(12) STANDARD PATENT APPLICATION (11) Application No. **AU 2017203940 A1**
(19) AUSTRALIAN PATENT OFFICE

(54) Title
Swimming pool heat exchangers and associated systems and methods

(51) International Patent Classification(s)

F28F 21/08 (2006.01)	***F24H 1/20*** (2006.01)
E04H 4/12 (2006.01)	***F24H 1/36*** (2006.01)
E04H 4/14 (2006.01)	***F28F 1/26*** (2006.01)

(21) Application No: **2017203940** (22) Date of Filing: **2017.06.09**

(30) Priority Data

(31) Number	(32) Date	(33) Country
62/348,186	**2016.06.10**	**US**

(43) Publication Date: **2018.01.04**
(43) Publication Journal Date: **2018.01.04**

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ABSTRACT

Exemplary embodiments are directed to swimming pool heat exchangers including a housing and one or more tube assemblies disposed within the housing. Each of the tube assemblies includes an elongated titanium tube and at least one fin welded to an outer surface of the elongated titanium tube. The elongated titanium tube and the at least one welded fin allow for corrosion resistance to swimming pool water while simultaneously allowing for improved heat transfer from the heat exchanger to the swimming pool water.

Australian Patents Act 1990

ORIGINAL COMPLETE SPECIFICATION
STANDARD PATENT

Invention Title

Swimming pool heat exchangers and associated systems and methods

The following statement is a full description of this invention, including the best method of performing it known to me/us:-

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the priority benefit of United States Provisional Application No. 62/348,186, filed June 10, 2016, which is hereby incorporated by reference in its entirety for all purposes.

TECHNICAL FIELD

[0002] The present disclosure relates to swimming pool heat exchangers and associated systems and methods and, in particular, to heat exchangers including a plurality of titanium tubes with welded copper fins for improved heat transfer in swimming pool heater applications.

BACKGROUND

[0003] Various types of heaters have been used over the years for heating fluids in applications such as residential heating systems and swimming pools. Although discussed herein with respect to water tube heat exchangers, fire tube heat exchangers have also been used in the industry. Most heaters include a heat exchanger disposed proximate a source of heat through which the fluid to be heated passes. The heat exchanger generally includes a metal conduit through which the fluid to be heated can pass and is positioned above a burning gas to absorb the heat of combustion and conduct it to the fluid passing through the conduit. To increase the efficiency of heat transfer, the heat exchanger can be configured to maximize the exterior surface area exposed to the heat of combustion by using metal fins on the conduit.

[0004] Different materials of construction for heat exchangers have been used. The advantages of using titanium tubing with swimming pool water to avoid corrosion has been well documented, and titanium tubing has been widely used in mechanical heating appliances (e.g., heat pumps). In particular, titanium has been successfully used with mechanical heating appliances due to the heat exchanger being used for a liquid-to-liquid heat transfer and, compared to gas-fired appliances, a relatively low amount of heat to be transferred into the swimming pool water.

[0005] Gas-fired appliances with an air-to-liquid heat exchanger generally have a higher heat capacity than liquid-to-liquid heat exchangers. However, achieving adequate heat transfer using titanium tubes in the air-to-liquid heat exchanger of a gas-fired appliance has proven elusive in the swimming pool heater industry. One hurdle to attaining adequate heat transfer is the inability to extrude titanium into a tube with a substantial number of integrated fins. Although the extrusion process is widely used with copper and cupro-nickel in the industry, fins for a titanium tube cannot be extruded to the desired size for proper heat transfer. Some swimming pool heat exchangers include extruded fin tubes manufactured from either copper or cupro-nickel and have fin heights that cannot be manufactured out of titanium.

[0006] Some manufacturers have welded stainless steel fins to stainless steel tubing. Some industries, such as boiler and fluid processing, have used fins of a dissimilar material than the tube welded to the titanium tubes. Some swimming pool heat exchangers include plate fin designs with tubes mechanically expanded into collars on the plates to bond the fins and tubes. However, such methods are unfeasible for use with titanium.

[0007] Thus, a need exists for swimming pool heat exchangers that include titanium tubes with welded copper fins that provide the desired amount of heat transfer and corrosion resistance in air-to-liquid applications. These and other needs are addressed by the swimming pool heat exchangers and associated systems and methods of the present disclosure.

SUMMARY

[0008] In accordance with embodiments of the present disclosure, exemplary swimming pool heat exchangers are provided that include a housing and one or more tube assemblies disposed within the housing. Each of the tube assemblies includes an elongated titanium tube and at least one fin welded (e.g., laser welded) to an outer surface of the elongated titanium tube. In some embodiments, any type of welding can be used to attach the fins to the outer surface of the titanium tube. In some embodiments, the tube assemblies can include a plurality of fins individually welded in a spaced manner along the outer surface of the elongated titanium tube. In some embodiments, the tube assemblies can each include one fin fabricated as a single material and defining a helical shape such that the inner surface of the helical fin is continuously welded along the outer surface of the elongated titanium tube. The elongated titanium tube and the welded fin(s) allow for corrosion resistance to swimming pool water while simultaneously allowing for improved heat transfer from the heat exchanger to the swimming pool water.

[0009] The at least one fin can be a copper fin. The at least one fin can define a circular configuration. The elongated titanium tube can define a cylindrical configuration with an inner passage extending therethrough. The heat exchanger can include at least one tube sheet secured to ends of the one or more tube assemblies.

[0010] In some embodiments, the heat exchanger can include a column of the tube assemblies aligned along a central axis. In some embodiments, the heat exchanger can include a plurality of the tube assemblies staggered relative to each other. In some embodiments, the one or more tube assemblies can be of the same outer diameter. In some embodiments, the one or more tube assemblies can be of different outer diameters. In some embodiments, the one or more tube assemblies can be arranged in, e.g., a U-shaped or cylindrical configuration, a flat configuration defining a single column of tube assemblies, a bent spiral configuration, a cylindrical configuration including a passage extending between the tube assemblies, an A-shaped configuration, a V-shaped configuration, a solid block configuration including multiple rows and columns of tube assemblies disposed adjacent to each other, combinations thereof, or the like.

[0011] In accordance with embodiments of the present disclosure, an exemplary method of heating swimming pool water is provided. The method includes introducing heated gas (or an alternative source) into one of the exemplary heat exchangers disclosed herein. In particular, the heated gas can be introduced into an area surrounding the one or more tube assemblies. The method includes introducing or circulating swimming pool water to the one or more tube assemblies of the heat exchanger to allow for heat transfer between the heated gas and the swimming pool water. The method includes adjusting a configuration of the one or more tube assemblies within the housing to adjust a heat transfer rate to the swimming pool water.

[0012] In accordance with embodiments of the present disclosure, an exemplary heat exchanger system is provided that includes a heat exchanger as disclosed herein, a gas source, and a swimming pool water source. The gas source can be fluidly connected to the heat exchanger and configured to supply heated gas (or an alternative source) to an area surrounding the one or more tube assemblies. The swimming pool water source can be fluidly connected to the heat exchanger and configured to supply swimming pool water to the one or more tube assemblies.

[0013] Other objects and features will become apparent from the following detailed description considered in conjunction with the accompanying drawings. It is to be understood, however, that the drawings are designed as an illustration only and not as a definition of the limits of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] To assist those of skill in the art in making and using the disclosed heat exchangers and associated systems and methods, reference is made to the accompanying figures, wherein:

[0015] FIG. 1 is a diagrammatic side view of an exemplary tube assembly of an exemplary heat exchanger according to the present disclosure.

[0016] FIG. 2 is a diagrammatic front view of an exemplary tube assembly of FIG. 1.

[0017] FIG. 3 is a perspective view of a plurality of exemplary tube assemblies of FIG. 1.

[0018] FIG. 4 is a front view of an exemplary heat exchanger including a plurality of tube assemblies of FIG. 1.

[0019] FIG. 5 is a front view of an exemplary heat exchanger including a plurality of tube assemblies of FIG. 1.

[0020] FIG. 6 is a front view of an exemplary heat exchanger including a plurality of tube assemblies of FIG. 1.

[0021] FIG. 7 is a front view of an exemplary heat exchanger including a plurality of tube assemblies of FIG. 1.

[0022] FIG. 8 is a front view of an exemplary heat exchanger including a plurality of tube assemblies of FIG. 1.

[0023] FIG. 9 is a front view of an exemplary heat exchanger including a plurality of tube assemblies of FIG. 1.

[0024] FIG. 10 is a front view of an exemplary heat exchanger including one column of a plurality of tube assemblies of FIG. 1.

[0025] FIG. 11 is a front view of an exemplary heat exchanger including two columns of a plurality of tube assemblies of FIG. 1.

[0026] FIG. 12 is a front view of an exemplary heat exchanger including three columns of a plurality of tube assemblies of FIG. 1.

[0027] FIG. 13 is a front view of an exemplary heat exchanger including two columns of a plurality of differently sized tube assemblies of FIG. 1.

[0028] FIG. 14 is a front view of an exemplary heat exchanger including one staggered column of a plurality of tube assemblies of FIG. 1.

[0029] FIG. 15 is a front view of an exemplary heat exchanger including two staggered columns of a plurality of tube assemblies of FIG. 1.

[0030] FIG. 16 is a front view of an exemplary heat exchanger including three staggered columns of a plurality of tube assemblies of FIG. 1.

[0031] FIG. 17 is a front view of an exemplary heat exchanger including two staggered columns and one aligned column of a plurality of differently sized tube assemblies of FIG. 1.

[0032] FIG. 18 is a perspective view of an exemplary heat exchanger including a plurality of tube assemblies of FIG. 1 in a horizontal cylindrical configuration.

[0033] FIG. 19 is a perspective view of an exemplary heat exchanger including a plurality of tube assemblies of FIG. 1 in a horizontal flat configuration.

[0034] FIG. 20 is a perspective view of an exemplary heat exchanger including a plurality of tube assemblies of FIG. 1 in a vertical flat configuration.

[0035] FIG. 21 is a perspective view of an exemplary heat exchanger including a tube assemblies of FIG. 1 in a spiral configuration.

[0036] FIG. 22 is a perspective view of an exemplary heat exchanger including a plurality of tube assemblies of FIG. 1 in a vertical cylindrical configuration.

[0037] FIG. 23 is a perspective view of an exemplary heat exchanger including a plurality of tube assemblies of FIG. 1 in a flat A-shaped configuration.

[0038] FIG. 24 is a perspective view of an exemplary heat exchanger including a plurality of tube assemblies of FIG. 1 in a flat slanted configuration.

[0039] FIG. 25 is a perspective view of an exemplary heat exchanger including a plurality of tube assemblies of FIG. 1 in a solid block configuration.

[0040] FIG. 26 is a perspective view of an exemplary heat exchanger including a plurality of tube assemblies of FIG. 1 in a flat slanted configuration.

[0041] FIG. 27 is a block diagram of an exemplary heat exchanger system according to the present disclosure.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0042] In accordance with embodiments of the present disclosure, exemplary heat exchangers including a plurality of tubes with welded fins (e.g., laser welded) are provided. The tubes can be smooth titanium tubes that include copper fins welded to the exterior surface to enhance heat transfer from hot combustion gases to swimming pool water flowing within the heat exchanger tubes of a gas-fired pool heater. In some embodiments, the heat exchanger can include a single welded fin tube attached to a water circulating system suspended over a small source of heat. The exemplary heat exchangers achieve improved heat transfer by using titanium tubes with the welded copper fins in an air-to-liquid heat exchanger system with corrosion resistance (normally found in heat pump heat exchangers) and with a higher heat capacity of gas-fired appliances. In particular, the exemplary heat exchangers include titanium tubes in gas-fired swimming pool heaters to achieve corrosion resistance by isolating the swimming pool water within the titanium tubes, while maintaining the heat transfer characteristics of high-finned heat exchanger tubes.

[0043] By using titanium tubes with fins welded to the exterior made from copper or another material, heat transfer far above what titanium tubes can achieve alone can be accomplished while still offering the corrosion resistance needed in the portion of the heat exchanger in direct contact with swimming pool water. In particular, rather than using extruded or expanded fins as normally done in the swimming pool heater industry, the fins are welded to the titanium tube to facilitate the higher heat transfer than normally achieved by the titanium tubes alone. The welded fins, which provide a significant increase in surface area and are manufactured from a material with a higher thermal conductivity than titanium, thereby transferring the required amount of heat from a heat source, typically a burner, to swimming pool water inside of the titanium tube. The titanium tube, in turn, is resistant to corrosion typically caused by exposure to swimming pool water. This heat transfer is aided by the fact that the entire length of fin is welded to the tube, resulting in a permanent thermal bond between the titanium tube and the fins. The bond would not be permanent if the fin was only attached at the endpoints or only by mechanical means. Therefore, the thermal bond between the titanium tube and the fins results in an improved attachment between the components.

[0044] Although discussed herein with respect to gas-fired swimming pool heaters, it should be understood that the exemplary heat exchangers can be used with any appliance that includes a heat exchanger configured to transfer heat from hot combustion gases to liquid where corrosion caused by the liquid is one of the primary concerns. In some embodiments, the exemplary tubes and fins can be used in heaters for fluids, such as the heater for fluids disclosed in U.S. Patent No. 6,026,804, incorporated herein by reference. In some embodiments, rather than laser welding, the titanium tube can be expanded into the plate fins. However, such methods are generally performed with larger and more complicated processing machines.

[0045] A plurality of titanium tubes can be arranged to form a heat exchanger and can be secured to one or more tube sheets to define the heat exchanger shape. The tube sheets provide a transition to the connected water system. In some embodiments, different geometries, configurations or arrangements of the heat exchanger can be used, resulting in different tube arrangements within the geometry and different airflow paths through the tubes. In some embodiments, varying sizes and/or numbers of the tubes can be used in flat horizontal or alternative configurations to differ airflow paths through the tubes.

[0046] In some embodiments, the material of the base tubing or the welded fins, or the geometry or arrangement of the fins relative to the tubes can be changed. Changing the fins, e.g., the height, material, fin density on the tube, combinations thereof, or the like, can allow for heat transfer at different rates. Thus, by changing characteristics of the fins welded to the tubes, the heat exchanger can be customized to adjust for the desired heat transfer rate. Changing the tube material can be used to accommodate for different types or sources of corrosion present in the heat exchanger system.

[0047] With reference to FIGS. 1 and 2, diagrammatic side and front views of an exemplary tube assembly 100 of an exemplary heat exchanger are provided. It should be understood that the heat exchanger can include one or more of the tube assemblies 100 arranged in various configurations depending on the heat transfer rate desired for the system. Each tube assembly 100 includes an elongated tube 102, e.g., an extruded titanium tube defining a cylindrical configuration with an inner passage 103 extending therethrough configured to receive swimming pool water. In some embodiments, the tube 102 can define a configuration other than cylindrical, e.g., square, rectangular, oval, or the like. The tube 102 can define an overall length 104 extending along a central longitudinal axis 106. The tube 102 can define an outer diameter 108 with a wall thickness 110. In some embodiments, the outer diameter 108 can be approximately 0.75 inches and the wall thickness 110 can be approximately 0.02 inches.

[0048] The tube assembly 100 includes a plurality of fins 112 (e.g., copper fins) secured to an outer surface 116 of the tube 102. The fins 112 can be welded (e.g., laser welded) to the outer surface 116 of the tube 102. In particular, rather than only a partial welding, the entire circumferential inner diameter of the fins 112 can be laser welded to the outer surface 116 of the tube 102. In some embodiments, the fins 112 can define a substantially circular configuration with a diameter 114. In some embodiments, the diameter 114 of each fin 112 can be approximately, e.g., 40 mm, 50 mm, or the like. In some embodiments, each fin 112 can define a thickness between approximately 0.015 inches to approximately 0.020 inches. In some embodiments, the plurality of fins 112 can be fabricated as a single piece of material helically wound around the outer surface 116 of the tube 102 and welded along the entire contact surface of the inner surface of the fins 112 and the outer surface 116 of the tube 102. Although illustrated as substantially circular, in some embodiments, the fins 112 can define different configurations, e.g., oval, rectangular, square, triangular, hexagonal, or the like. In some embodiments, fins 112 having multiple different configurations can be secured to the outer surface 116 of the tube 102. For example, rather than being symmetrical relative to the vertical and horizontal central axes 128, 130 as shown in FIG. 2, the fins 112 can define an asymmetrical configuration.

[0049] In some embodiments, the fins 112 can be spaced substantially uniformly relative to each other along the tube 102. In some embodiments, the spacing between the fins 112 can be different. In some embodiments, the fins 112 can be welded to the tube 102 such that the fins 112 extend substantially perpendicularly relative to the longitudinal axis 106. In some embodiments, the fins 112 can be welded to the tube 102 at non-perpendicular angles relative to the longitudinal axis 106. The fins 112 can extend only along a partial length 118 of the overall length 104 of the tube 102. In particular, the proximal end 120 and the distal end 122 of the tube 102 can remain uncovered (e.g., without fins 112). For example, a proximal length 124 and a distal length 126 of the tube 102 can remain uncovered or exposed. In some embodiments, the proximal and distal lengths 124, 126 can be substantially similar in dimension. In some embodiments, the proximal and distal lengths 124, 126 can be different in dimension.

[0050] FIG. 3 shows a plurality of tube assemblies 100 positioned adjacent to each other. As shown in FIG. 3, the tube assemblies 100 can be aligned along the longitudinal axis 106 of each tube assembly 100 to form a substantially planar configuration of a heat exchanger. Alternative configurations or arrangements of the tube assemblies 100 will be discussed in greater detail below.

[0051] FIGS. 4-9 show front views of exemplary heat exchangers 150a-f with different configurations or arrangements of the tube assemblies 100 (referred to as primary tube assemblies 100a and secondary tube assemblies 100b). The diameter of the tube assemblies 100 defines the diameter of the fins of each respective tube assembly 100. The tube assemblies 100a, 100b can be arranged in a pattern relative to each other and secured on opposing sides (e.g., the proximal and distal ends 120, 122) by endplates or tube sheets. In particular, FIGS. 4-9 show different sizes and arrangements of the tube assemblies 100 that can fit within the same structure 152 that defines a height 154 and a width 156. For example, different sizes and combinations of the tube assemblies 100 can be used to fit within a structure 152 that defines the width 156. It should be understood that the tube assemblies 100 of FIGS. 4-9 can include tube sheets disposed on each side of the tube assemblies 100a, 100b. In some embodiments, the tube sheets can define a substantially rectangular configuration.

[0052] In the embodiment of FIG. 4, the primary tube assemblies 100a can be aligned along the horizontal central axis 130. The primary tube assemblies 100a can be spaced relative to each other to receive the secondary tube assemblies 100b therebetween. In particular, the secondary tube assemblies 100b can be disposed between the primary tube assemblies 100a in a staggered or offset manner in a diagonal direction. The secondary tube assemblies 100b are therefore aligned along their respective horizontal central axes, with the horizontal central axis of the secondary tube assemblies 100b being offset from the horizontal central axis 130 of the primary tube assemblies 100a. As an example, the heat exchanger 150a can include six tube assemblies 100a, 100b. The fins of the tube assemblies 100a, 100b can be oriented substantially tangent relative to each other to avoid bypassed combustion gasses from escaping the heat exchanger. In some embodiments, each of the tube assemblies 100a, 100b can be spaced relative to each other such that no tube assemblies 100a, 100b are positioned directly against each other. In some embodiments, the fins of the tube assemblies 100a, 100b can be positioned adjacent to each other in an abutting relationship.

[0053] The heat exchanger 150b of FIG. 5 can be substantially similar in structure and function to the heat exchanger 150a of FIG. 4, except that seven tube assemblies 100a, 100b can be used. In particular, the outer diameter of the fins of the tube assemblies 100a, 100b can be dimensioned smaller than the tube assemblies 100a, 100b of FIG. 4, allowing a greater number of tube assemblies 100a, 100b to fit within the same width 156 of the structure 152.

[0054] The heat exchanger 150c of FIG. 6 can be substantially similar in structure and function to the heat exchanger of 150a of FIG. 4, except that ten tube assemblies 100a, 100b can be used. In particular, the outer diameter of the fins of the tube assemblies 100a, 100b can be dimensioned smaller than the tube assemblies 100a, 100b of FIGS. 4 and 5, allowing a greater number of tube assemblies 100a, 100b to fit within the same width 156 of the structure 152.

[0055] The heat exchanger 150d of FIG. 7 can be substantially similar in structure and function to the heat exchanger 150a of FIG. 4, except that sixteen tube assemblies 100a, 100b can be used. In particular, the outer diameter of the fins of the tube assemblies 100a, 100b can be dimensioned smaller than the tube assemblies 100a, 100b of FIGS. 4-6, allowing a greater number of tube assemblies 100a, 100b to fit within the same width 156 of the structure 152.

[0056] The heat exchanger 150e of FIG. 8 can be substantially similar in structure and function to the heat exchanger 150a of FIG. 4, except that fourteen tube assemblies 100a, 100b can be used. In particular, the outer diameter of the fins of the tube assemblies 100a, 100b can be dimensioned smaller than the tube assemblies 100a, 100b of FIGS. 4-6, allowing a greater number of tube assemblies 100a, 100b to fit within the same width 156 of the structure 152.

[0057] The heat exchanger 150f of FIG. 9 can be substantially similar in structure and function to the heat exchanger 150a of FIG. 4, except that twelve tube assemblies 100a, 100b can be used. In particular, the outer diameter of the fins of the tube assemblies 100a, 100b can be dimensioned smaller than the tube assemblies 100a, 100b of FIGS. 4-6, allowing a greater number of tube assemblies 100a, 100b to fit within the same width 156 of the structure 152.

[0058] FIGS. 10-17 are front views of exemplary heat exchangers 200a-h including a plurality of tube assemblies 100 arranged in different configurations. Each configuration provides a variation in heat transfer flow rates from the combustion gas to the swimming pool water. In particular, the different configurations result in varied heat transfer either by affecting the surface area in contact with the combustion gases (e.g., the number of rows and diameter of the tube assemblies 100) or by affecting the airflow pattern and distance the combustion gases stay in contact with the heat exchanger (e.g., staggered rows and diameter of the tube assemblies 100). For example, FIG. 10 shows a heat exchanger 200a that includes a single column 204 of tube assemblies 100 of the same size (e.g., four tube assemblies). The tube assemblies 100 can be arranged to align along a vertical central axis 202. Air flow can enter the heat exchanger 200a from, e.g., a first direction 206 substantially perpendicular to the vertical central axis 202, a second direction 208 substantially aligned with the vertical central axis 202, combinations thereof, or the like.

[0059] FIG. 11 shows a heat exchanger 200b that includes two columns 204a, 204b of tube assemblies 100 of the same size (e.g., each column including four tube assemblies). The tube assemblies 100 can be arranged such that four tube assemblies 100 are aligned along a first vertical central axis 202a and four tube assemblies 100 are aligned along a second vertical central axis 202b, the first and second vertical central axes 202a, 202b being spaced from each other. The two columns 204a, 204b of the tube assemblies 100 can be disposed adjacent to each other. Further, the adjacently positioned tube assemblies 100 can be aligned along horizontal central axes 210a-d. Air flow can enter the heat exchanger 200b from, e.g., a first direction 206 substantially perpendicular to the first and second vertical central axes 202a, 202b, a second direction 208 substantially aligned with the first and second vertical central axes 202a, 202b, combinations thereof, or the like.

[0060] FIG. 12 shows a heat exchanger 200c that includes three columns 204a-c of tube assemblies 100 of the same size (e.g., each column including four tube assemblies). The tube assemblies 100 can be arranged such that four tube assemblies 100 are aligned along a first vertical central axis 202a, four tube assemblies 100 are aligned along a second vertical central axis 202b, and four tube assemblies 100 are aligned along a third vertical central axis 202c, the vertical central axes 202a, 202b, 202c being spaced from each other. The three columns 204a-c of the tube assemblies 100 can be disposed adjacent to each other. Further, the adjacently positioned tube assemblies 100 can be aligned along horizontal central axes 210a-d. Air flow can enter the heat exchanger 200c from, e.g., a first direction 206 substantially perpendicular to the vertical central axes 202a-c, a second direction 208 substantially aligned with the vertical central axes 202a-c, combinations thereof, or the like.

[0061] FIG. 13 shows a heat exchanger 200d that includes two columns 204a, 204b of tube assemblies 100a, 100b of different sizes. The tube assemblies 100a of the same size can be arranged such that four tube assemblies 100a are aligned along a first vertical central axis 202a, and two tube assemblies 100b of a size different from the tube assemblies 100a are aligned along a second vertical central axis 202b. The first and second vertical central axes 202a, 202b are spaced from each other. In some embodiments, the each tube assembly 100b can be approximately double in diameter as compared to each tube assembly 100a. The two columns 204a, 204b of the tube assemblies 100a, 100b can be disposed adjacent to each other. A horizontal central axis 212a of one of the tube assemblies 100b can be aligned between the horizontal central axes 210a, 210b of the tube assemblies 100a. Similarly, a horizontal central axis 212b of the other tube assembly 100b can be aligned between the horizontal central axes 210c, 210d of the tube assemblies 100a. Air flow can enter the heat exchanger 200d from, e.g., a first direction 206 substantially perpendicular to the vertical central axes 202a, 202b, a second direction 208 substantially aligned with the vertical central axes 202a, 202b, a third direction 214 substantially perpendicular to the vertical central axes 202a, 202b and opposing the first direction 206, combinations thereof, or the like.

[0062] FIG. 14 shows a heat exchanger 200e that includes one staggered column 204 of tube assemblies 100 of the same size (e.g., the column including four tube assemblies). The tube assemblies 100 can be arranged such that every other tube assembly 100 is aligned along a first vertical central axis 202a and a second vertical central axis 202b, respectively. The first and second vertical central axes 202a, 202b are spaced from each other. Each of the adjacently positioned tube assemblies 100 can be staggered by an angle relative to horizontal central axes 210a-d. The fins of the tube assemblies 100 can be disposed in a substantially tangent and abutting configuration. Air flow can enter the heat exchanger 200e from, e.g., a first direction 206 substantially perpendicular to the vertical central axes 202a, 202b, a second direction 208 substantially aligned with the vertical central axes 202a, 202b, combinations thereof, or the like.

[0063] FIG. 15 shows a heat exchanger 200f that includes two staggered columns 204a, 204b of tube assemblies 100 of the same size (e.g., each column including four tube assemblies). The tube assemblies 100 can be arranged such that every other tube assembly 100 is aligned along a first to fourth vertical central axes 202a-d, with two tube assemblies 100 aligned per vertical central axis 202a-d. The vertical central axes 202a-d are spaced from each other. Each of the adjacently positioned tube assemblies 100 can be staggered by an angle relative to horizontal central axes 210a-d. The fins of the tube assemblies 100 can be disposed in a substantially tangent and abutting configuration. For example, the fins of the tube assemblies 100 aligned along the horizontal central axes 210a-d can abut each other. Air flow can enter the heat exchanger 200f from, e.g., a first direction 206 substantially perpendicular to the vertical central axes 202a-d, a second direction 208 substantially aligned with the vertical central axes 202a-d, combinations thereof, or the like.

[0064] FIG. 16 shows a heat exchanger 200g that includes three staggered columns 204a-c of tube assemblies 100 of the same size (e.g., each column including four tube assemblies). The tube assemblies 100 can be arranged such that every other tube assembly 100 is aligned along a first to sixth vertical central axes 202a-f, with two tube assemblies 100 aligned per vertical central axis 202a-f. The vertical central axes 202a-f are spaced from each other. Each of the adjacently positioned tube assemblies 100 can be staggered by an angle relative to horizontal central axes 210a-d. The fins of the tube assemblies 100 can be disposed in a substantially tangent and abutting configuration. For example, the fins of the tube assemblies 100 aligned along the horizontal central axes 210a-3 can abut each other. Air flow can enter the heat exchanger 200g from, e.g., a first direction 206 substantially perpendicular to the vertical central axes 202a-f, a second direction 208 substantially aligned with the vertical central axes 202a-f, combinations thereof, or the like.

[0065] FIG. 17 shows a heat exchanger 200h that includes one staggered column 204a of tube assemblies 100a of the same size (e.g., the column including four tube assemblies) and one column 204b of tube assemblies 100b sized differently than the tube assemblies 100a. The tube assemblies 100a can be arranged such that every other tube assembly 100 is aligned along a first vertical central axis 202a and a second vertical central axis 202b, respectively. The first and second vertical central axes 202a, 202b are spaced from each other. Each of the adjacently positioned tube assemblies 100a can be staggered by an angle relative to horizontal central axes 210a-f. The tube assemblies 100b can be arranged such that the two tube assemblies 100b are aligned along a third vertical central axis 202c. The tube assemblies 100b can be aligned with respective horizontal central axes 210b, 210e of two tube assemblies 100a. In some embodiments, the tube assemblies 100b can be disposed along horizontal central axes that are parallel to (but not aligned with) the horizontal central axes 210a-f). The fins of the tube assemblies 100a, 100b can be disposed in a substantially tangent and abutting configuration. Air flow can enter the heat exchanger 200h from, e.g., a first direction 206 substantially perpendicular to the vertical central axes 202a-c, a second direction 208 substantially aligned with the vertical central axes 202a-c, a third direction 214 substantially perpendicular to the vertical central axes 202a-c and opposing the first direction 206, combinations thereof, or the like.

[0066] FIGS. 18-26 show perspective views of exemplary heat exchangers 250a-i including tube assemblies 100 in different configurations. Although illustrated as substantially square or rectangular in cross-section, in some embodiments, the tube assemblies 100 can have a substantially round cross-section (such as the tube assemblies of FIGS. 1-17). For example, FIG. 18 shows a heat exchanger 250a including a plurality of tube assemblies 100 stacked and aligned relative to each other, and bent into a substantially U-shaped, tear-shaped or horizontal cylindrical configuration. The tube assemblies 100 can extend in a direction substantially aligned with horizontal. The ends of the tube assemblies 100 can be disposed adjacent to each other and secured to a single tube sheet 252. Due to the curved shape of the tube assemblies 100, a passage 254 is formed between the tube assemblies 100 and extends the height of the heat exchanger 250a. Air flow can enter into the passage 254 from above 256 and below 258. Air flow can enter/exit the heat exchanger 250a in opposing directions 260, 262 perpendicular to the tube assemblies 100.

[0067] FIG. 19 shows a heat exchanger 250b including a plurality of tube assemblies 100 aligned relative to each other and forming a substantially horizontal flat configuration (e.g., a single row of tube assemblies 100). Particularly, the tube assemblies 100 can extend in a direction substantially aligned with horizontal. The ends of the tube assemblies 100 can be aligned and secured to tube sheets 252a, 252b on opposing sides of the tube assemblies 100. Air flow can enter/exit the heat exchanger 250b in opposing directions 256, 258 perpendicular to the tube assemblies 100.

[0068] FIG. 20 shows a heat exchanger 250c including a plurality of tube assemblies 100 aligned relative to each other and forming a substantially vertical flat configuration (e.g., a single column of tube assemblies 100). In particular, the tube assemblies 100 in the vertical configuration can be aligned substantially perpendicular to the alignment of the horizontal configuration, and substantially perpendicular to horizontal. The ends of the tube assemblies 100 can be aligned and secured to tube sheets 252a, 252b on opposing sides of the tube assemblies

100. Air flow can enter/exit the heat exchanger 250c in opposing directions 256, 258 perpendicular to the tube assemblies 100.

[0069] FIG. 21 shows a heat exchanger 250d including a single tube assembly 100 curved into a spiral configuration. In particular, the tube assembly 100 can be bent into a spiral shape with the ends of the tube assembly 100 being secured to tube sheets 252a, 252b sized for only a single tube assembly 100. The spiral configuration results in a passage 254 formed between the tube assembly 100 components and extending the height of the heat exchanger 250d. Air flow can enter/exit the heat exchanger 250d in opposing directions 256, 258 perpendicular to the tube assembly 100, via a direction 260 passing through the passage 254, combinations thereof, or the like.

[0070] FIG. 22 shows a heat exchanger 250e including a plurality of tube assemblies 100 disposed adjacent to each other and curved into a vertical cylindrical configuration (e.g., a curved single row of tube assemblies 100 extending substantially perpendicularly to horizontal). In particular, due to the cylindrical configuration of the tube assemblies 100, a passage 254 is formed between the tube assemblies 100 and extends the height of the heat exchanger 250e. The ends of the tube assemblies 100 can be aligned and secured to tube sheets 252a, 252b. Air flow can enter/exit the heat exchanger 250e in opposing directions 256, 258 perpendicular to the tube assemblies 100, via a direction 260 passing through the passage 254, combinations thereof, or the like.

[0071] FIG. 23 shows a heat exchanger 250f including a plurality of tube assemblies 100a, 100b aligned and formed into a substantially flat A-shaped or upside down V-shaped configuration. In particular, the heat exchanger 250f includes a first flat group of tube assemblies 100a and a second flat group of tube assemblies 100b that are joined at one central tube assembly 100. The first and second flat group of tube assemblies 100a, 100b connect at the central tube assembly 100 and extend in opposing directions to form an angle 264 therebetween (e.g., between approximately 30° and approximately 90°, or the like). Each of the tube assemblies 100a, 100b can extend substantially parallel to horizontal. The ends of the tube assemblies 100a, 100b can be aligned and secured to tube sheets 252a, 252b on opposing sides of the tube assemblies 100a, 100b. Air flow can enter/exit the heat exchanger 250f via direction

256 perpendicular to the second flat group of tube assemblies 100b, direction 258 perpendicular to the first flat group of tube assemblies 100a, via direction 260 perpendicular to the central tube assembly 100, combinations thereof, or the like.

[0072] FIG. 24 shows a heat exchanger 250g including a plurality of tube assemblies 100 aligned and formed into a flat slanted configuration (e.g., a single row of tube assemblies 100 each extending substantially parallel to horizontal, with the combined row of tube assemblies 100 being slanted relative to horizontal). In particular, the tube assemblies 100 can be disposed adjacent to each other and aligned into a flat configuration, and the heat exchanger 250g can be slanted by an angle 264 (e.g., between approximately 30° and approximately 90°) relative to a horizontal plane 266. The ends of the tube assemblies 100 can be aligned and secured to tube sheets 252a, 252b on opposing sides of the tube assemblies 100. In the orientation of FIG. 24, the tube sheets 252a, 252b are at the sides of the heat exchanger 250g. Air flow can enter/exit the heat exchanger 250g via direction 256 parallel to the horizontal plane 266, via direction 258 perpendicular to the horizontal plane 266, combinations thereof, or the like.

[0073] While the above configurations were formed from a single column of tube assemblies 100, FIG. 25 shows a heat exchanger 250h including a plurality of tube assemblies 100 aligned and formed into a solid block configuration. In particular, the tube assemblies 100 can be disposed adjacent to each other in multiple rows and columns to form the solid block configuration. Each of the tube assemblies 100 can extend substantially parallel to horizontal. It should be understood that a variety of shapes can be formed by varying the number of rows and columns of the heat exchanger 250h. The ends of the tube assemblies 100 can be aligned and secured to tube sheets 252a, 252b on opposing sides of the tube assemblies 100. Air flow can enter/exit the heat exchanger 250h via direction 256 perpendicular to the tube assemblies 100.

[0074] FIG. 26 shows a heat exchanger 250i including a plurality of tube assemblies 100 aligned and formed into a flat slanted configuration (e.g., a single row of aligned tube assemblies 100, with each tube assembly 100 extending at an angle relative to horizontal). In particular, the tube assemblies 100 can be disposed adjacent to each other and aligned into a flat configuration, and the heat exchanger 250i can be slanted by an angle 264 (e.g., between approximately 30° and approximately 90°) relative to a horizontal plane 266. The ends of the tube assemblies 100 can be aligned and secured to tube sheets 252a, 252b on opposing sides of the tube assemblies 100. In the orientation of FIG. 26, the tube sheets 252a, 252b are substantially at the top and bottom of the heat exchanger 250i. The tube sheets 252a, 252b can be substantially perpendicular to the ends of the tube assemblies 100, and angled relative to the horizontal plane 266. Air flow can enter/exit the heat exchanger 250i via direction 256 parallel to the horizontal plane 266, via direction 258 perpendicular to the horizontal plane 266, combinations thereof, or the like.

[0075] FIG. 27 is a block diagram of an exemplary heat exchanger system 300. The heat exchanger system 300 can include at least one of the exemplary heat exchangers 302 described herein. The heat exchanger 302 includes one or more tube assemblies 304. The heat exchanger 302 can be disposed within a heater housing 306. A gas source 308 can be fluidly connected to the heater housing 306 and/or the heat exchanger 302 to introduce heated gas into an area surrounding the tube assemblies 304. A water circulating system or source 310 can be fluidly connected to the heater housing 306 to introduce swimming pool water into the tube assemblies 304. Due to the heated gas surrounding the tube assemblies 304, the swimming pool water can be heated to the desired temperature. As noted above, the titanium structure of the elongated tubes with the copper fins welded to the tubes provides for corrosion resistance by isolating the swimming pool water within the tubes, while allowing for improved heat transfer to the swimming pool water.

[0076] While exemplary embodiments have been described herein, it is expressly noted that these embodiments should not be construed as limiting, but rather that additions and modifications to what is expressly described herein also are included within the scope of the invention. Moreover, it is to be understood that the features of the various embodiments described herein are not mutually exclusive and can exist in various combinations and permutations, even if such combinations or permutations are not made express herein, without departing from the spirit and scope of the invention.

[0077] Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

[0078] The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavor to which this specification relates.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A heat exchanger for a swimming pool or spa, comprising:
   a housing; and
   a water heating system of one or more tube assemblies disposed within the housing, each of the tube assemblies including an elongated titanium tube and at least one fin welded to an outer surface of the elongated titanium tube, wherein the water heating system is configured for fluid communication with a fluid circulation line of said swimming pool or spa.

2. The swimming pool heat exchanger of claim 1, wherein the at least one fin is a copper fin.

3. The swimming pool heat exchanger of claim 1, wherein the elongated titanium tube defines a cylindrical configuration with an inner passage.

4. The swimming pool heat exchanger of claim 1, wherein the at least one fin defines a circular configuration.

5. The swimming pool heat exchanger of claim 1, comprising at least one tube sheet secured to ends of the one or more tube assemblies.

6. The swimming pool heat exchanger of claim 1, comprising a column of the tube assemblies aligned along a central axis.

7. The swimming pool heat exchanger of claim 1, comprising a plurality of the tube assemblies staggered relative to each other.

8. The swimming pool heat exchanger of claim 1, wherein the one or more tube assemblies are of the same outer diameter.

9. The swimming pool heat exchanger of claim 1, wherein the one or more tube assemblies are of different outer diameters.

10. The swimming pool heat exchanger of claim 1, wherein the one or more tube assemblies are arranged in a U-shaped or cylindrical configuration.

11. The swimming pool heat exchanger of claim 1, wherein the one or more tube assemblies are arranged into a flat configuration defining a single column of tube assemblies.

12. The swimming pool heat exchanger of claim 1, wherein the one or more tube assemblies are bent into a spiral configuration.

13. The swimming pool heat exchanger of claim 1, wherein the one or more tube assemblies are arranged in a cylindrical configuration including a passage extending between the tube assemblies.

14. The swimming pool heat exchanger of claim 1, wherein the one or more tube assemblies are arranged in an A-shaped or a V-shaped configuration.

15. The swimming pool heat exchanger of claim 1, wherein the one or more tube assemblies are arranged in a solid block configuration including multiple rows and columns of tube assemblies.

16. A method of heating swimming pool water, comprising:

introducing heated gas into a heat exchanger, the heat exchanger including (i) a housing, and (ii) one or more tube assemblies disposed within the housing, each of the tube assemblies including an elongated titanium tube and at least one fin welded to an outer surface of the elongated titanium tube, the heated gas being introduced into an area surrounding the one or more tube assemblies; and

introducing swimming pool water to the one or more tube assemblies to allow for heat transfer between the heated gas and the swimming pool water.

17. The method of claim 16, comprising adjusting a configuration of the one or more tube assemblies within the housing to adjust a heat transfer rate to the swimming pool water.

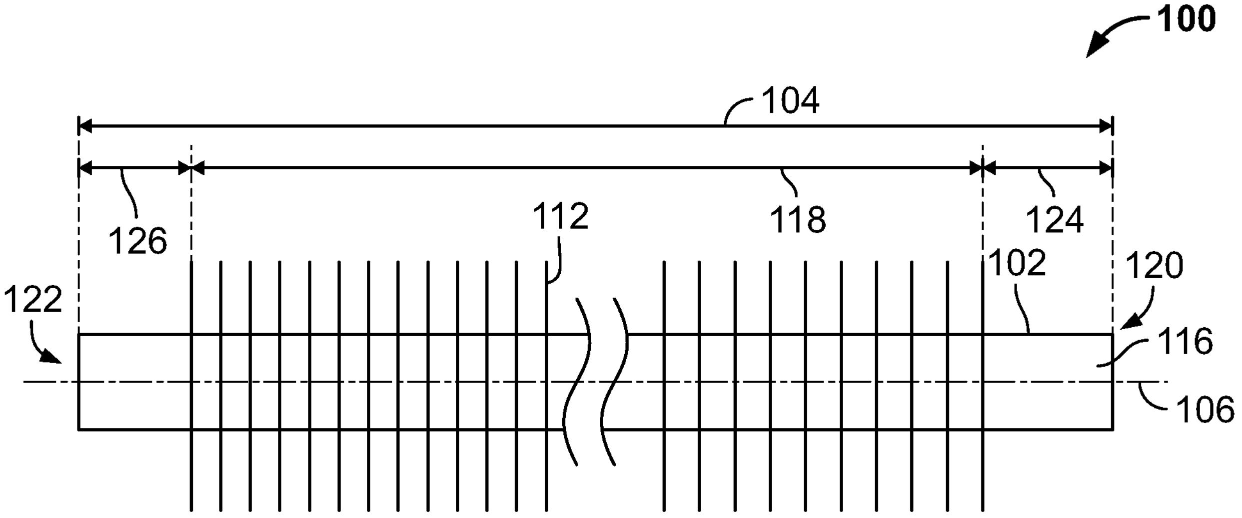
18. The method of claim 16, wherein the at least one fin is a copper fin.

19. A heat exchanger system, comprising:

a heat exchanger including (i) housing, and (ii) one or more tube assemblies disposed within the housing, each of the tube assemblies including an elongated titanium tube and at least one fin welded to an outer surface of the elongated titanium tube;

a gas source fluidly connected to the heat exchanger and configured to supply heated gas to an area surrounding the one or more tube assemblies; and a swimming pool water source fluidly connected to the heat exchanger and configured to supply swimming pool water to the one or more tube assemblies.

20. The system of claim 19, wherein the at least one fin is a copper fin.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106

FIG. 1

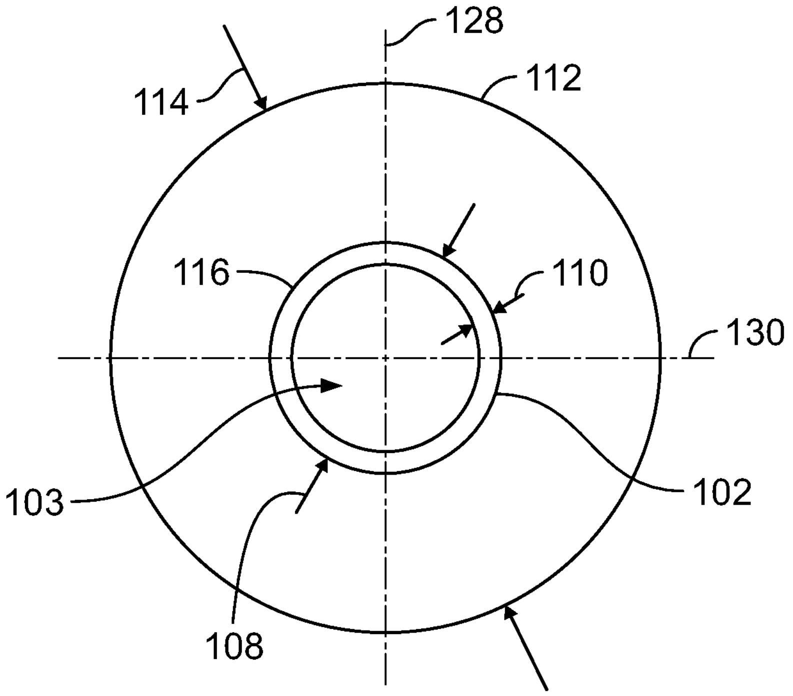
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FIG. 2

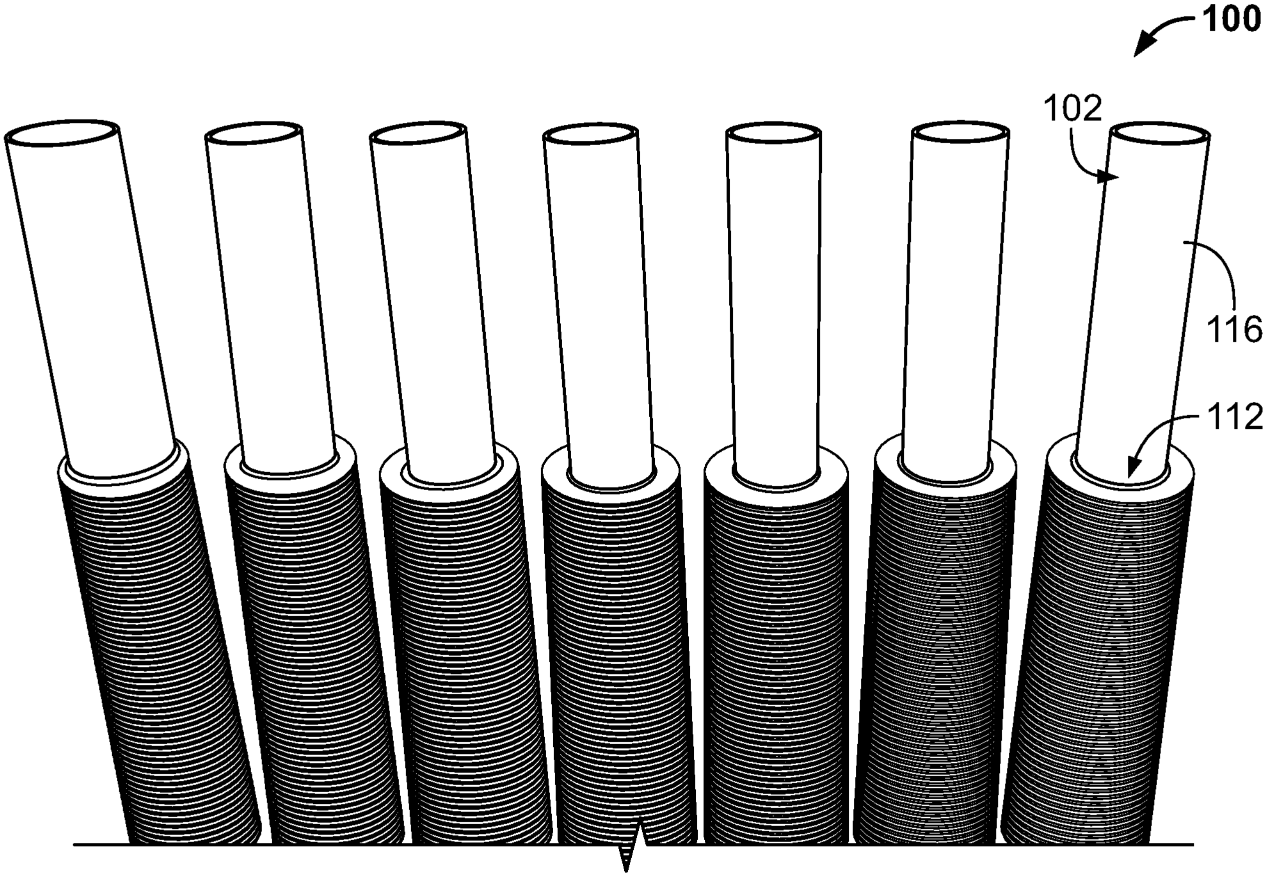
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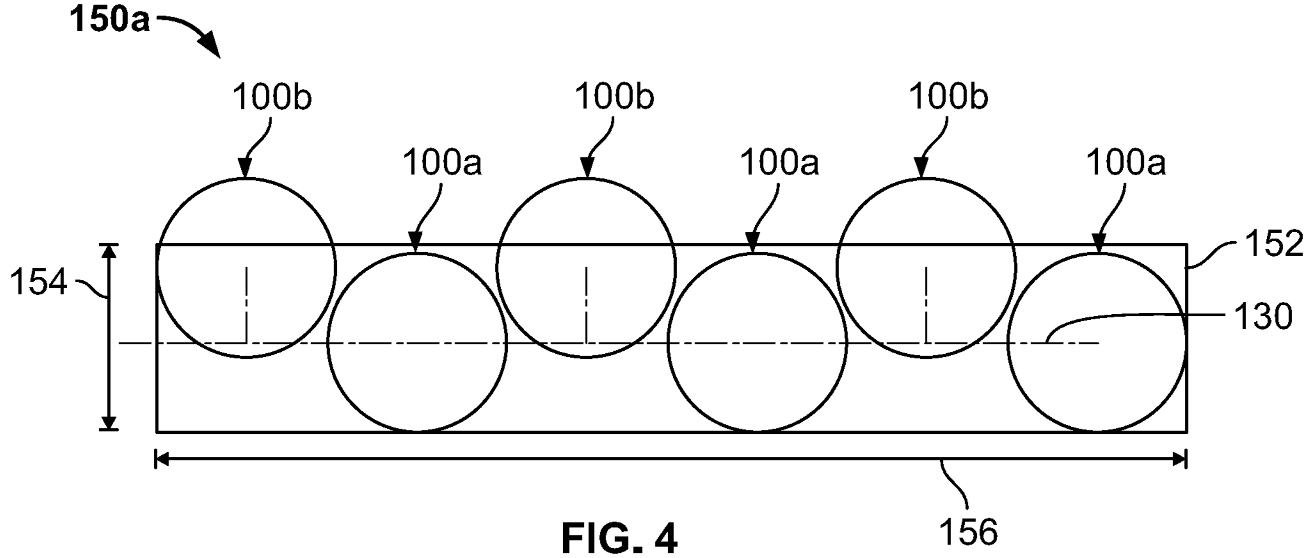
FIG. 3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156

FIG. 4

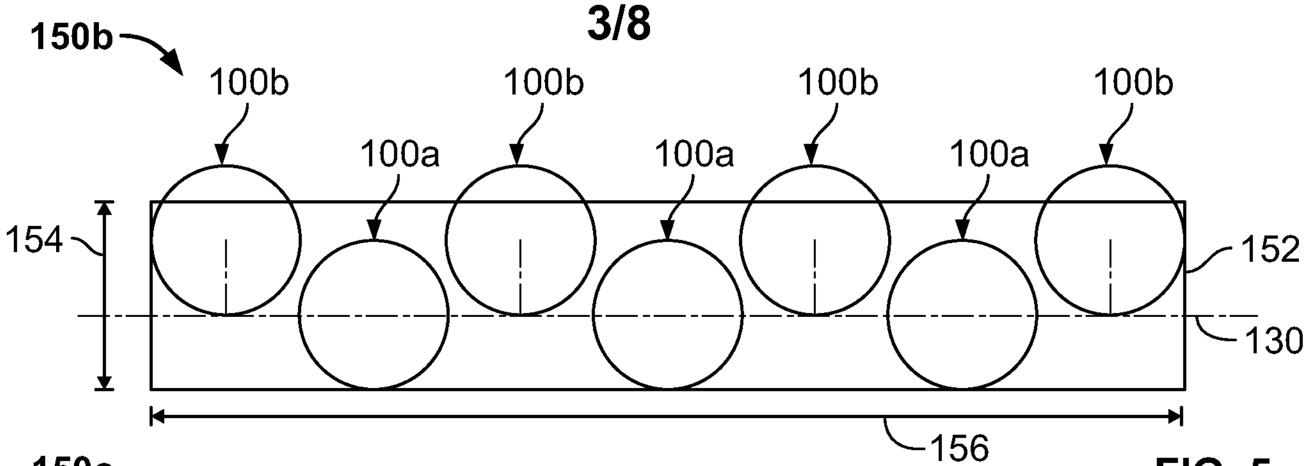

FIG. 5

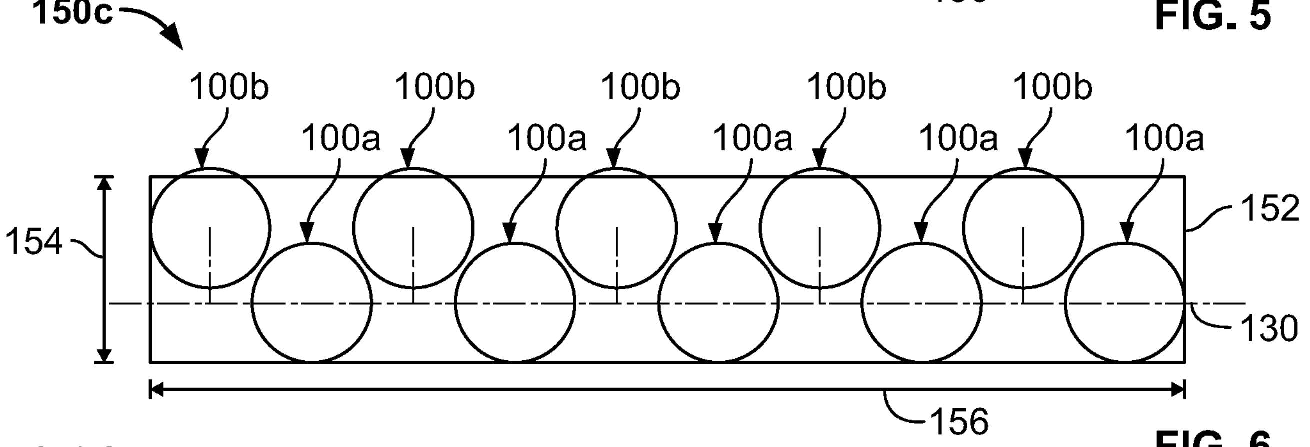

FIG. 6

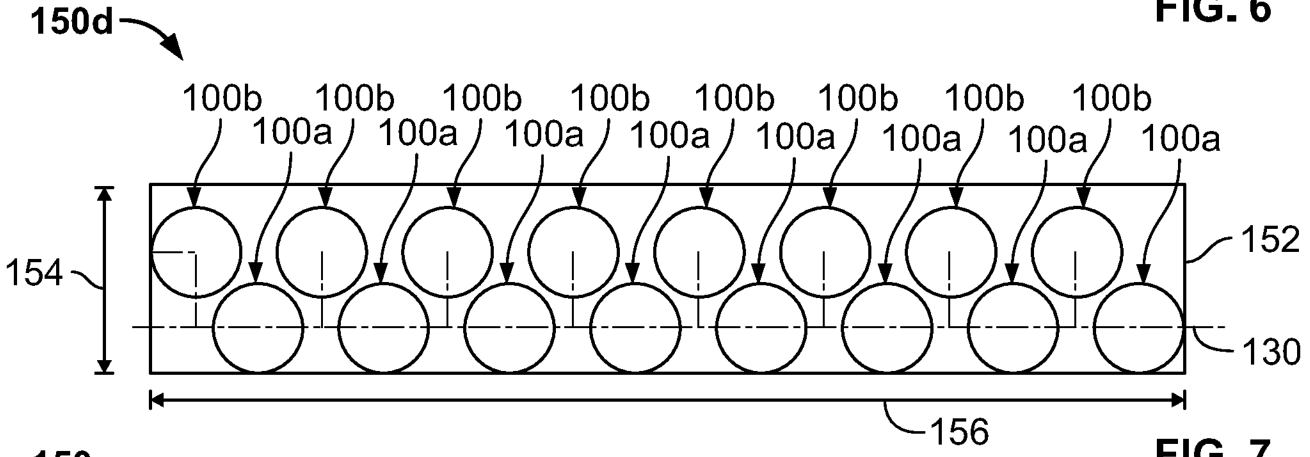

FIG. 7

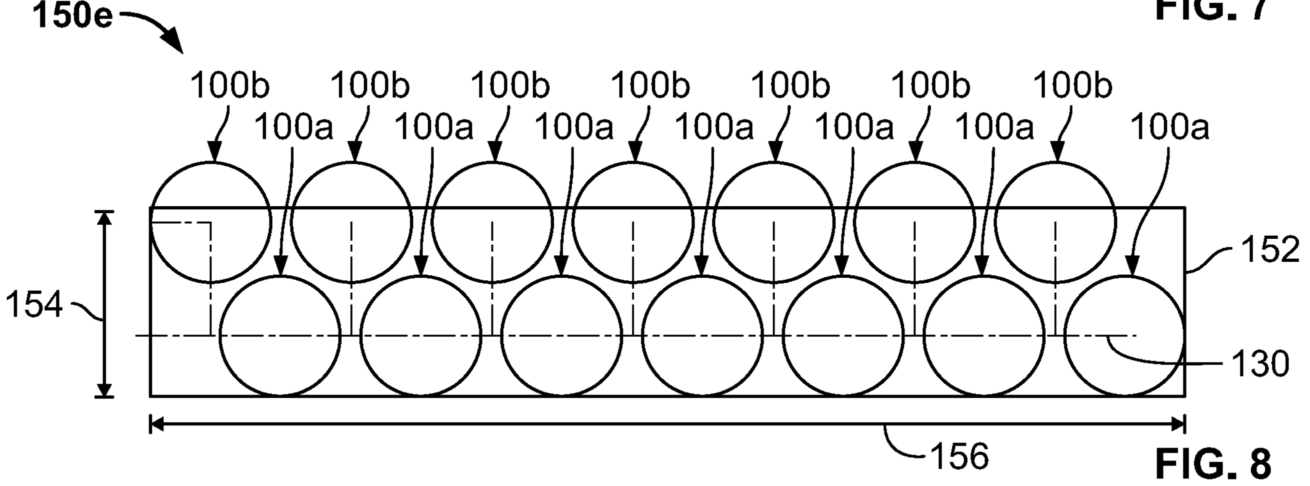

FIG. 8

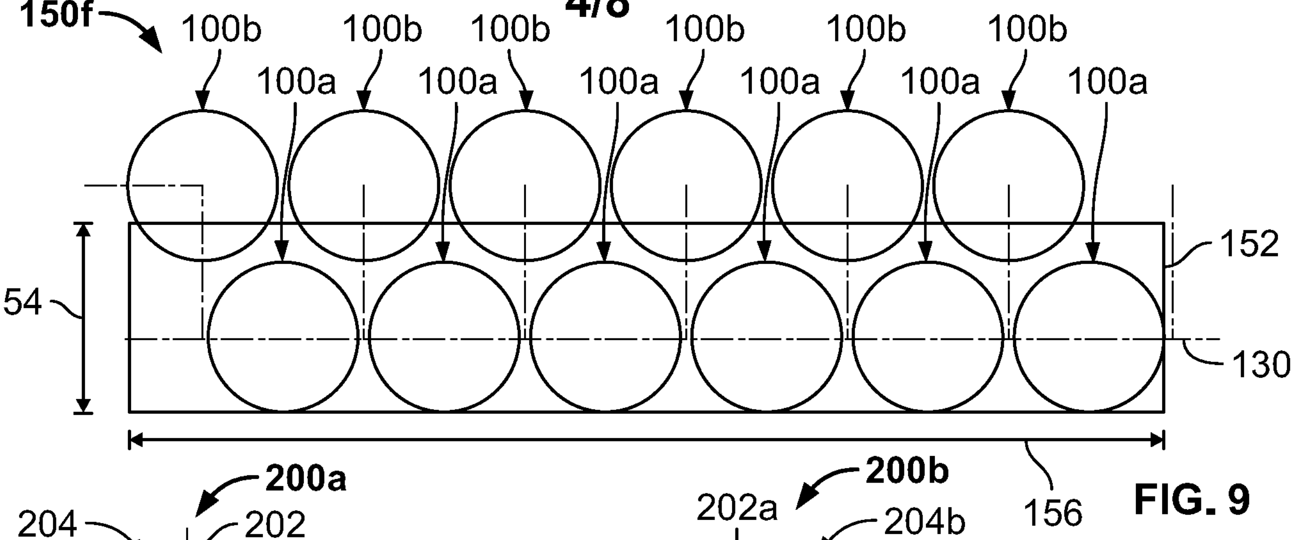

FIG. 9

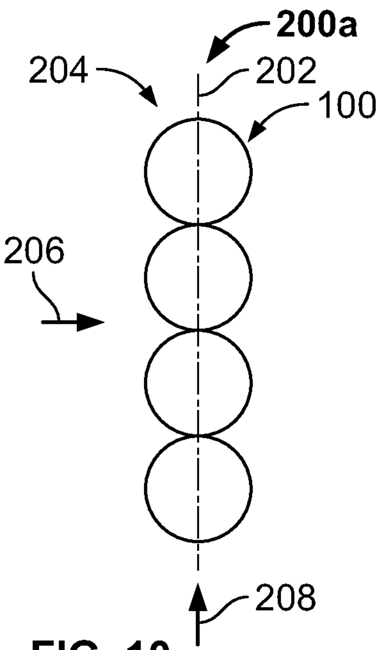

FIG. 10

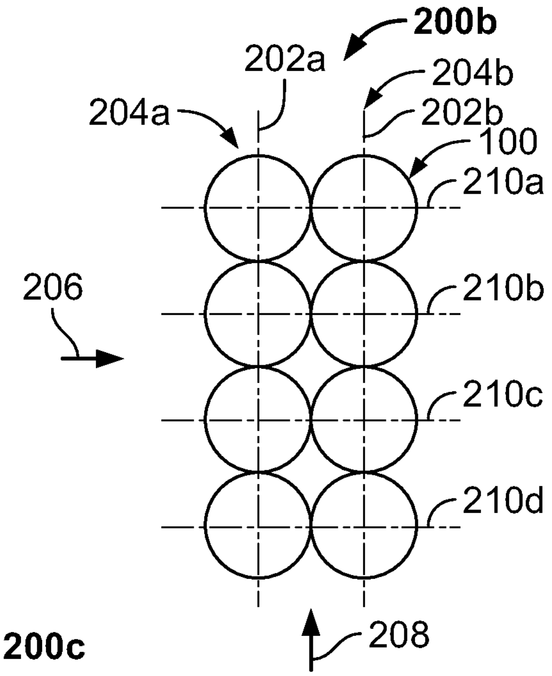

FIG. 11

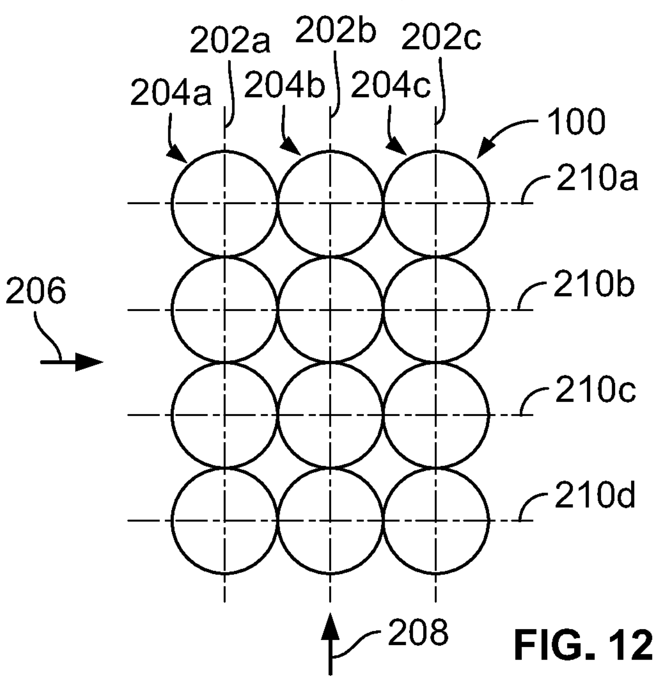

FIG. 12

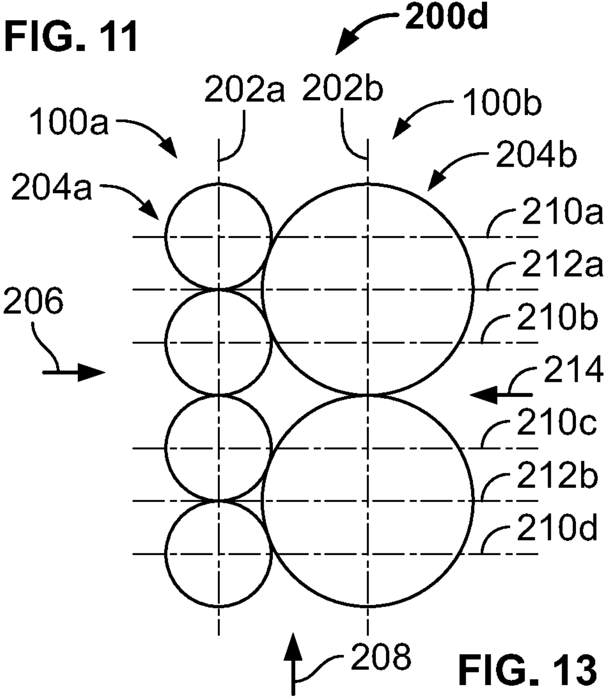

FIG. 13

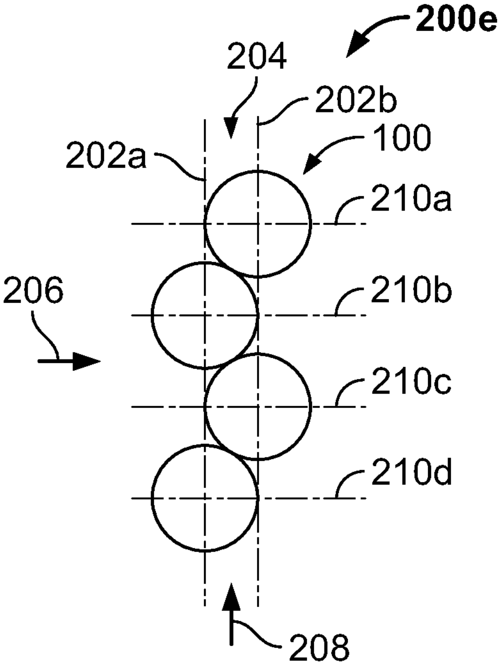

FIG. 14

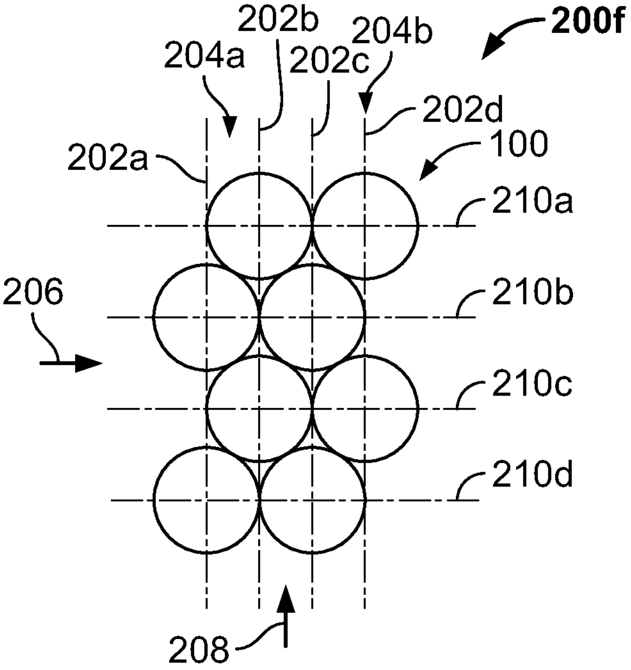

FIG. 15

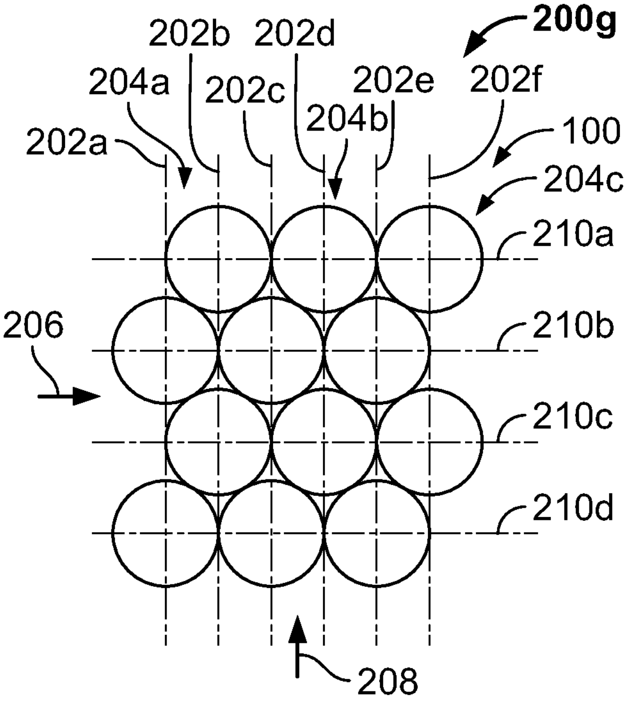

FIG. 16

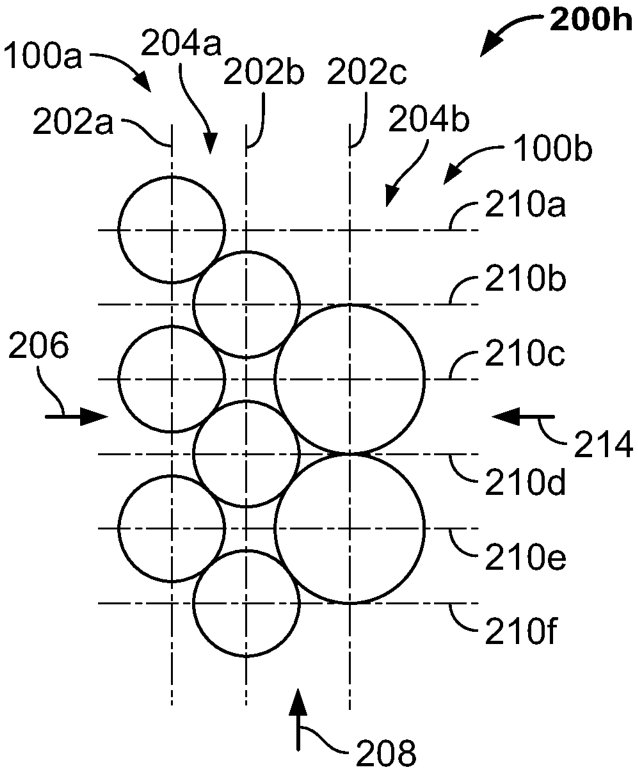

FIG. 17

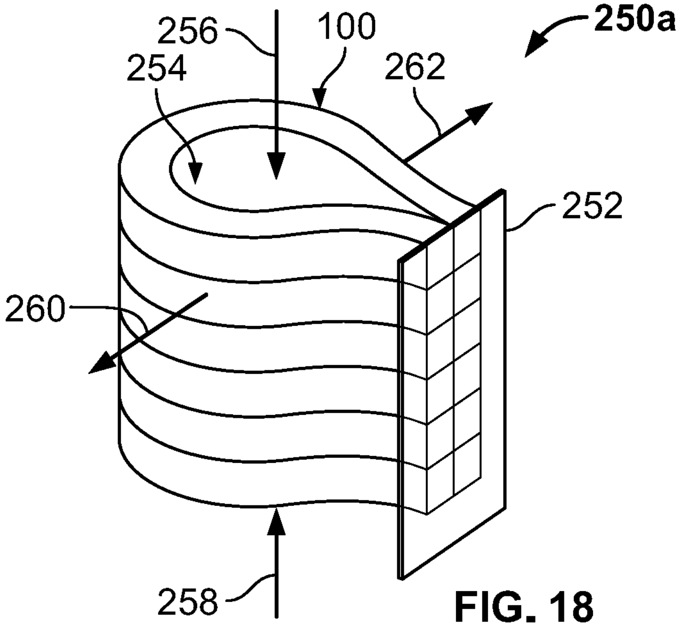

FIG. 18

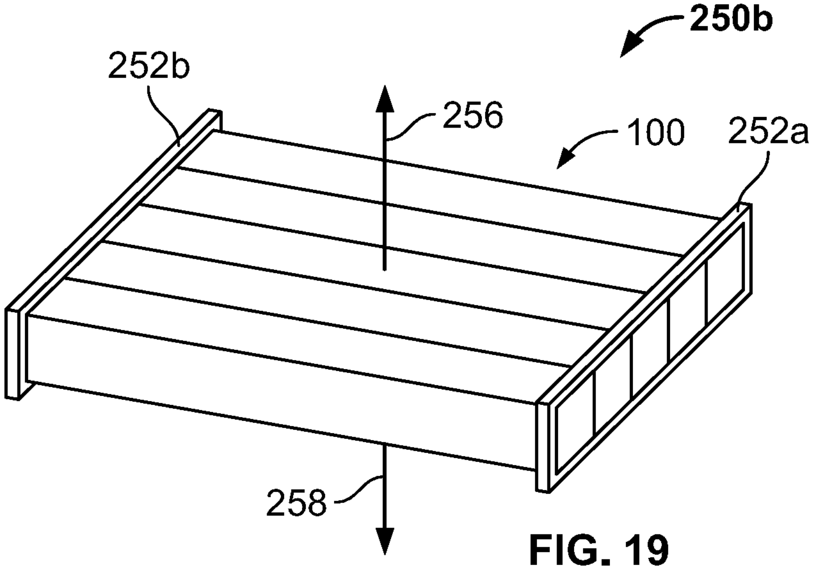

FIG. 19

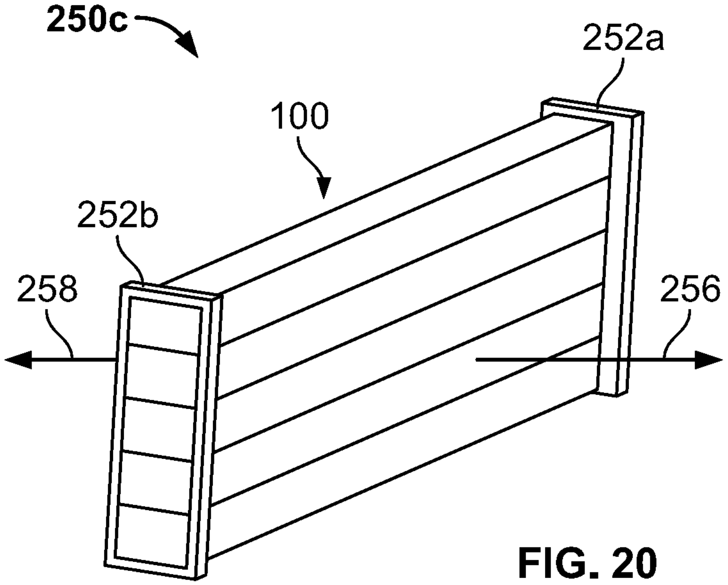

FIG. 20

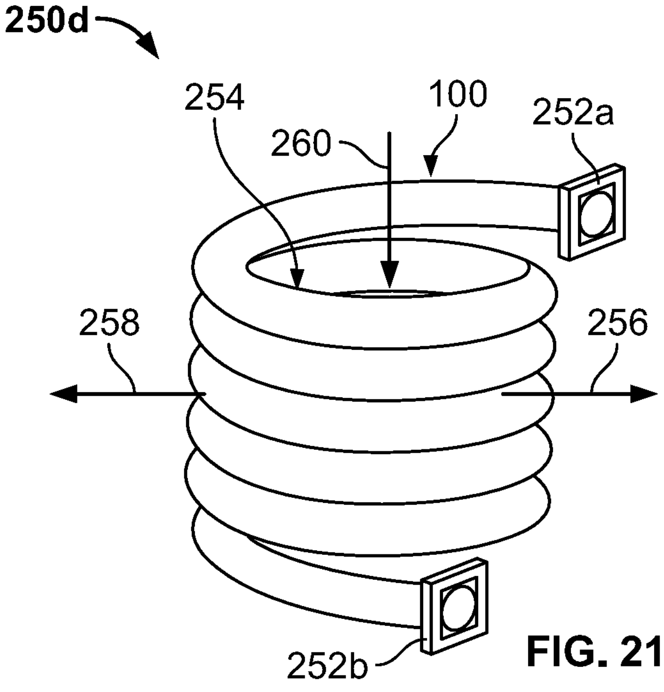

FIG. 21

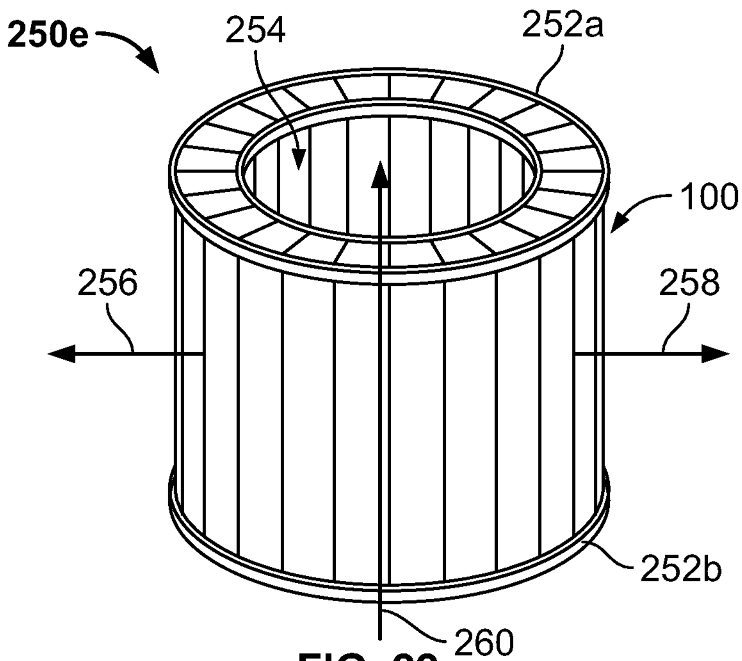

FIG. 22

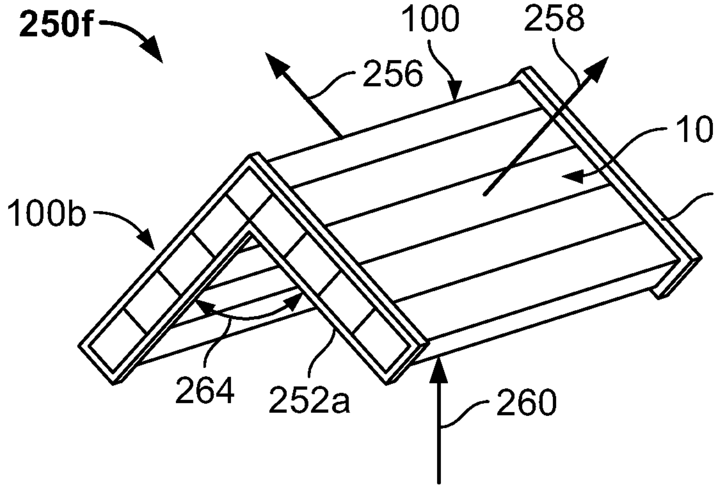

FIG. 23

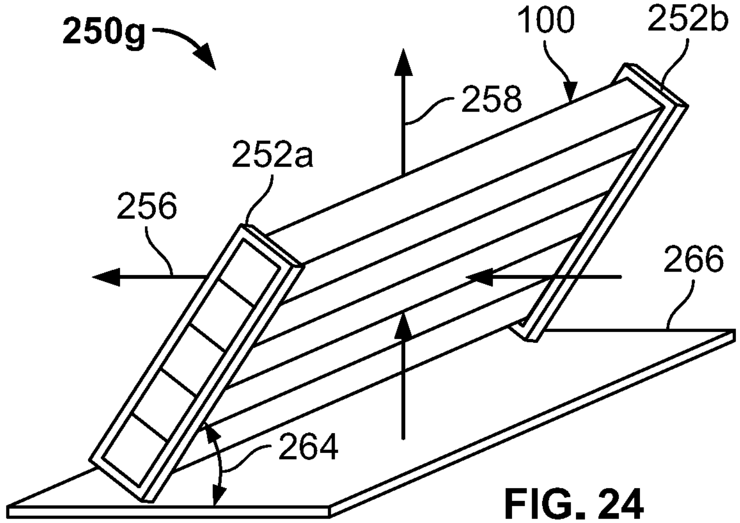

FIG. 24

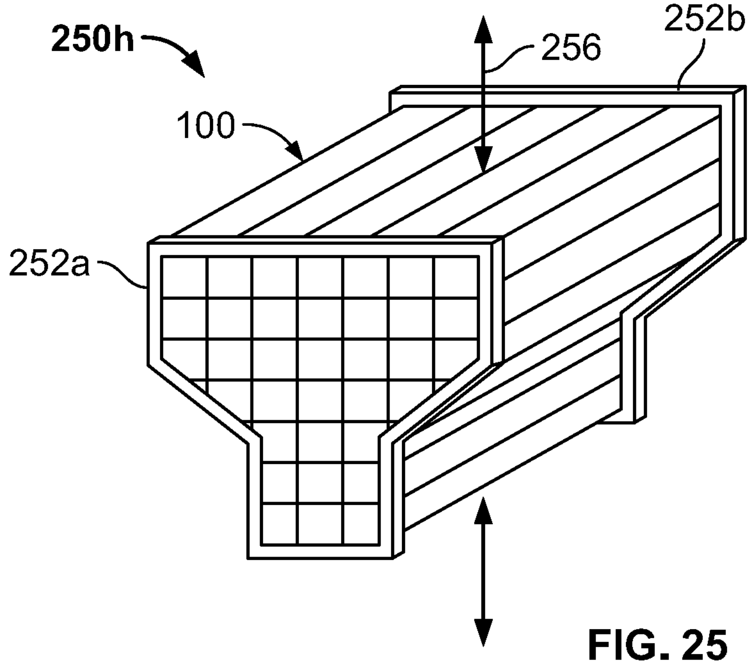

FIG. 25

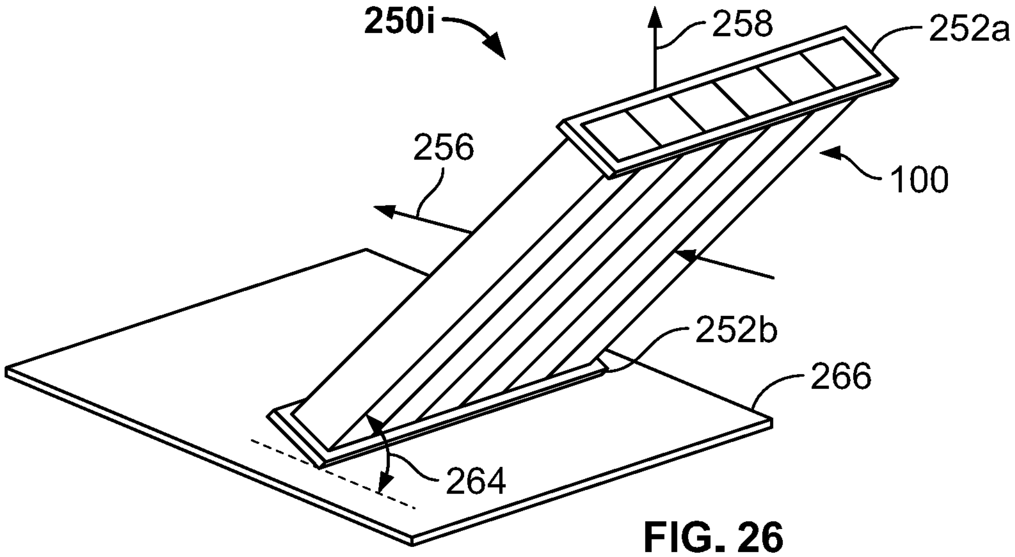

FIG. 26

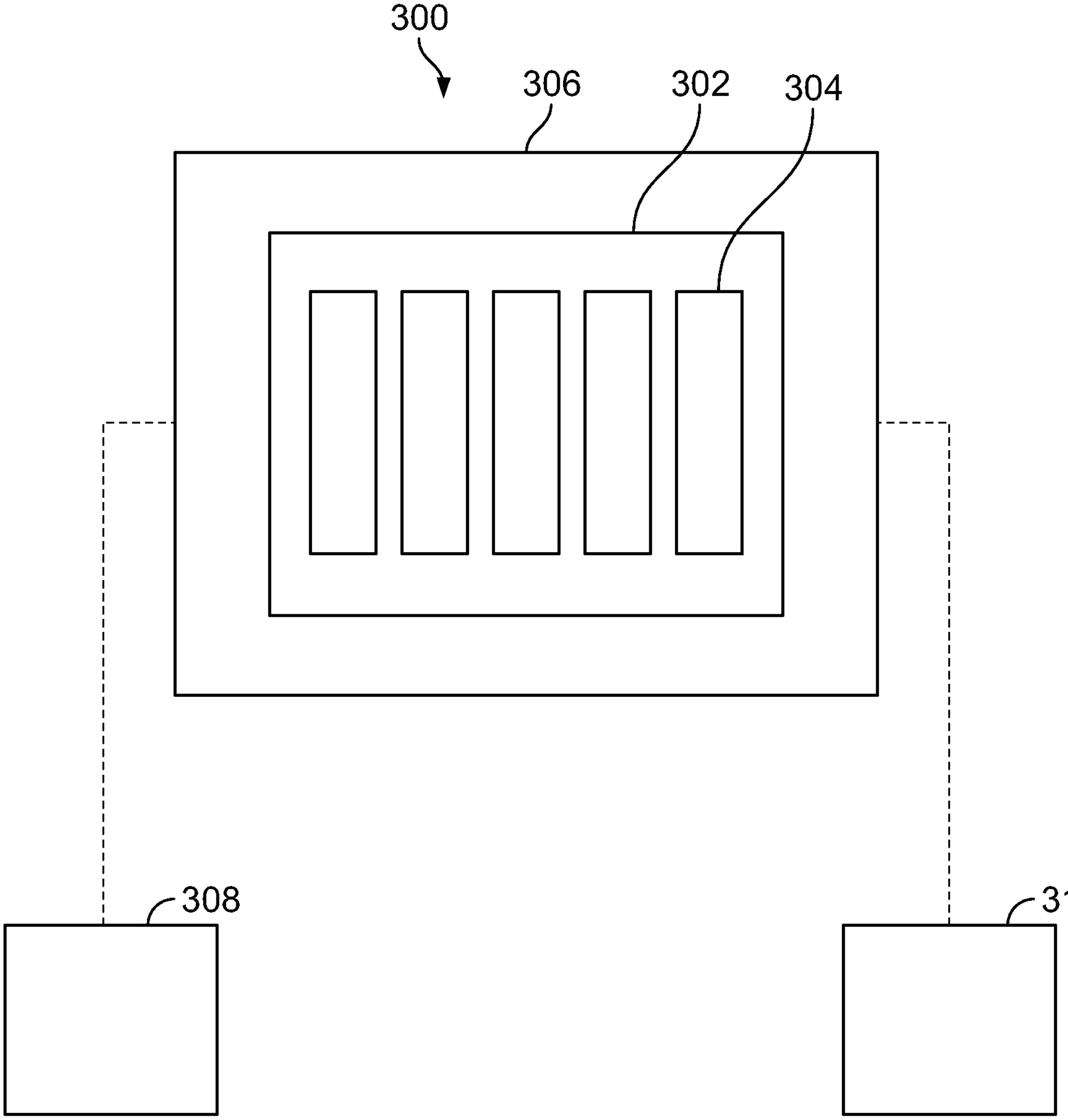

FIG. 27