpendicular to the plane of the fill sheet, and the other spacer of a pair formed in the opposite direction perpendicular to the plane of the fill sheet, with the result that no matter the perspective, one spacer of a pair is pressed into the fill sheet, “the female spacer” (212a) and the other spacer of the pair extends out of the fill sheet, the “male spacer” (212b). Each male spacer, viewed from the perspective of one side of a fill sheet, is a female spacer when viewed from the perspective of the opposite side of the same sheet. Conversely, each female spacer, when viewed from the perspective of one side of a fill sheet, is a male spacer when viewed from the perspective of the opposite side of the same sheet.

[0052] The preferred aspect ratio of the elliptical shapes of the spacers 212 (ratio of the length of the major axis to the length of the minor axis) is 2:1, although any aspect ratio between 4:1 and 1.5:1 would be understood to provide similar benefits and is therefore considered to be within the scope of the invention.

[0053] When the “A” and “B” fill sheets 202 are stacked against one-another with their tops aligned, the male spacers 212b of facing surfaces of adjacent “A” and “B” sheets align with and contact one-another to create a space between the fill sheets that is equivalent to the height of two male spacers.

[0054] According to various embodiments of the elliptical spacer invention, a) the major axes of the elliptically shaped spacers may all be arranged horizontally, in which case the air passes generally straight through the sheets of fill. See, e.g., Figure 11, in which the two sets of spacers on the first three rows of spacers on a single fill sheet are represented (similar to the field of view of Figure 4). In Figure 11, as well as Figures 12-15, the blue ellipses represent the male spacers on one side of a fill sheet (extending out of the plane of the sheet, toward the reader), and the red ellipses represent the female spacers (that is, the male spacers on the reverse side of the same fill sheet, extending into the plane of the fill sheet, away from the reader). According to another embodiment, b) the major axes of the elliptically shaped spacers on one side of a fill sheet may alternate in upwardly tilting and downwardly tilting directions, see, e.g., Figure 12. According to this embodiment, the air on one side of a fill sheet is forced up, then down, then up, then down, and so on, and air on the opposite side of the same fill sheet is alternatively forced down, then up, then down, then up, and so on. According to a further embodiment, c) the major axes of the elliptically shaped male spacers on one side of a fill sheet may all be tilted upwardly, and the major axes of the elliptically shaped male spacers on the opposite side of fill sheet may all be tilted downwardly, see, e.g., Figure 13, in which the blue ellipses represent the elliptically-shaped spacers on one side of a fill sheet, and the red ellipses represent the elliptically-shaped spacers on the reverse side of the same fill sheet. According to yet another embodiment, d), the major axes of all of the elliptically shaped male spacers on both sides of a fill sheet may be tilted upwardly, in which case the air is continuously forced upward as it crosses the fill sheet, see, e.g., Figure 14. According to yet another embodiment, e), the major axes of all of the elliptically shaped male spacers on both sides of a fill sheet may be tilted downwardly; in which case the air is continuously forced downward as it crosses the fill sheet, see, e.g., Figure 15.

[0055] According to the above-described invention, the aerodynamic shape of the elliptical-shaped spacers 212 reduces the drag coefficient and associated pressure drop relative to typical round spacers. The reduced pressure drop results in higher thermal capability.

[0056] According to the embodiment in which the elliptically-shaped spacers 212 are all aligned parallel to the horizontal axis of the fill sheet, the fill pack may be aligned so that the major axes of the elliptical-shaped spacers are essentially parallel to the airflow when installed in cooling tower. According to the other embodiments in which the elliptically-shaped spacers are arranged at an angle relative to the horizontal in order to enhance mixing of the airflow through the fill pack, it is preferred that the major axes of the spacers be arranged so that the major axes of the spacers do not exceed fifteen (15) degrees relative to horizontal in order to minimize drag coefficient.

[0057] According to preferred embodiments, facing male spacers 212b on adjacent sheets may be bonded together according to various known methods, e.g., solvent adhesives, ultrasonic welding, etc.

[0058] The first invention having been described above, the second invention presented herein will now be described. The second invention presented herein is a fill sheet 202 and fill pack 200 where each fill sheet 202 defines a continuous wave 214 having a wavelength that is parallel to the direction of air flow, see, e.g., Figures 16-20. The fill sheet 202 may include elliptically-shaped spacers 212 as described with respect to the first invention herein; the fill sheet 202 may include round spacers, or spacers of other shapes. In any event, the spacers may be formed in pairs, pressed in first and second directions perpendicular to the plane of the sheet as described above, with the pairs distributed across and down the sheet in a series of rows.

[0059] The wavy fill sheets of this invention increase the structural performance of a mechanically bonded pack when supported from the bottom. Compared to a cross-flow fill sheet made from a flat sheet, the wavy fill sheets of the invention enhance the bending stiffness and buckling load of the fill sheet. The wave-shaped sheets maintain a constant spacing between adjacent sheets via spacers, which may be prior art spacers or the elliptical spacers according to the first invention herein, but the wavy shape induces turbulence to increase air water contact and thermal efficiency. The period and the amplitude of the wave shape may be optimized to balance increased pressure drop vs. increased thermal efficiency. According to a preferred embodiment the period of the wave form is 3 inches to 6 inches, preferably 4 inches to 5.5 inches, and more preferably 4.7 inches and the amplitude is 0.05 inches to .5 inches, preferably 0.1 inches-0.35 inches, and more preferably 0.2 inches.

[0060] It will be appreciated by those skilled in the art that changes could be made to the preferred embodiments described above without departing from the inventive concept thereof. It is understood, therefore, that this invention is not limited to the particular embodiments disclosed, but it is intended to cover modifications within the spirit and scope of the present invention as outlined in the present disclosure and defined according to the broadest reasonable reading of the claims that follow, read in light of the present specification.

What is claimed:

1. A fill sheet for cooling a cooling medium in a cooling tower, the fill sheet comprising:
a first end;
a second end;
a first side;
a second side;
said second end extending substantially parallel to the first end and generally perpendicularly relative to a vertical axis (with respect to water travel), the first and second ends extending substantially parallel to a lateral axis of the fill sheet;
said first second side extending substantially parallel to the first side and generally parallel to said vertical axis, said first and second sides connecting said first and second ends;
said first end, second end, first side and second side defining a first face and a second face, said first and second faces mirror images of one-another;
said first face of said fill sheet comprising a plurality of first-face elliptically-shaped projections and depressions arranged in a plurality of rows across said fill sheet, each of said first-face elliptically shaped projections corresponding to a second-face elliptically shaped depression on said second face, each of said first-face elliptically shaped depressions corresponding to a second-face elliptically shaped projection on said second face.
2. A fill sheet according to claim 1, wherein said first-face elliptically-shaped projections and depressions are arranged in pairs, each of said pairs having a single first-face elliptically shaped projection and a single first-face elliptically shaped depression.
3. A fill sheet according to claim 1, wherein each of said first-face elliptically-shaped projections and depressions has a major axis that is parallel to a direction of air travel across said fill sheet.
4. A fill sheet according to claim 1, wherein all of said first-face elliptically-shaped projections and depressions have a major axis that is aligned at a same angle that is equal to or less than + 15 degrees from horizontal.

5. A fill sheet according to claim 1, wherein all of said first-face elliptically-shaped projections and depressions have a major axis that is aligned at a same angle that is equal to or less than - 15 degrees from horizontal.
6. A fill sheet according to claim 2, wherein each first-face elliptically-shaped projection is oriented in an opposite direction, up or down, to horizontal compared to its paired first-face elliptically-shaped depression, and to each horizontally and vertically adjacent first-face elliptically-shaped projection.
7. A fill sheet according to claim 1, wherein all of said first-face elliptically-shaped projections have a major axis that is aligned at a same angle that is equal to or less than + 15 degrees from horizontal, and all of said first-face elliptically-shaped depressions have a major axis that is aligned at a same angle that is equal or less than negative 15 degrees from horizontal.
8. A fill pack assembly for cooling a fluid flowing through the pack with a gas flowing through the pack in a substantially horizontal direction, the fill pack assembly comprising a plurality of identical fill sheets according to any one of claims 1-7, wherein said plurality of fill sheets are arranged so that elliptically-shaped projections on adjacent faces of adjacent sheets contact one-another.
9. A fill sheet for cooling a cooling medium in a cooling tower, the fill sheet comprising:
a first end;
a second end;
a first side;
a second side;
said second end extending substantially parallel to the first end and generally perpendicularly relative to a vertical axis (with respect to water travel), the first and second ends extending substantially parallel to a lateral axis of the fill sheet;
said first second side extending substantially parallel to the first side and generally parallel to said vertical axis, said first and second sides connecting said first and second ends;

said first end, second end, first side and second side defining a first face and a second face, said first and second faces mirror images of one-another;
said fill sheet further defining a continuous wave extending in a direction parallel to a direction of air flow.

10. A fill sheet according to claim 9, wherein said continuous wave has a period of 3 inches to 6 inches and an amplitude of 0.05 inches to 0.5 inches.

11. A fill sheet according to claim 9, wherein said continuous wave has a period of 4 inches to 5.5 inches and an amplitude of 0.1 inches to 0.35 inches

12. A fill sheet according to claim 9, wherein said continuous wave has a period of 4.7 inches and an amplitude of 0.2 inches.

13. A fill sheet according to any one of claims 9-12 having elliptically-shaped spacers formed thereon.

14. A fill pack for cooling a fluid flowing through the pack with a gas flowing through the pack in a substantially horizontal direction, the fill pack assembly comprising a plurality of identical fill sheets according to any one of claims 9-13.

15. A fill pack according to claim 14, wherein said plurality of fill sheets are arranged so that elliptically-shaped projections on adjacent faces of adjacent sheets contact one-another.

16. A cross-flow cooling tower comprising a plurality of fill sheets according to any one of claims 1-7 and 9-13 wherein said plurality of fill sheets are individually hanging in a direct heat exchange section, are hanging in said direct heat exchange section in the form of fill packs, or supported from below by cooling tower structure in said direct heat exchange section in the form of fill packs.

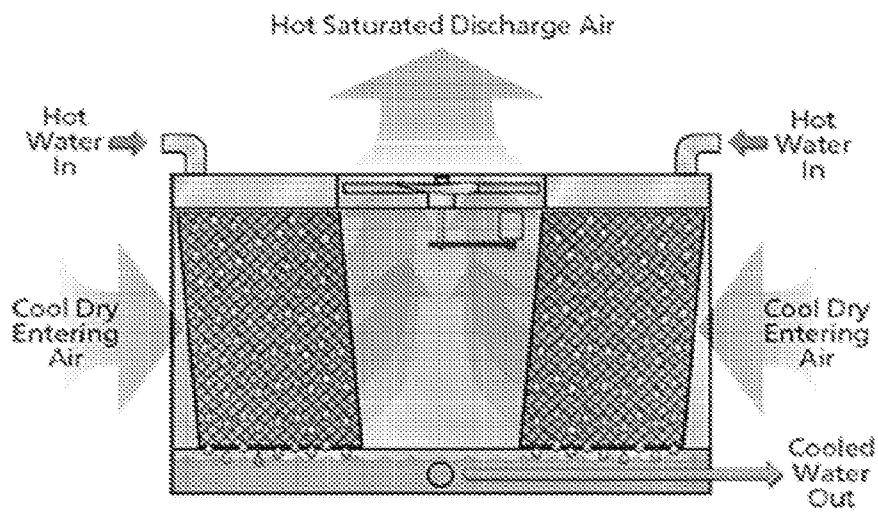
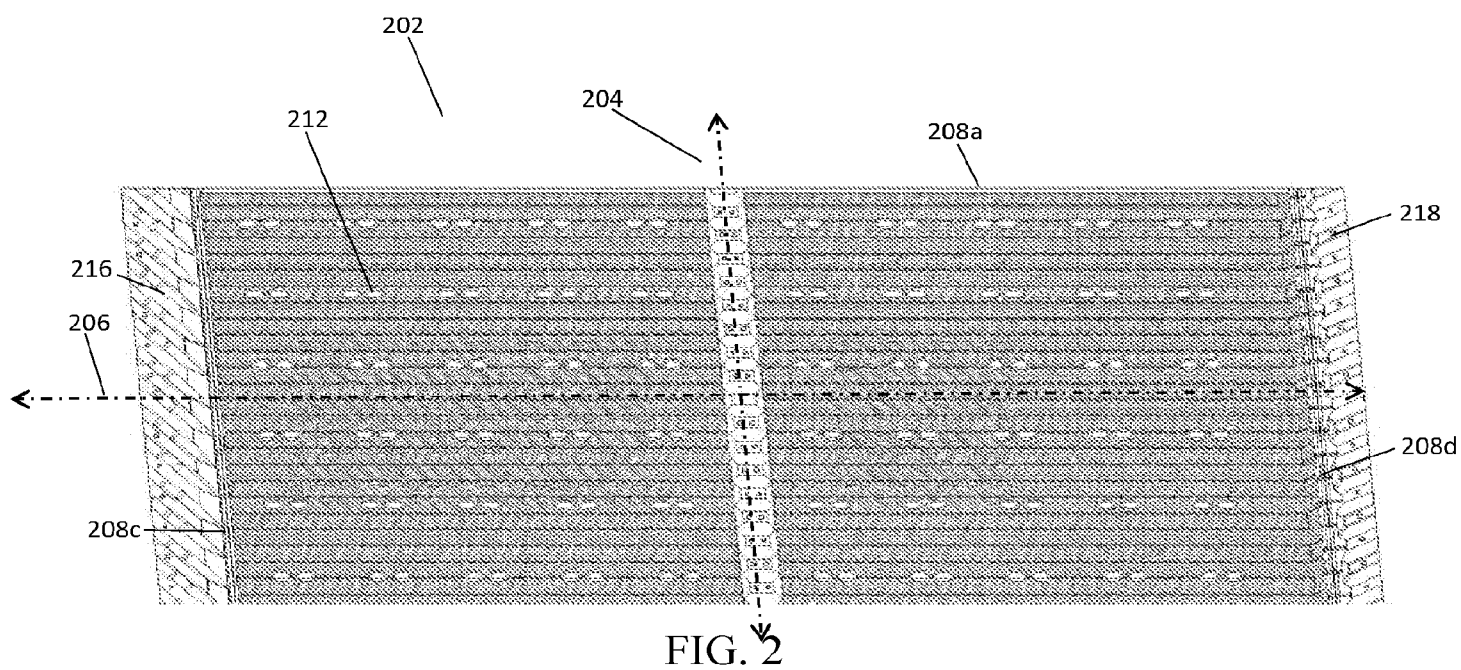


FIG. 1



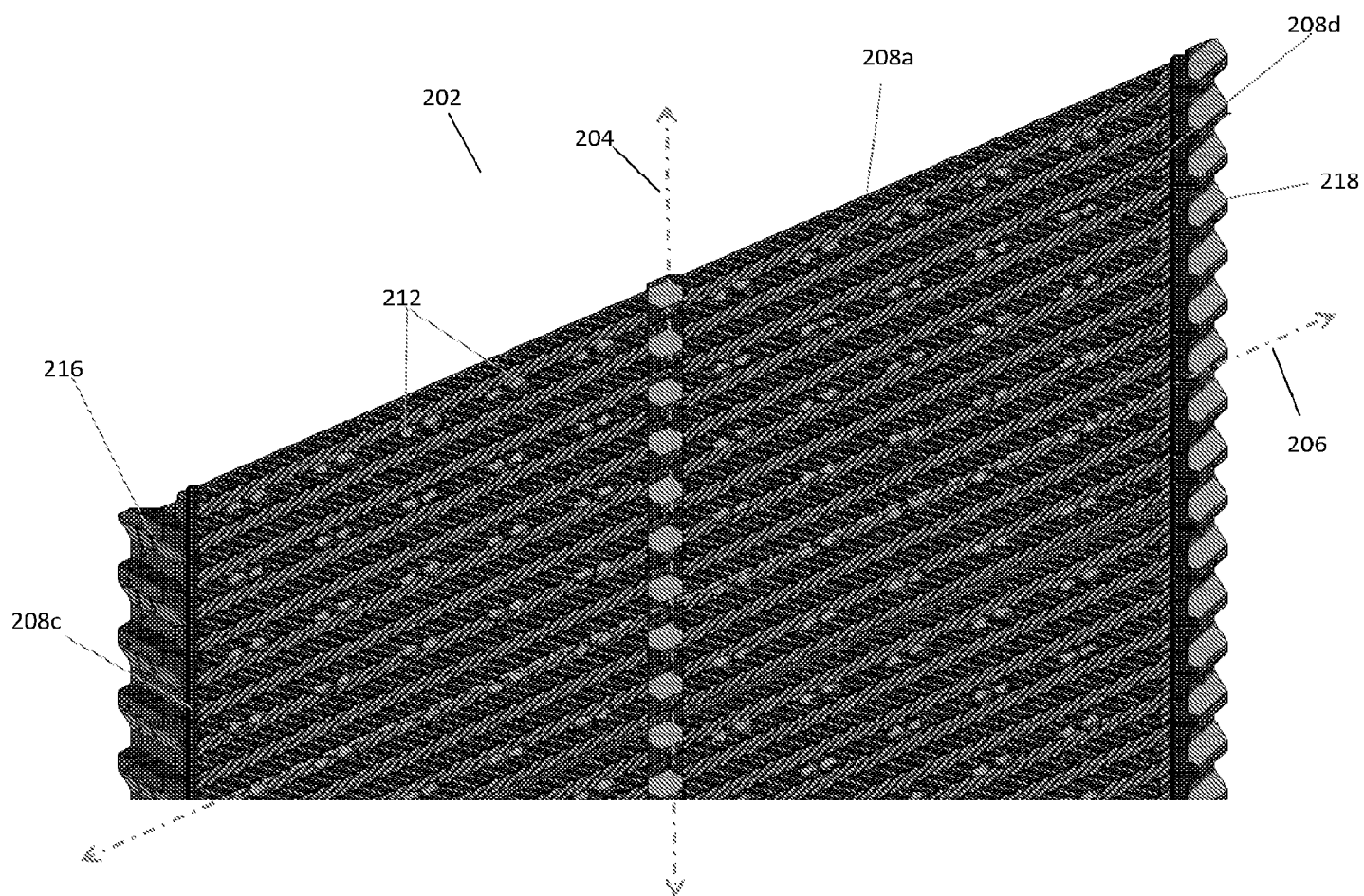


FIG. 3

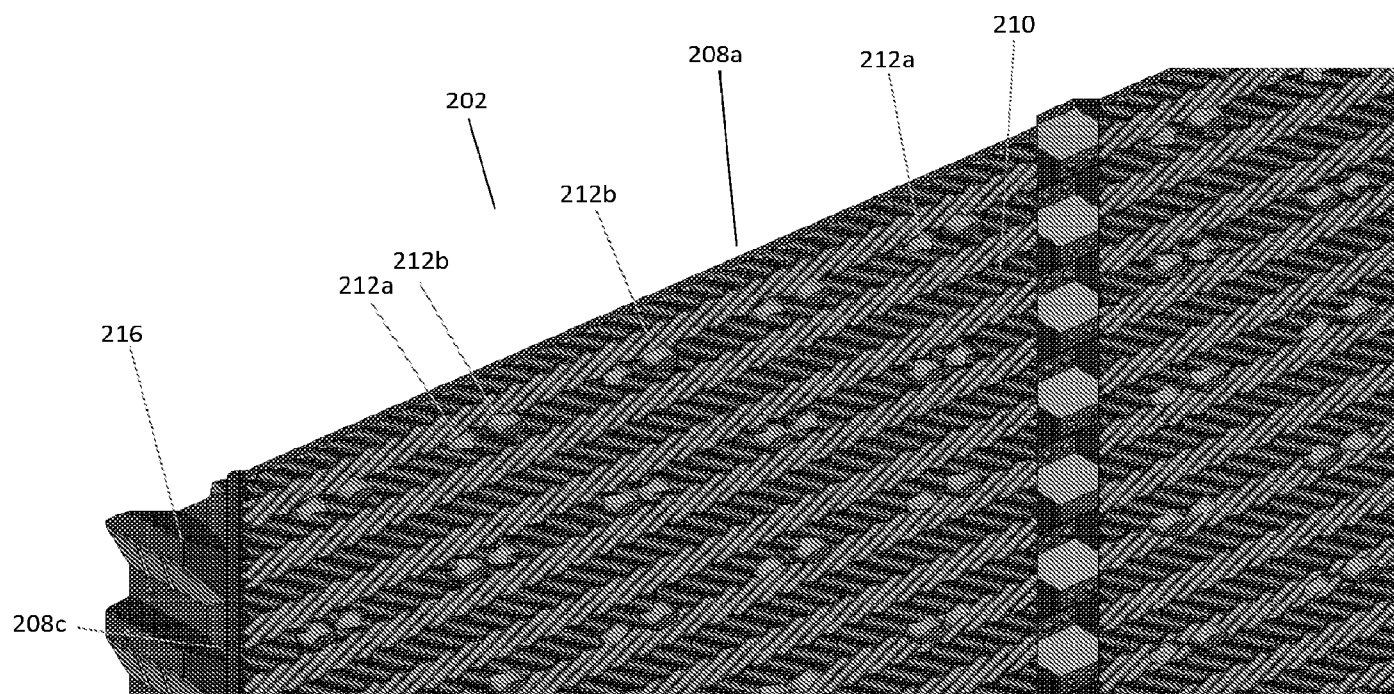


FIG. 4

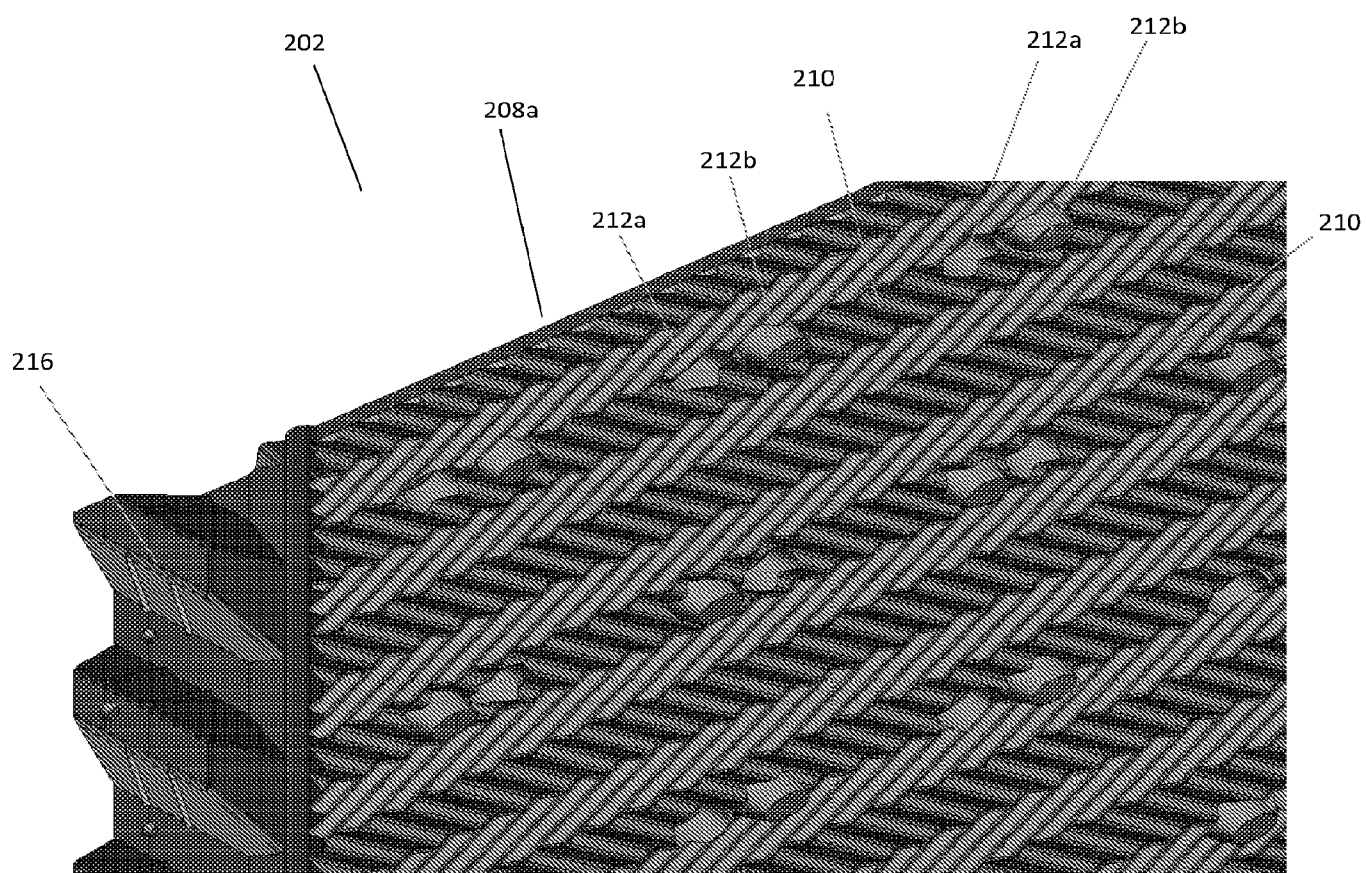


FIG. 5

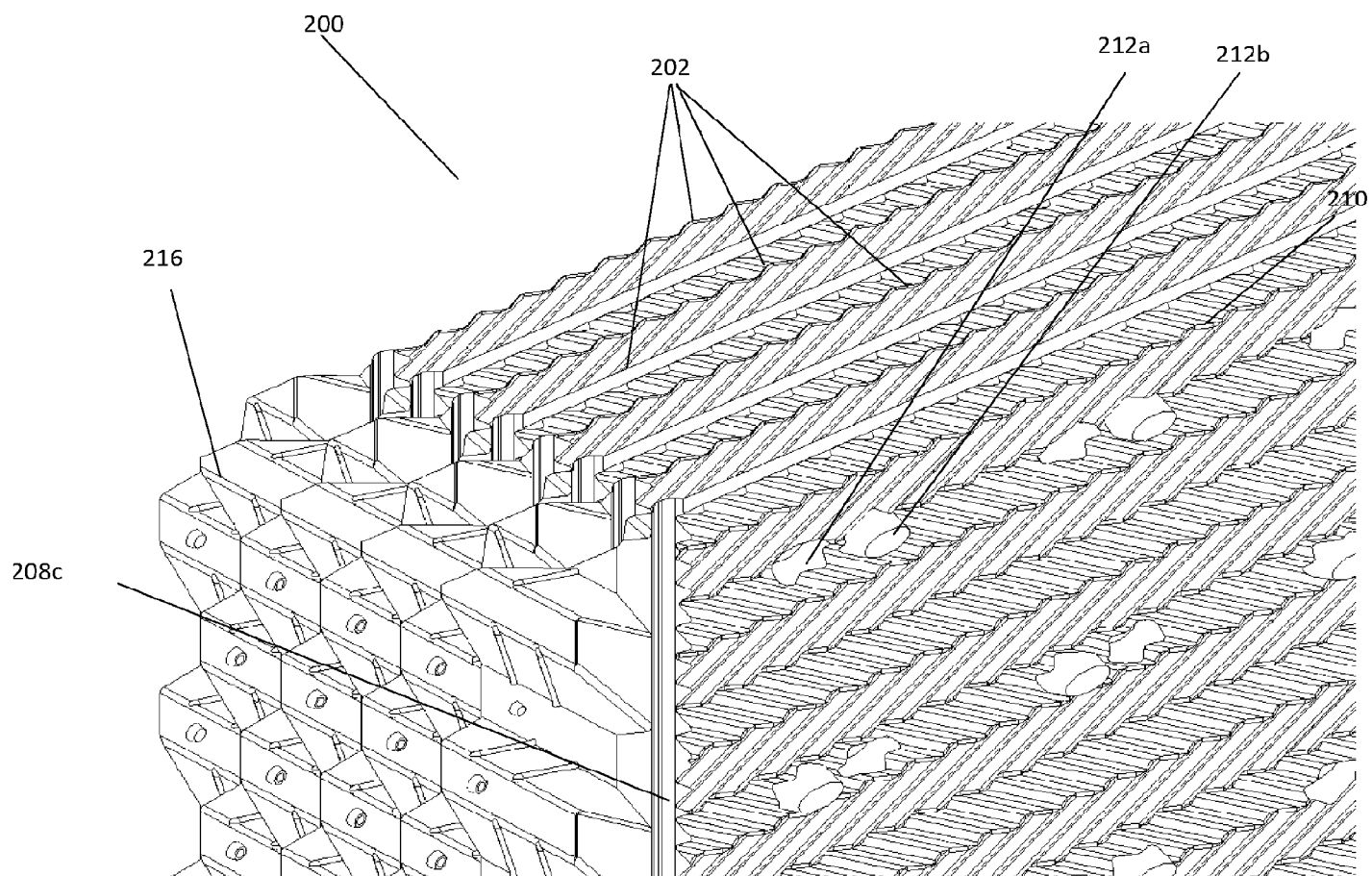


FIG. 6

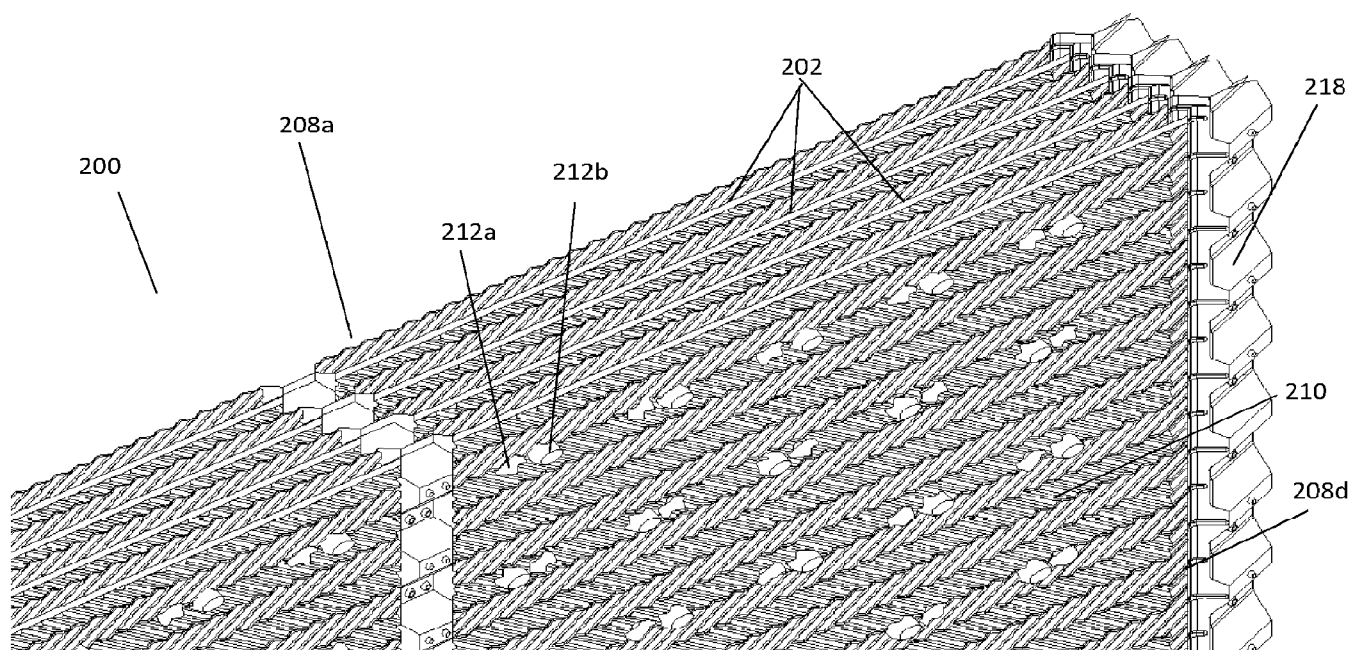


FIG. 7

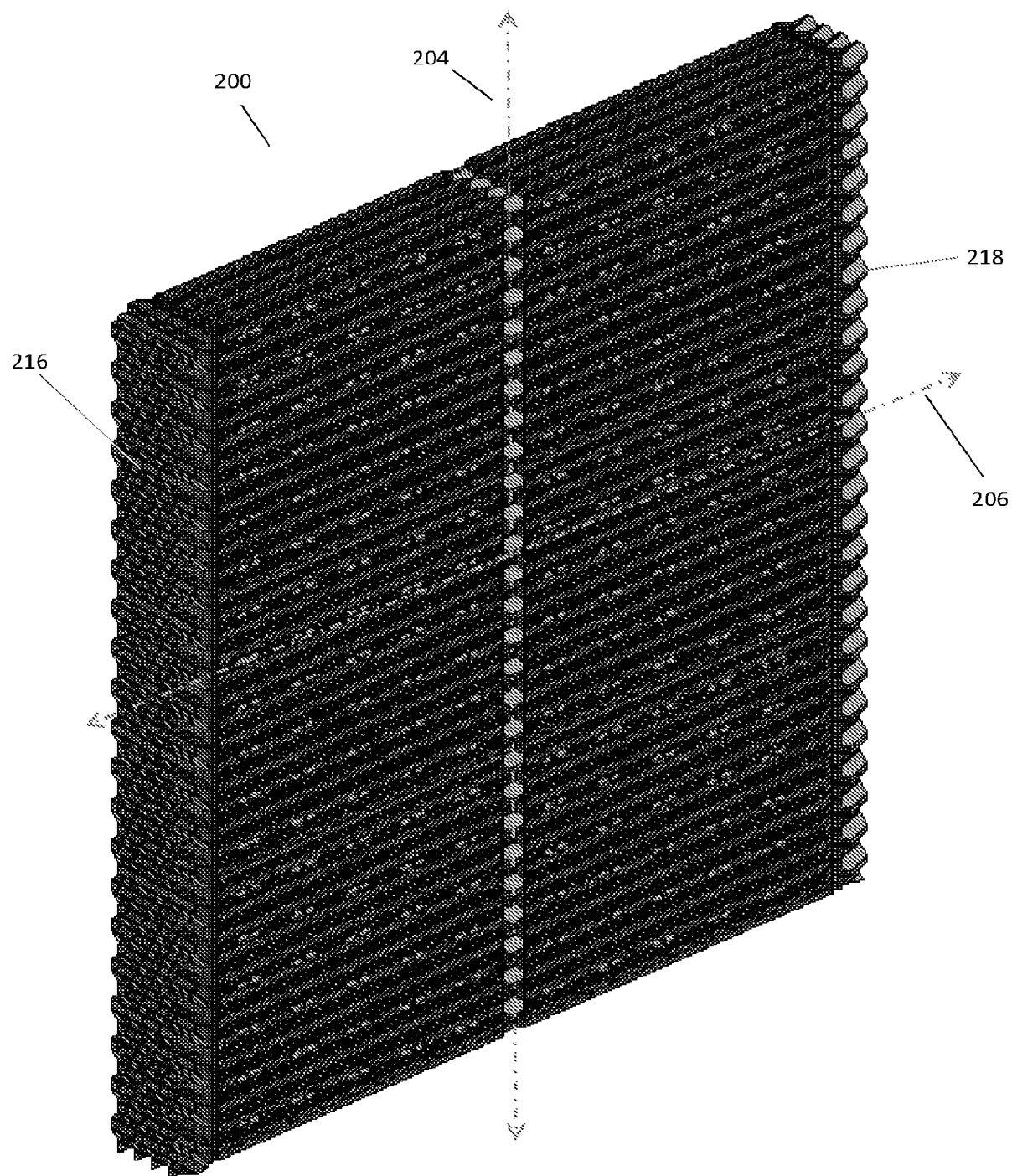


FIG. 8

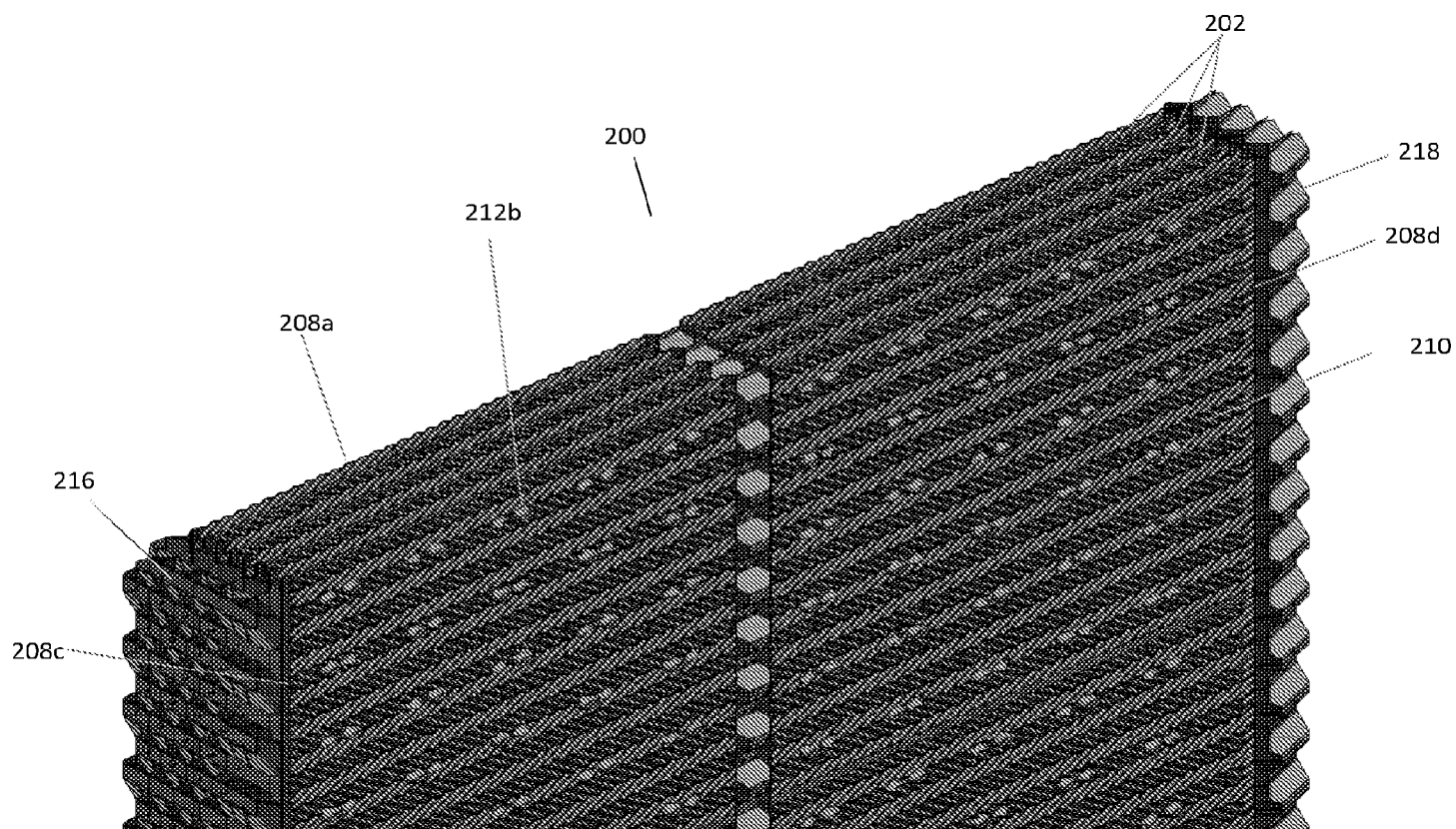


FIG. 9

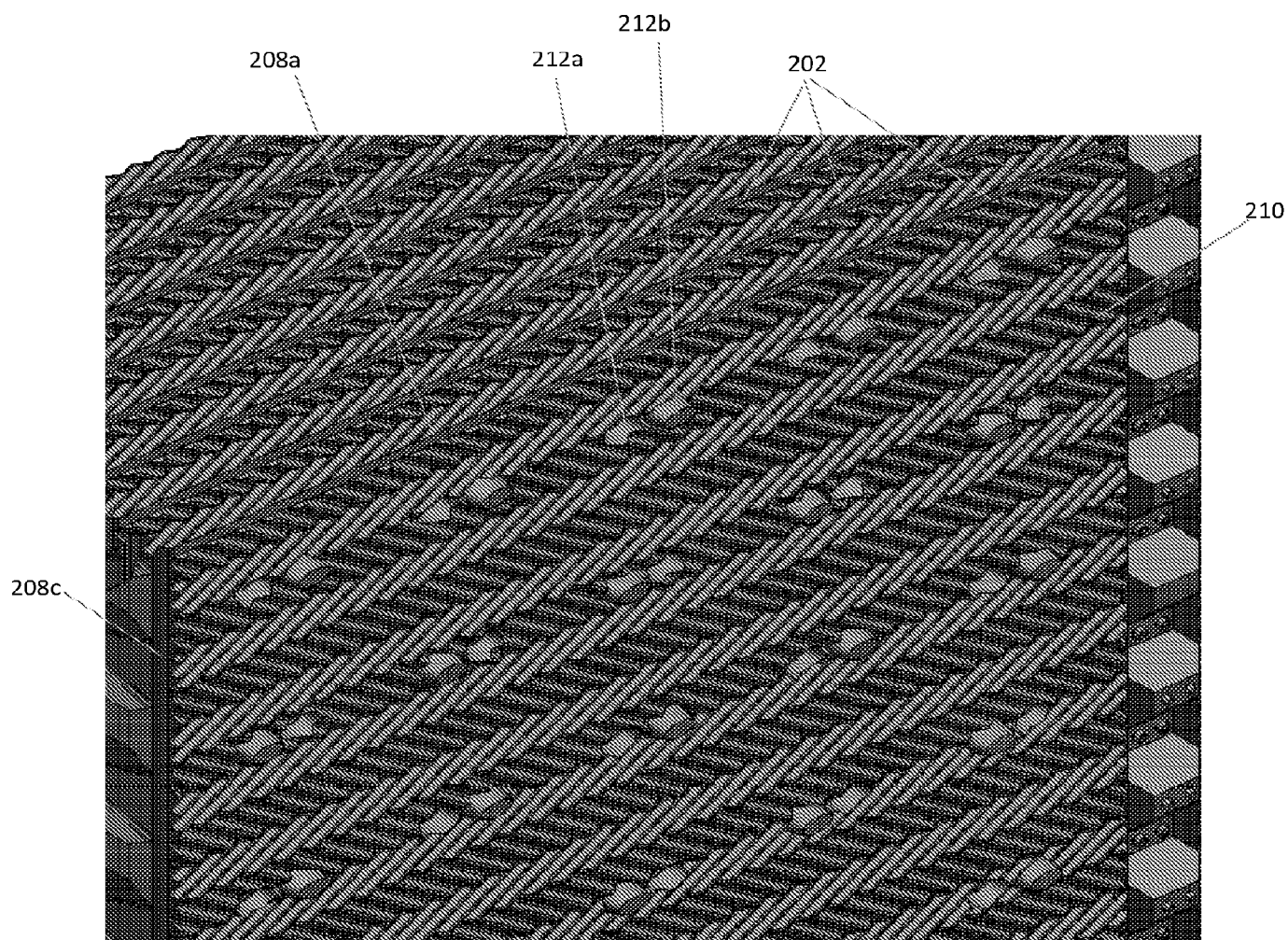


FIG. 10

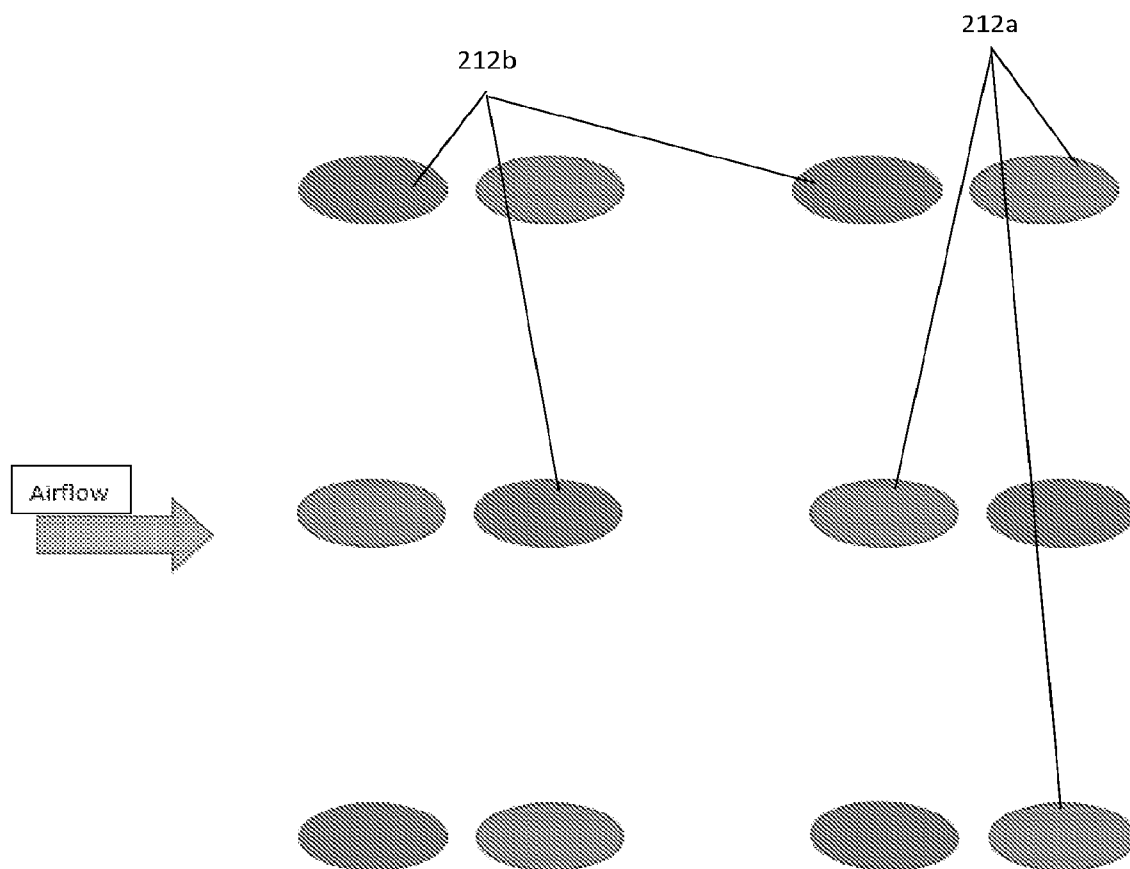


FIG. 11

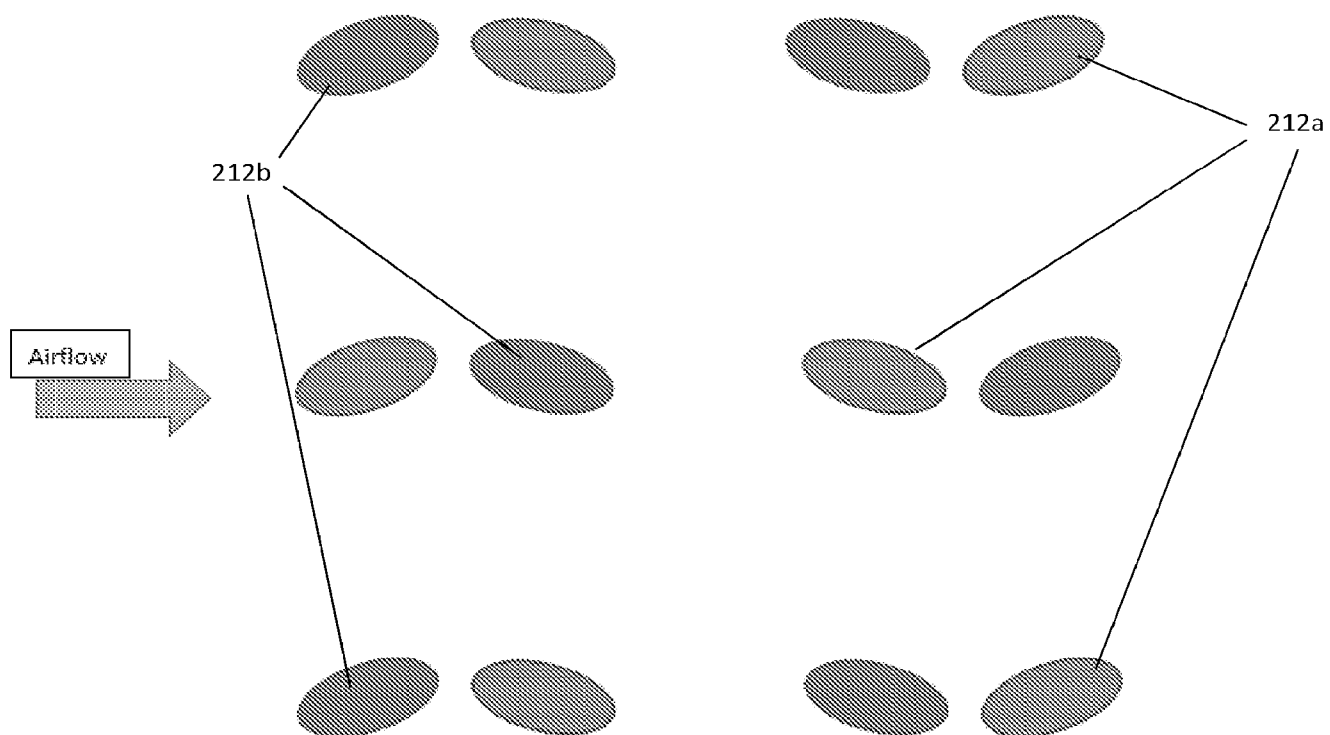


FIG. 12

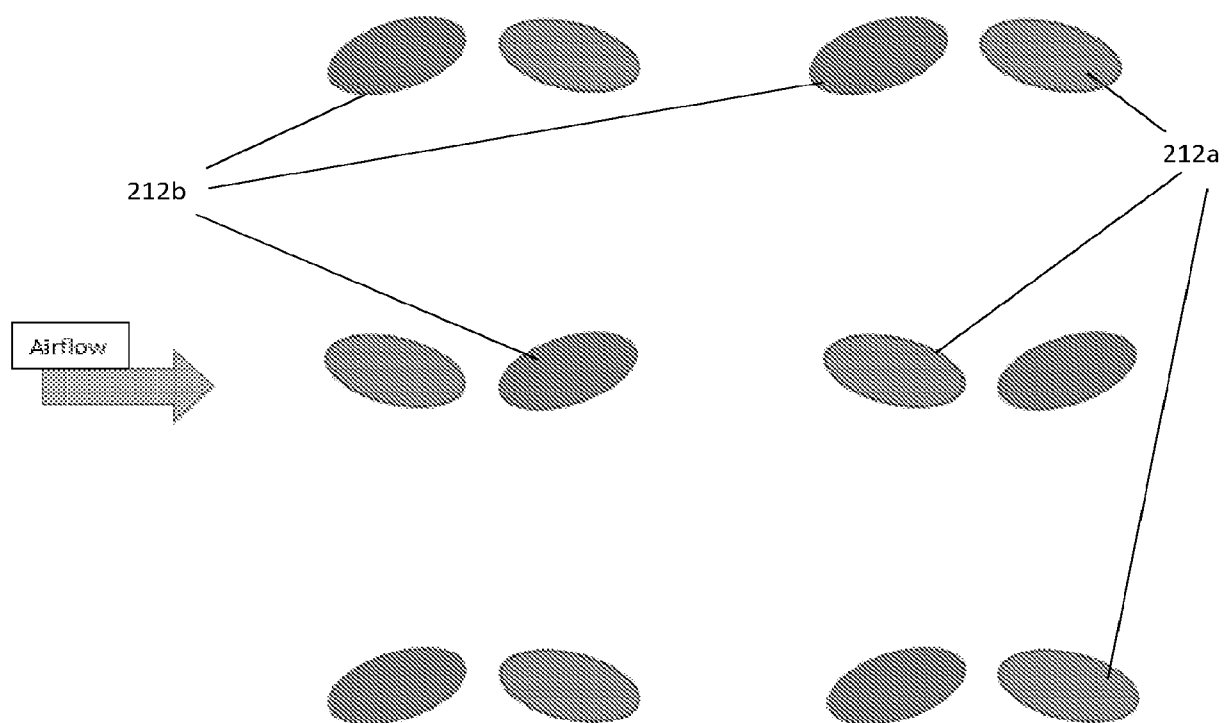


FIG. 13

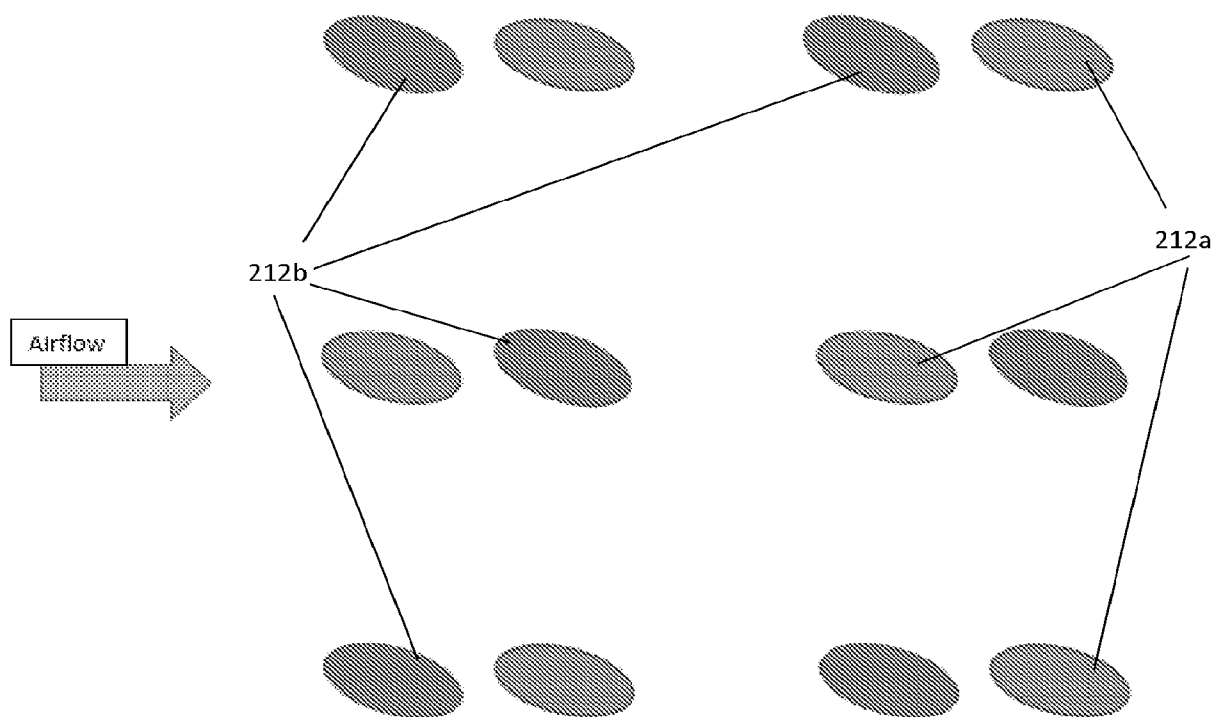


FIG. 14

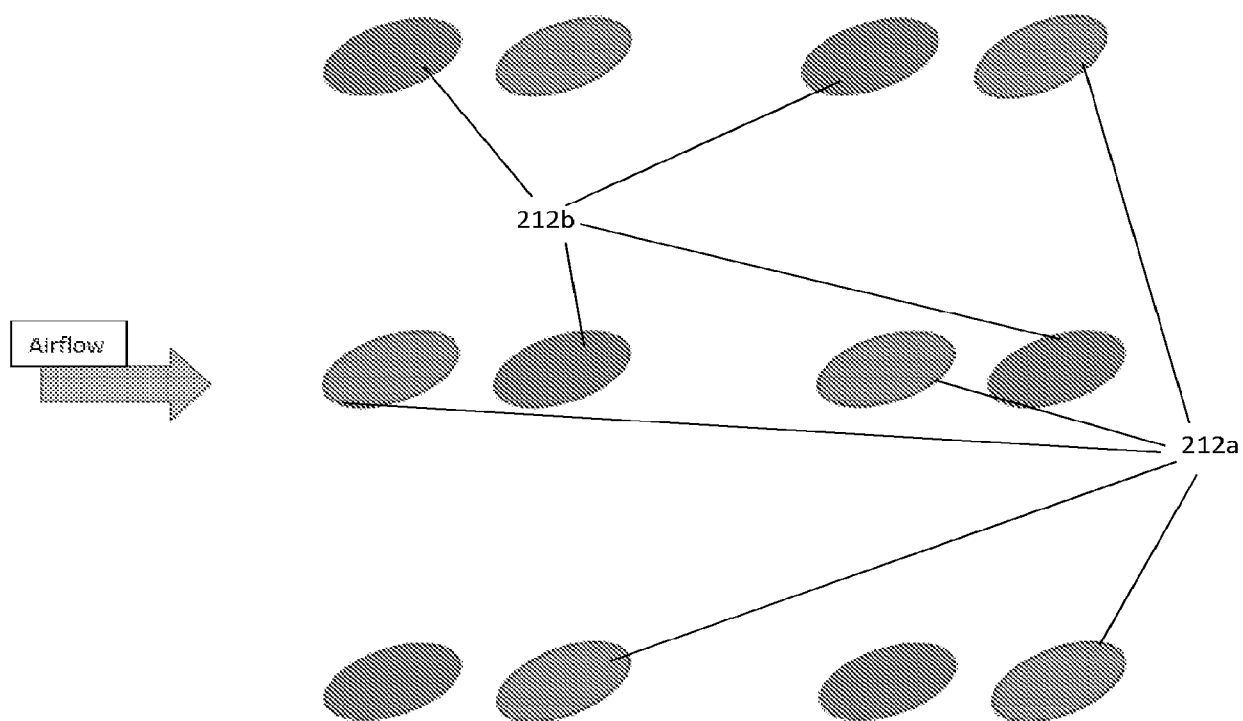


FIG. 15

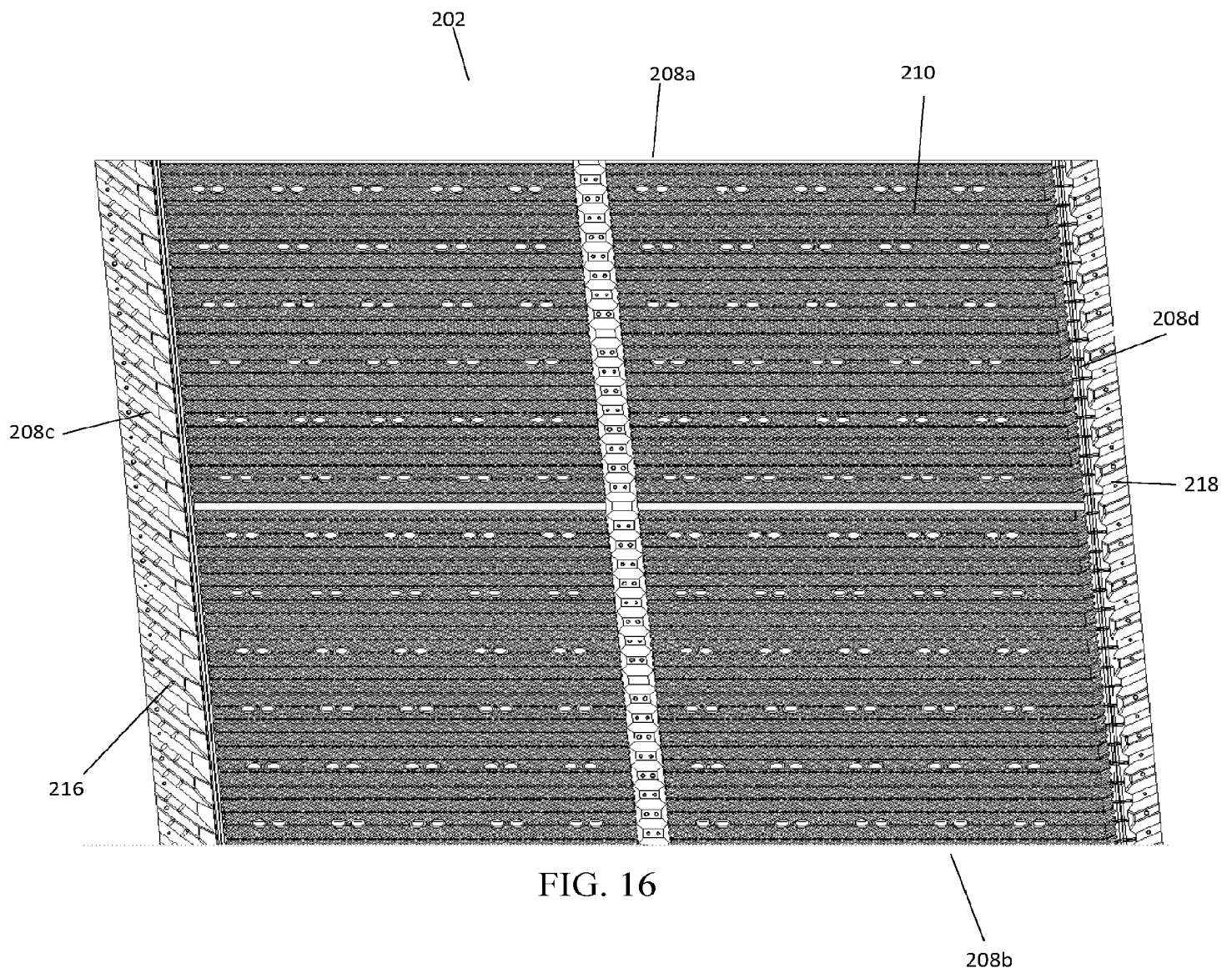


FIG. 16

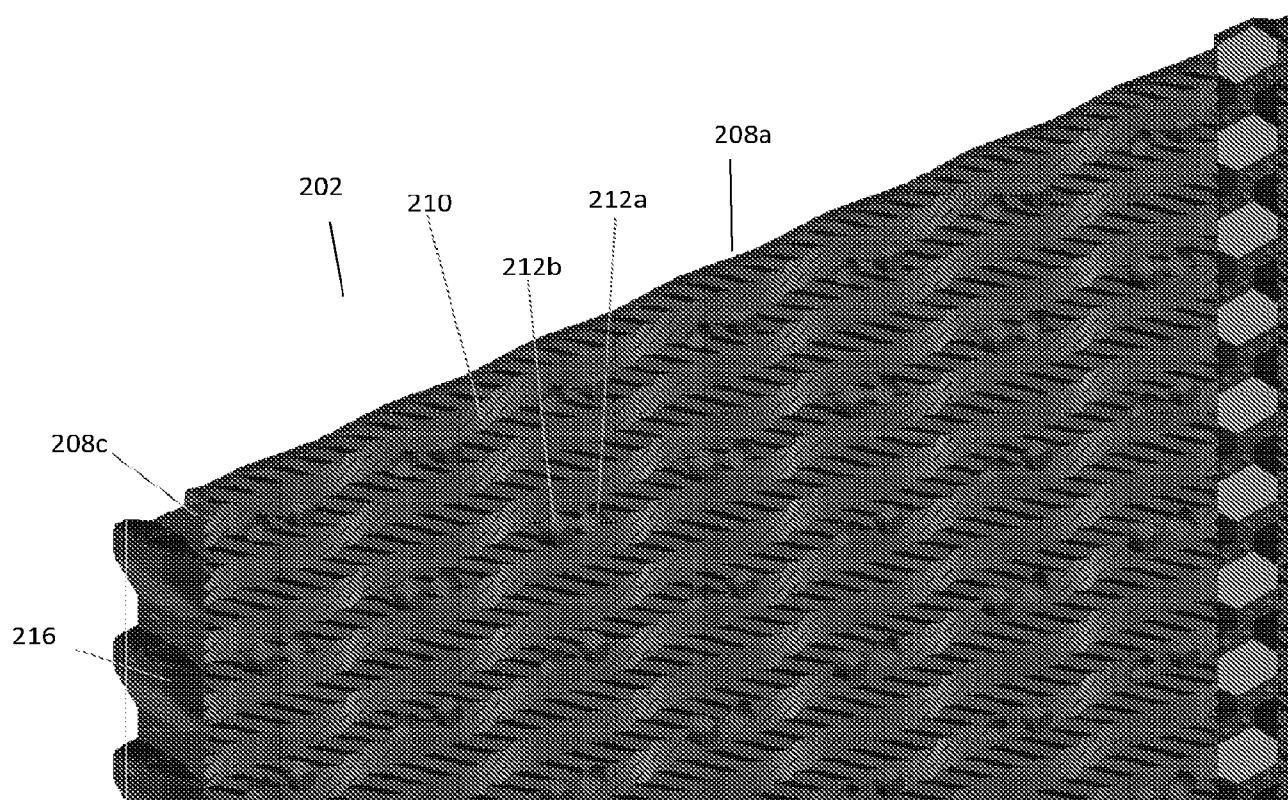


FIG. 17

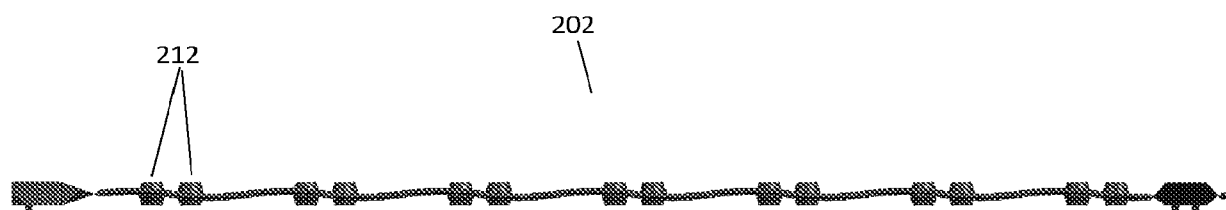


FIG. 18

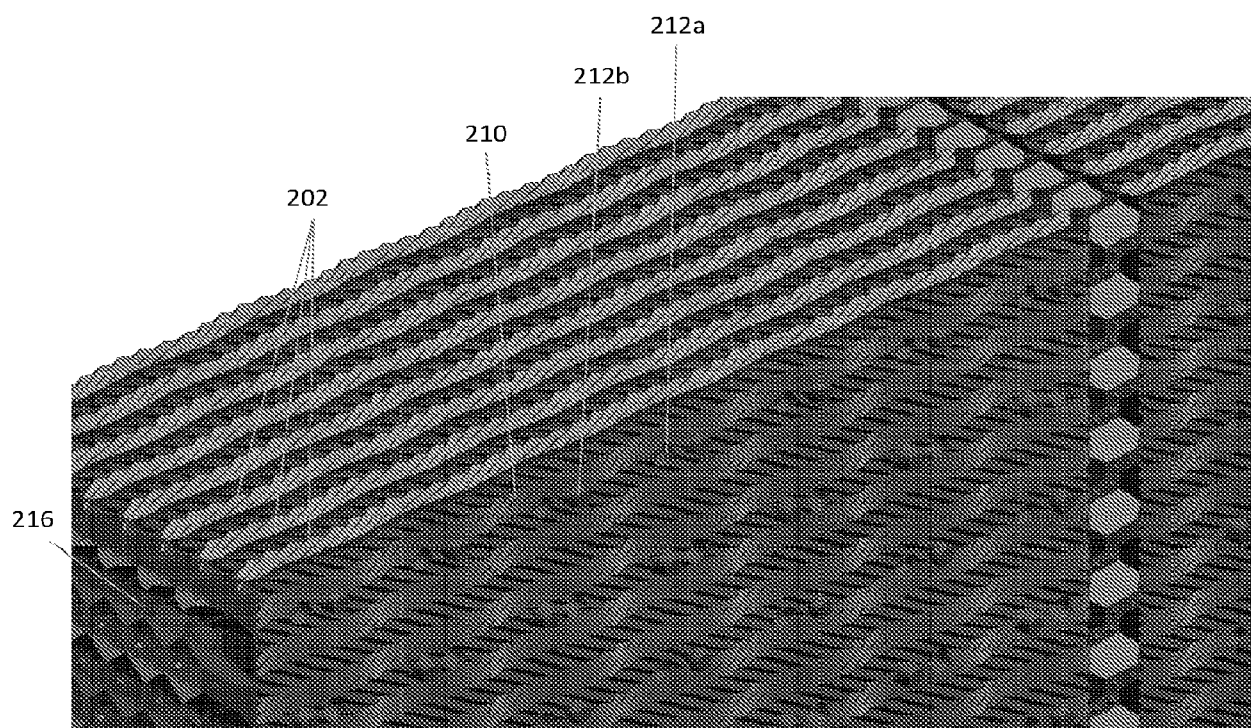


FIG. 19

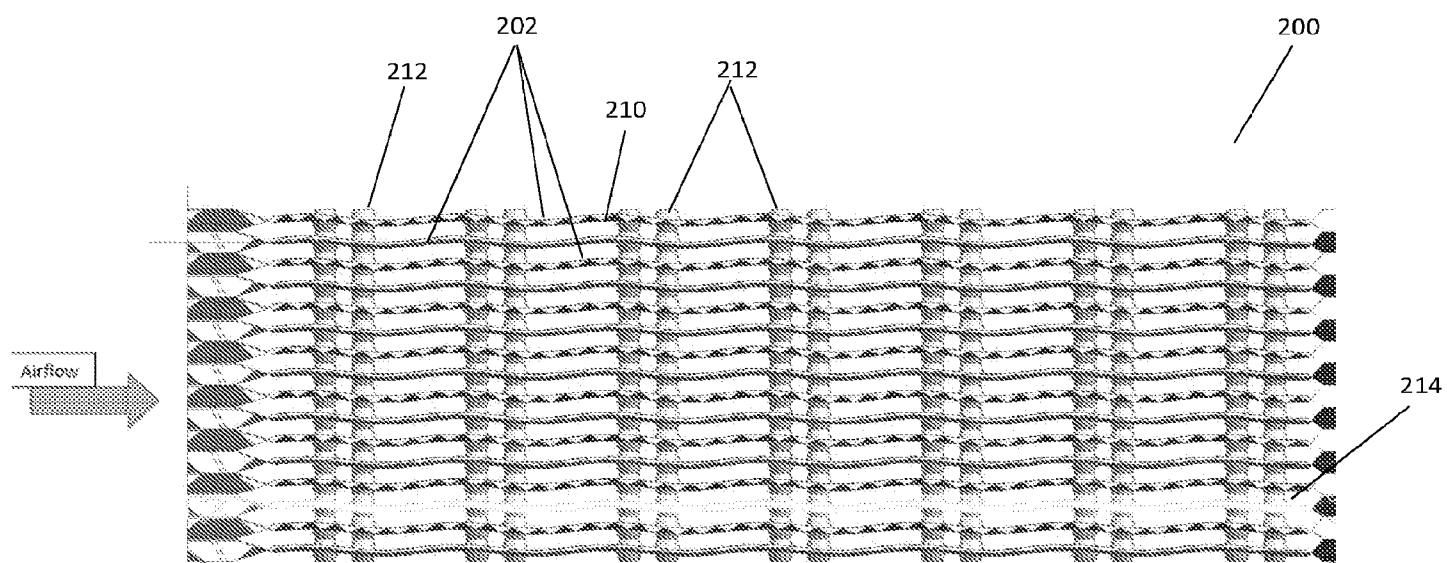


FIG. 20

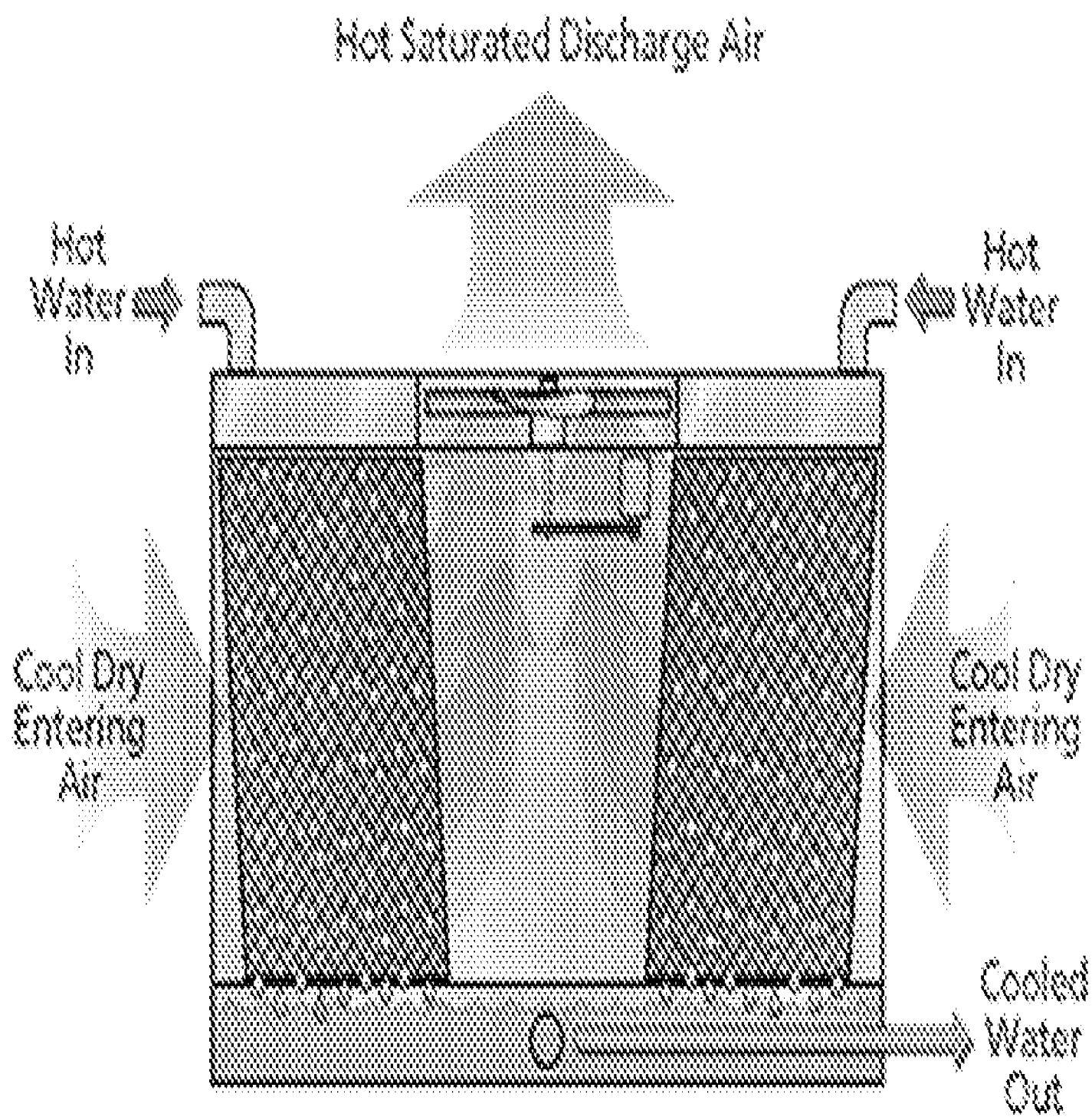


FIG. 1