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(54) CONDENSER FOR WATER HEATER

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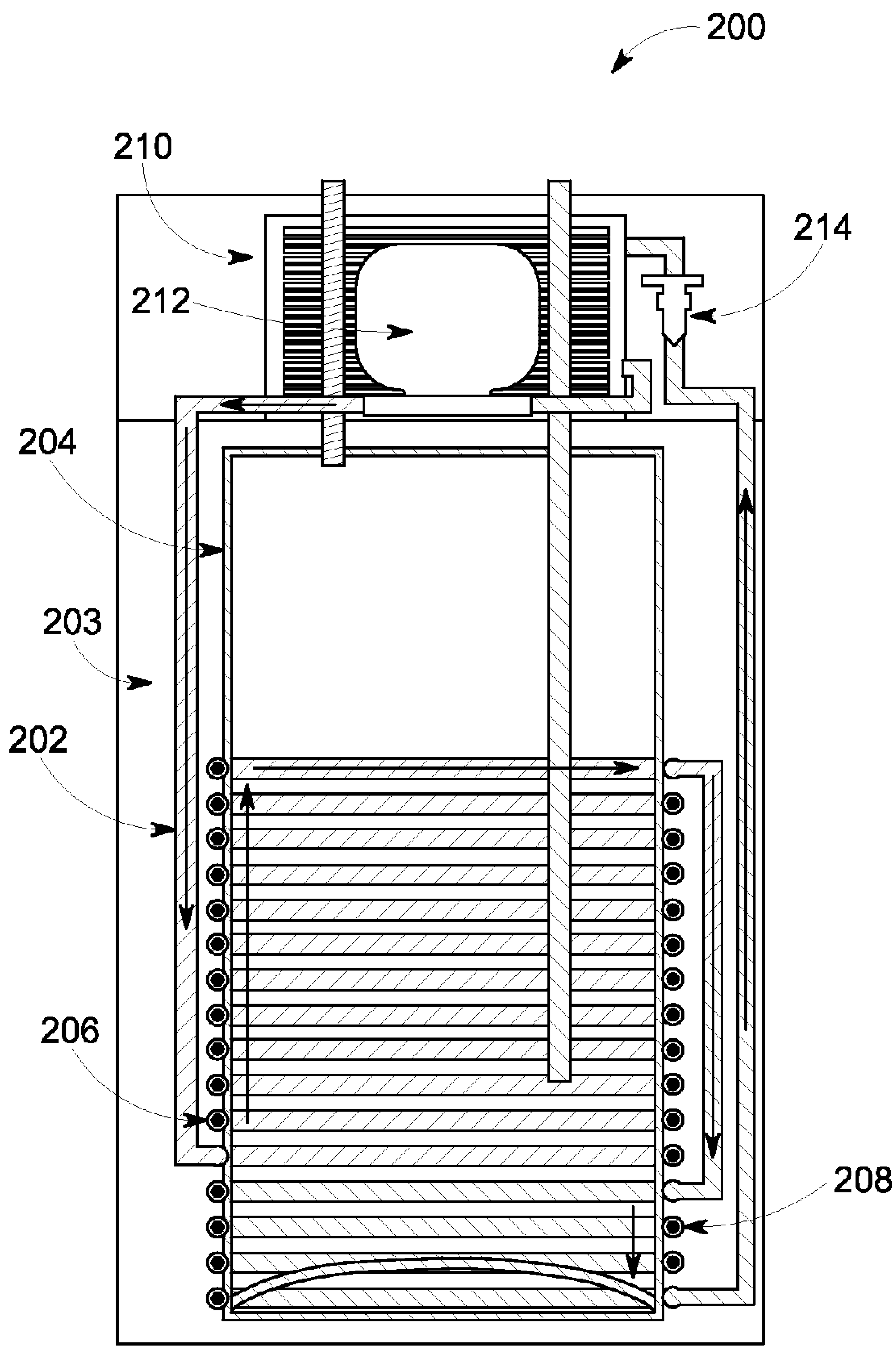
(57) **ABSTRACT**

A water heater comprises a tank, a cylinder coil section and a return-flow coil section. The cylinder coil section is in a heat transfer relationship with the tank and encircles a first portion of the tank. The return-flow coil section is in a heat transfer relationship with the tank and encircles a second portion of the tank. The cylinder coil section and the return-flow coil section are continuous over at least the first and second portions of the tank.



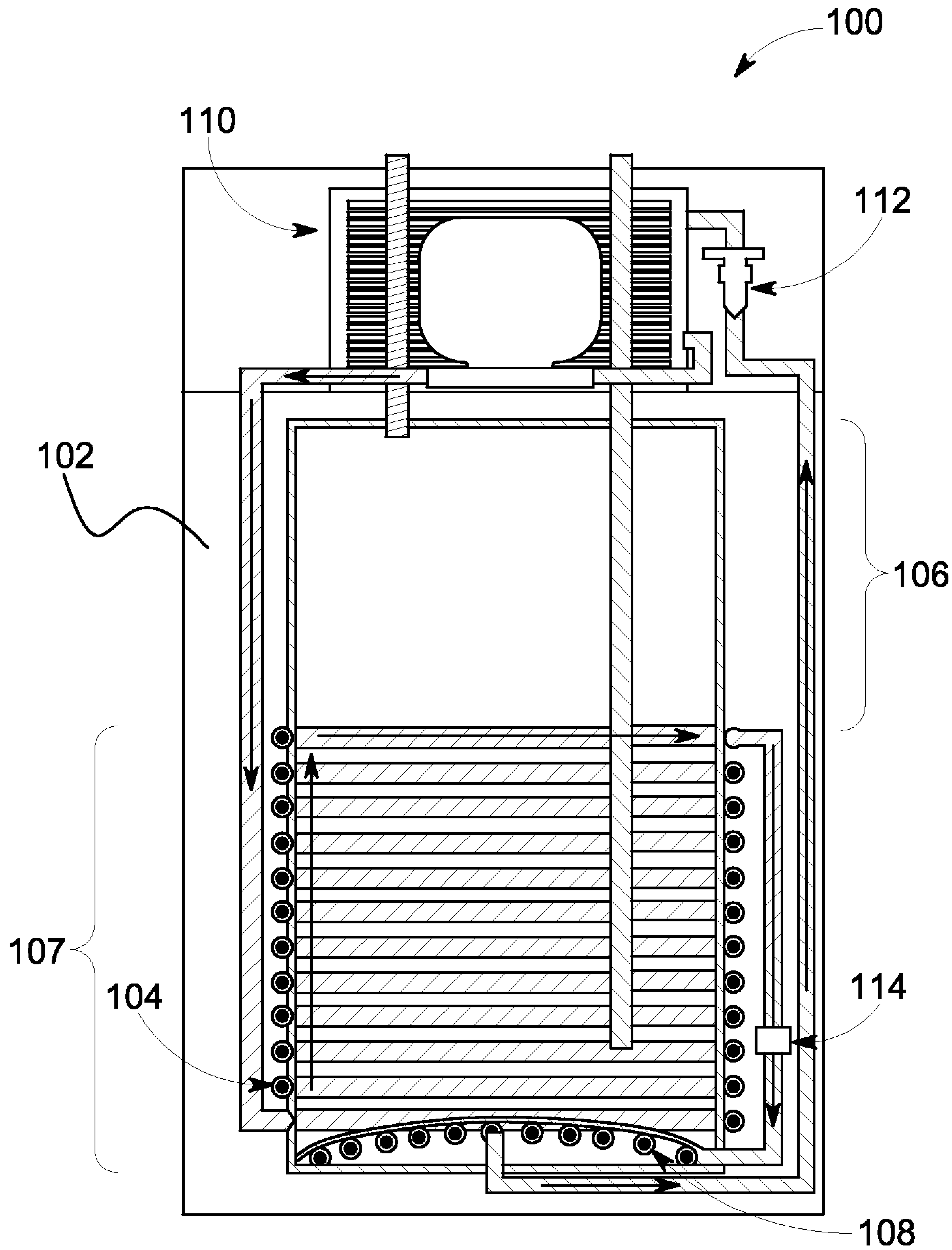


FIG. 1
(PRIOR ART)

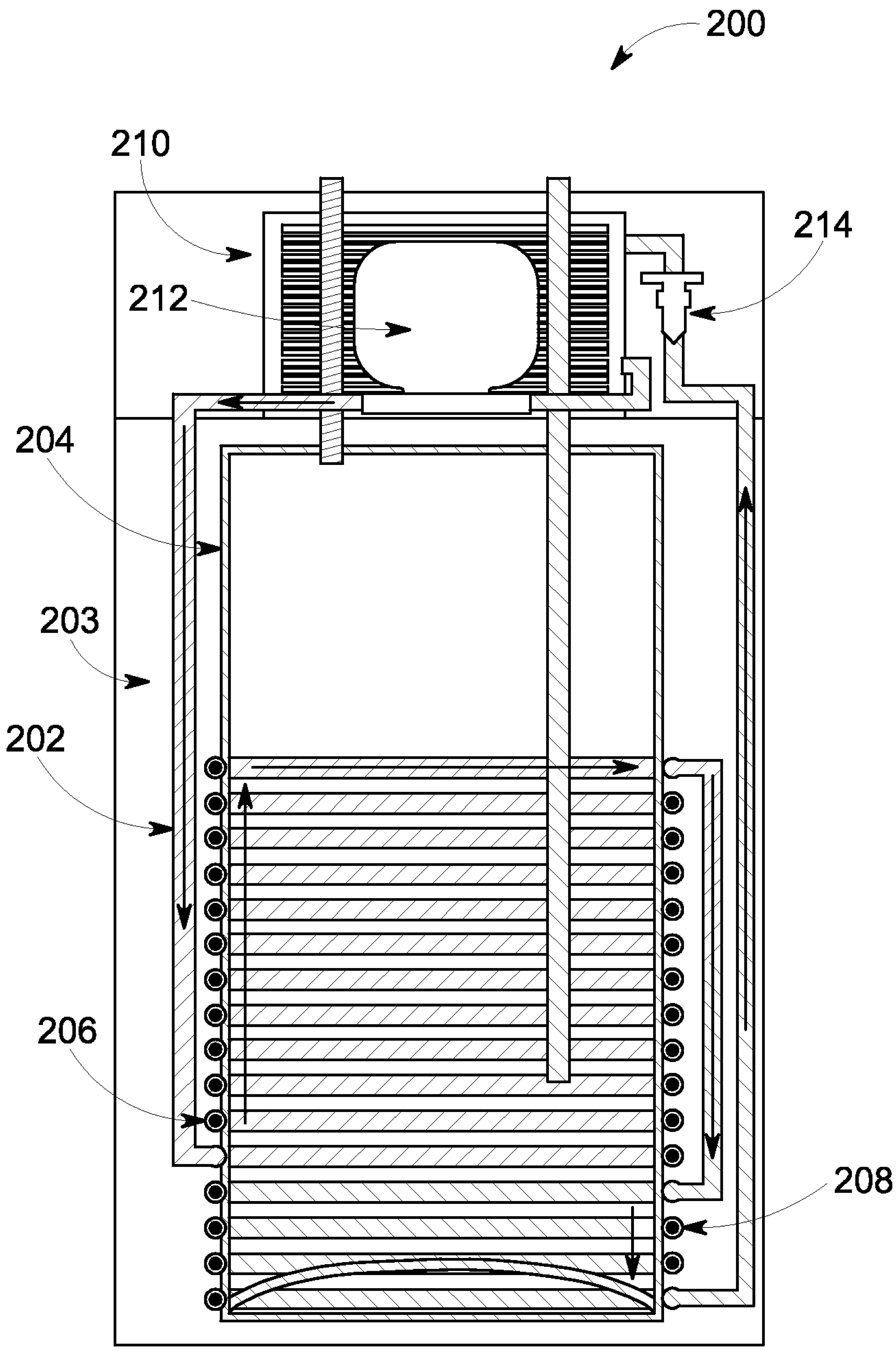


FIG. 2

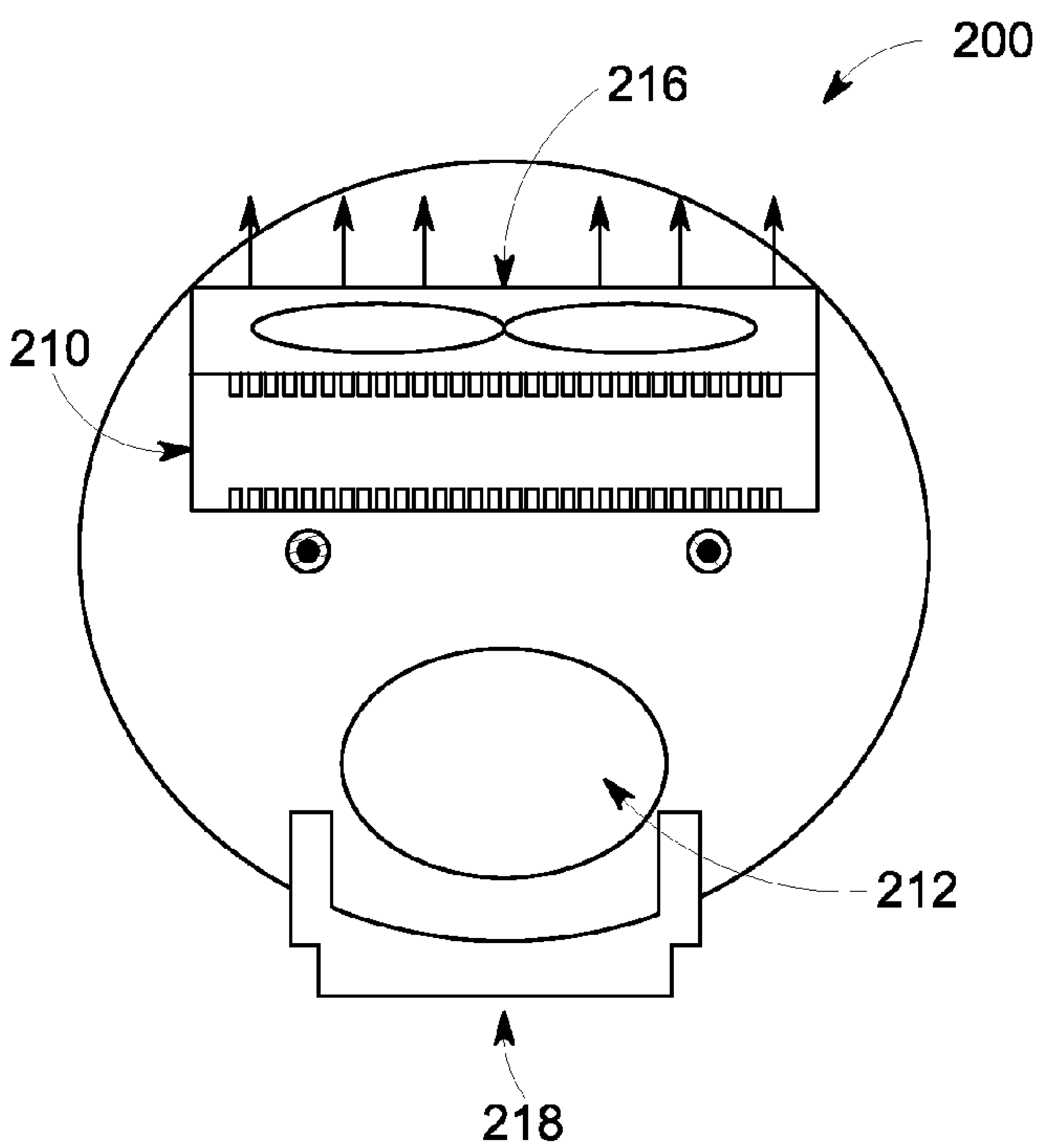


FIG. 3

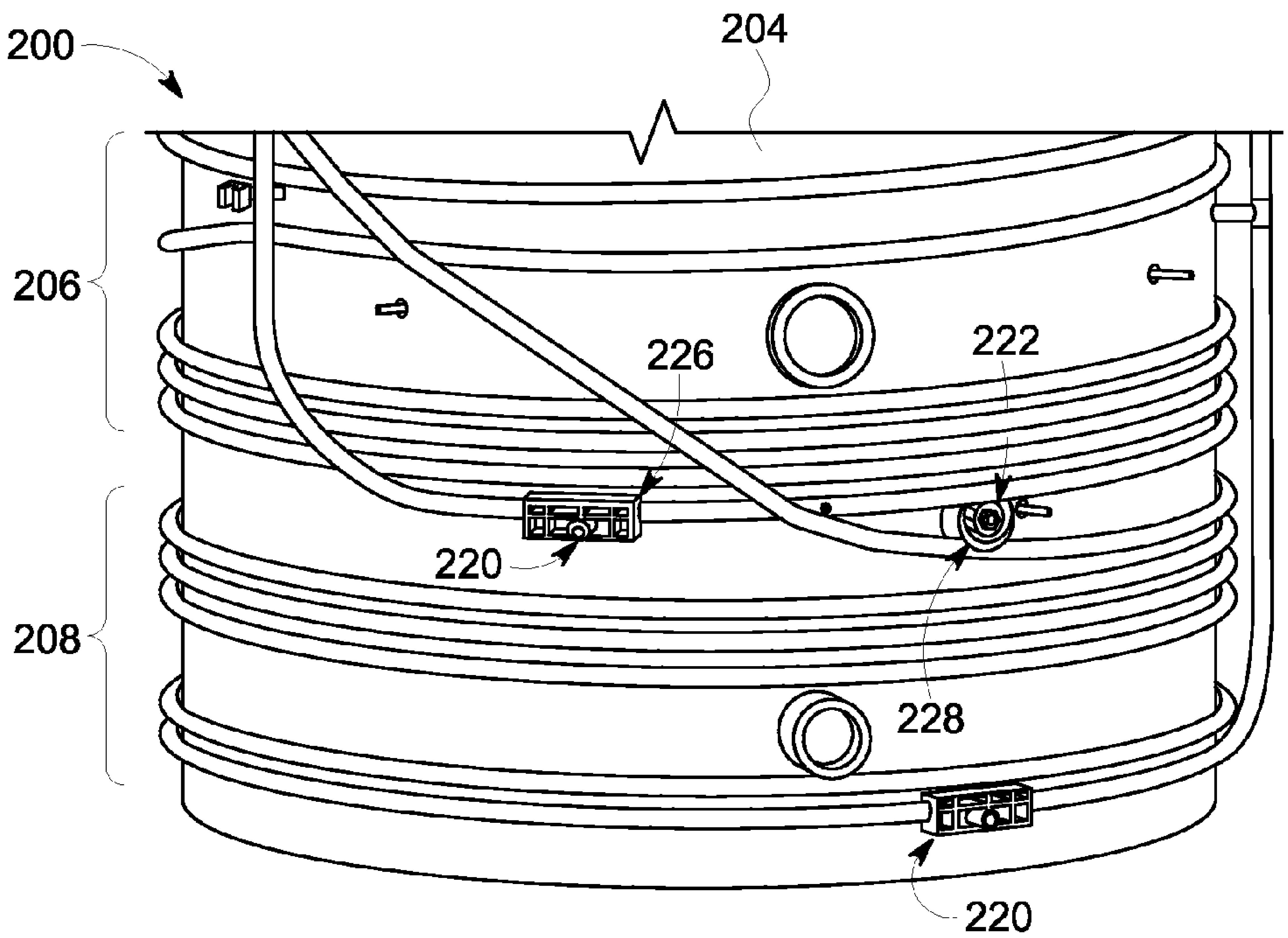


FIG. 4

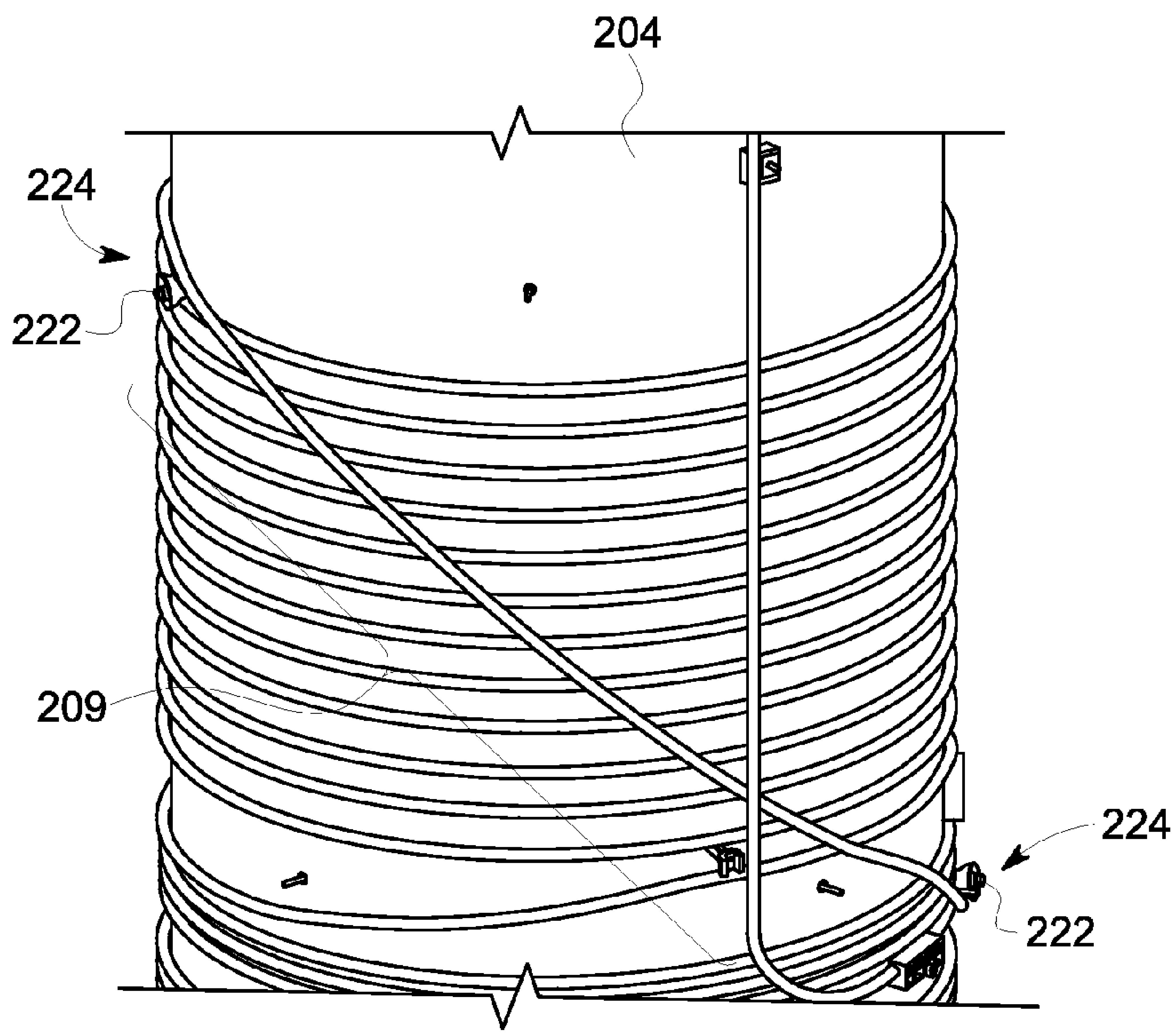


FIG. 5

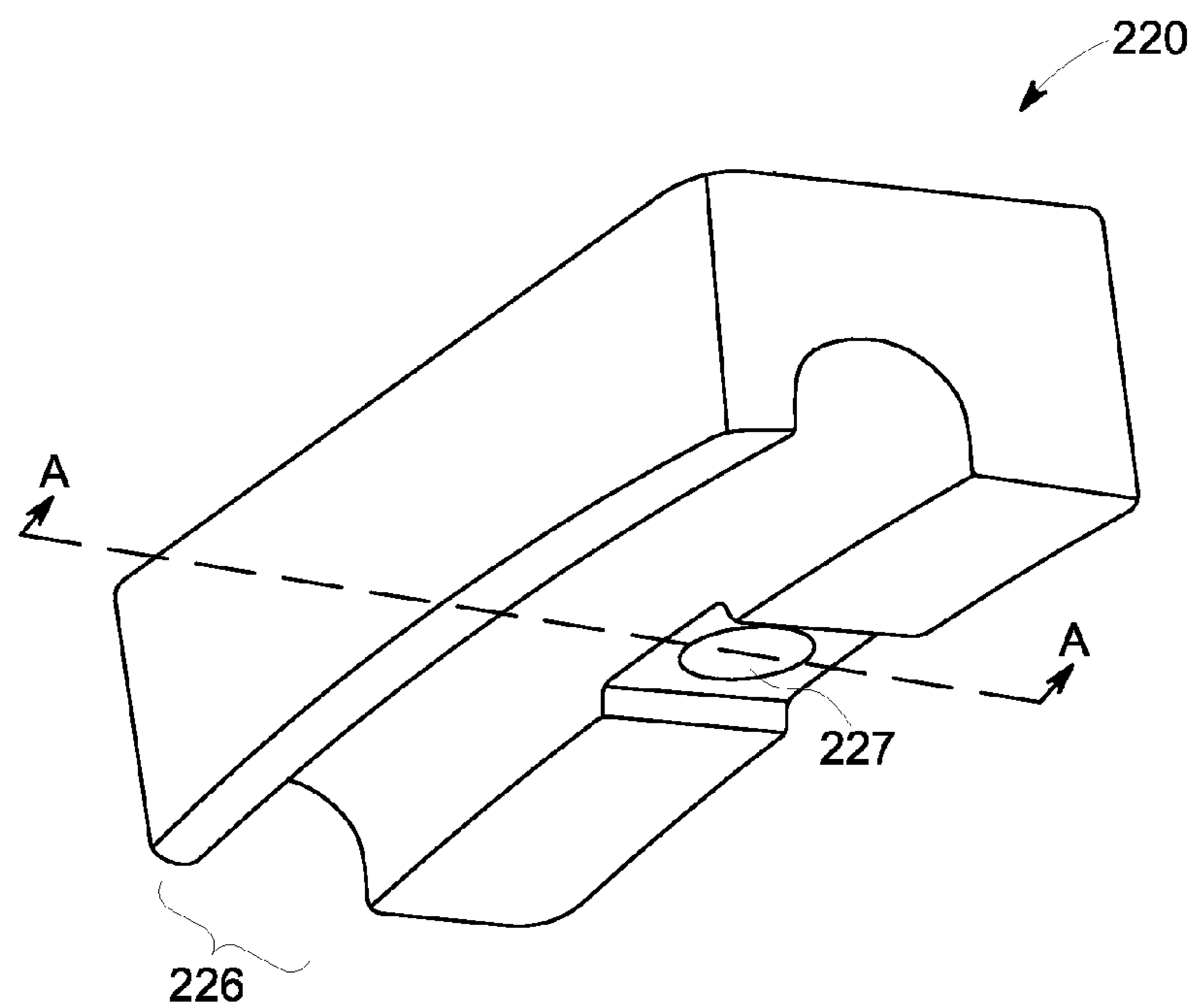


FIG. 6

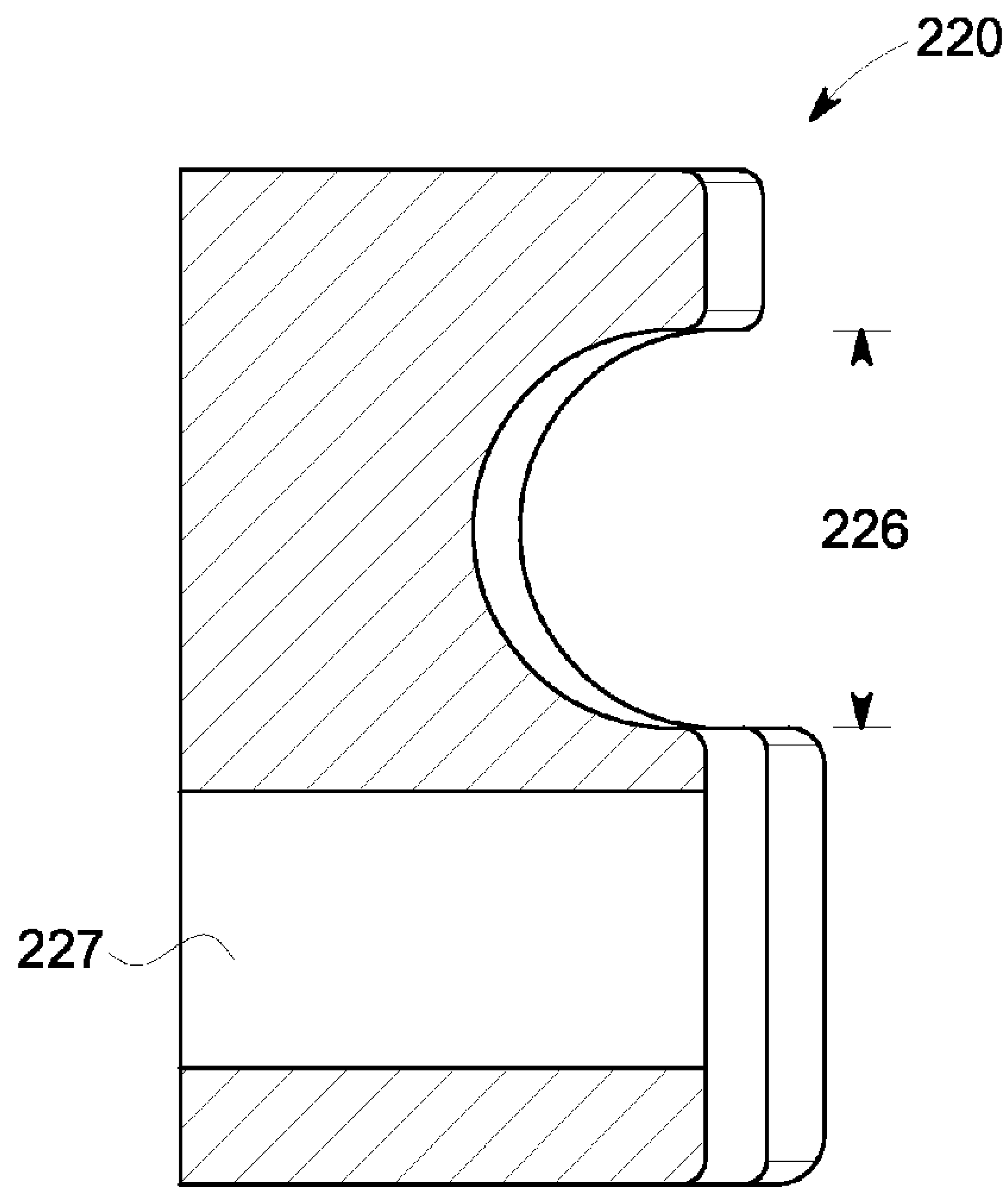


FIG. 7

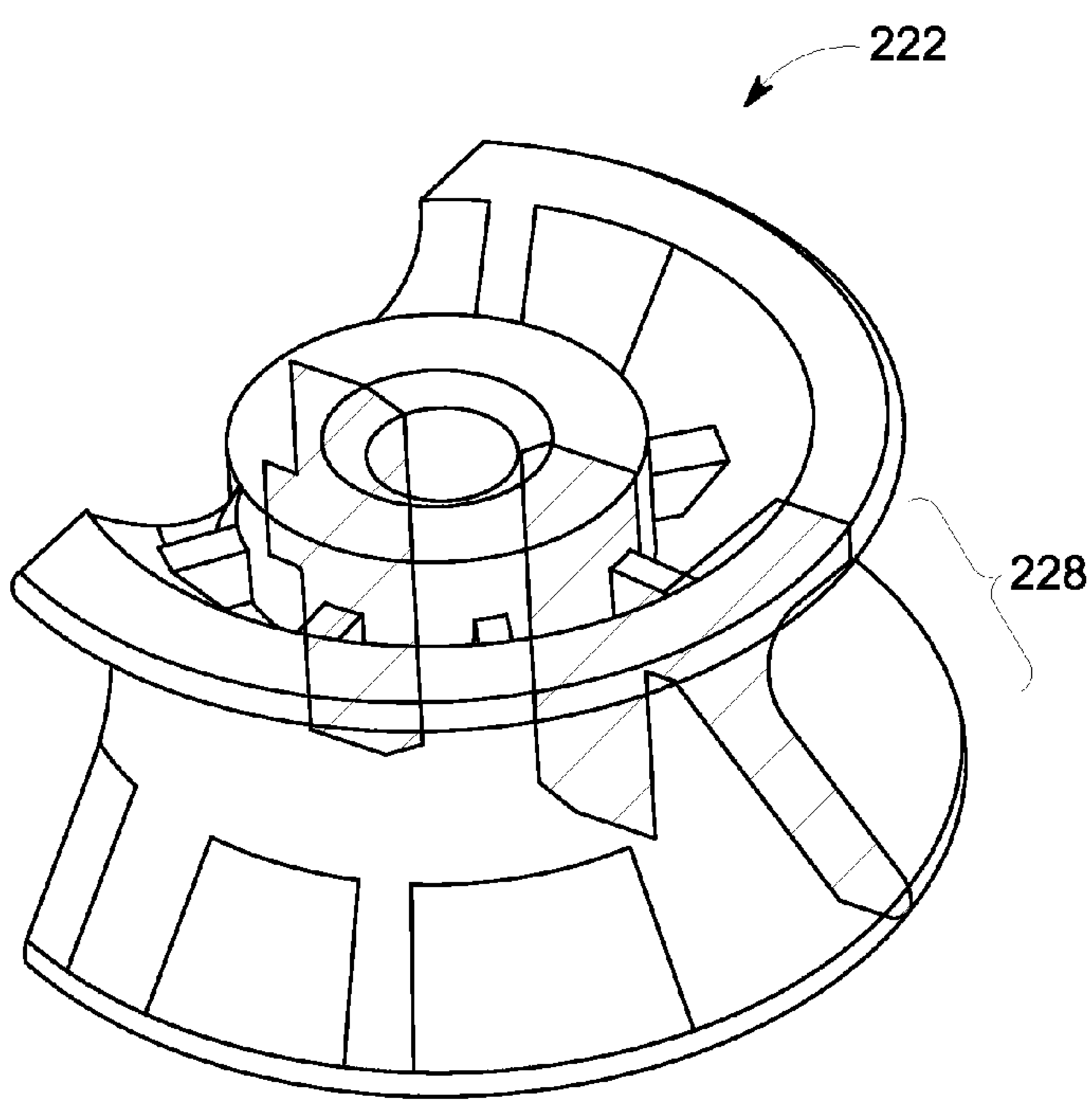


FIG. 8

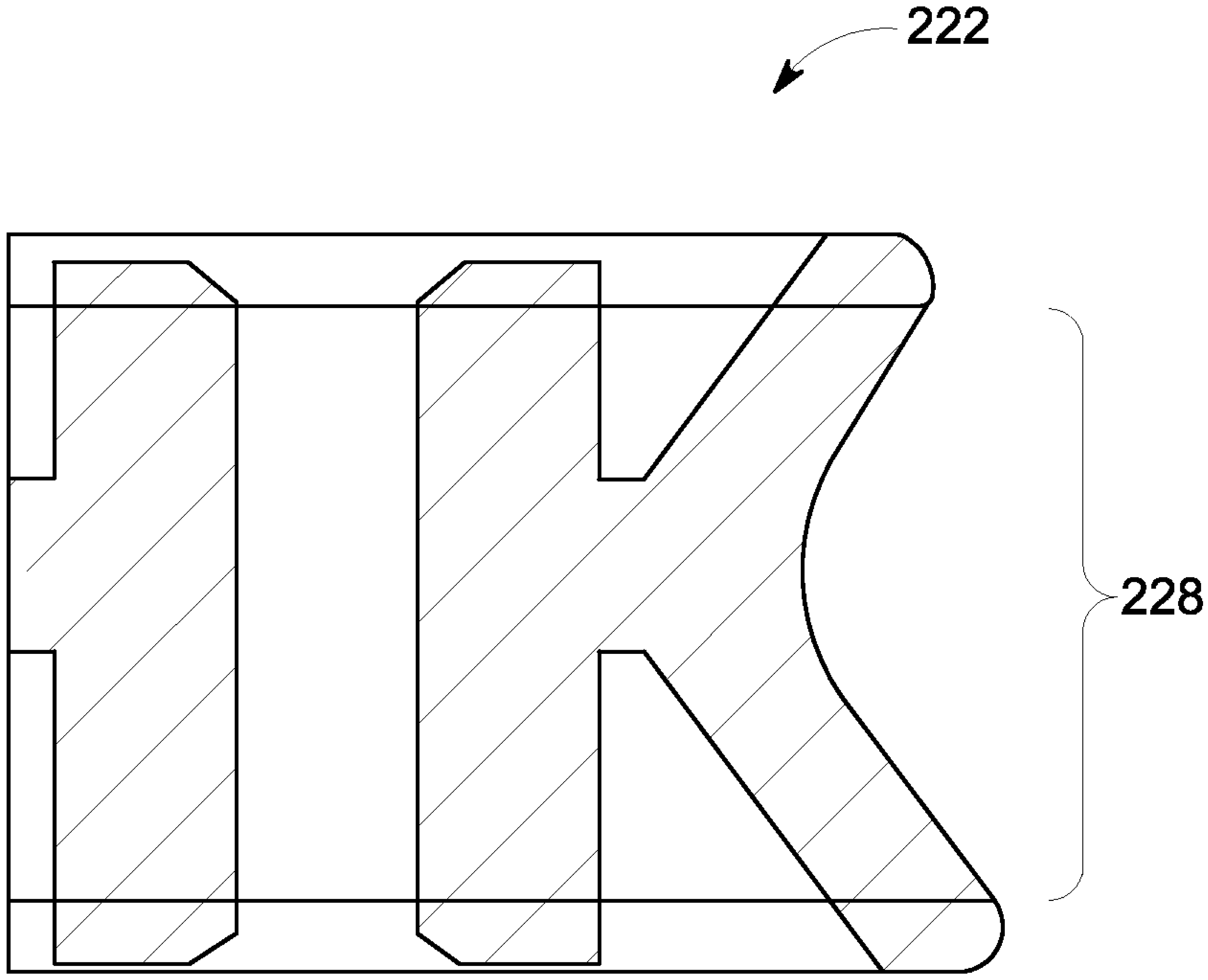


FIG. 9

CONDENSER FOR WATER HEATER

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to the U.S. Provisional Application identified as Ser. No. 61/524,418, filed on Aug. 17, 2011, entitled "Condenser, Shroud, Foam Dam and Drip Plate for Water Heater," the disclosure of which is incorporated by reference herein.

BACKGROUND OF THE INVENTION

[0002] The subject matter disclosed herein relates to water heaters, and more particularly to condensers in water heaters.

[0003] Water heaters such as heat pump water heaters (HPWHs) typically utilize one of three categories of condenser designs: (1) internal; (2) remote-located; and (3) external. In practice, almost all condensers used in the HPWH industry are made of copper, due to its excellent thermal transfer properties and workability.

[0004] Internal condensers are in contact with water, and are typically located inside the tank of a HPWH. Internal condensers that are placed in direct contact with the water have the advantage of excellent heat transfer, but there is a risk of contamination if a refrigerant/oil leak occurs. Thus, internal condensers must generally have a double wall to abate this risk, thus increasing the cost and resulting in a minor loss in heat transfer efficiency. Internal condensers are also susceptible to the formation of hard water scale in moderate-to-hard-water conditions, which reduces heat transfer efficiency over time.

[0005] Remote-located heat exchanger condensers are located away from the tank of a HPWH. Water is pumped from the tank at a first temperature, through a heat exchanger, and returned to the tank at a second temperature higher than the first temperature. Remote-located heat exchanger type condensers require a costly pump to circulate water from the tank to the heat exchanger. This approach also results in a rapid change of outlet water temperature from the water heater because the pump is quickly mixing the incoming cold water throughout the tank as hot water is used. Remote-located heat exchanger type heat condensers are also subject to the risk of contamination of the water supply if a refrigerant/oil leak occurs. Similar to internal condensers, remote-located condensers are made with a double wall, resulting in higher cost and a minor impact in heat transfer efficiency. Also similar to internal condensers, remote-located condensers are susceptible to the formation of scale in the heat exchanger in moderate-to-hard water conditions, ultimately resulting in a reduced circulation, and thus reduced heating.

[0006] External condensers, also referred to as externally applied or wound condensers, usually employ a flow path from the top to the bottom of a tank of a HPWH. External condensers are externally wound or of a roll-bond type. The amount of the tank covered by the condenser may vary based on the desired performance and cost tradeoffs. This top-to-bottom flow path directs the hottest refrigerant coming from the compressor to the top of the tank, and the refrigerant loses its heat to the tank/water as it moves toward the bottom of the tank. The result is a large (as much as ~25 degrees) temperature gradient in the tank from top to bottom. The larger the gradient, the more the consumer feels the water temperature drop while using hot water. Also, the larger the gradient, the less usable hot water can be delivered in the first draw from the tank.

[0007] To reduce the gradient in the tank, a bottom-to-top condenser flow path has been developed, such as that described in U.S. Patent Application Publication No. 2010/0209084, entitled "Residential Heat Pump Water Heater," which is assigned to General Electric Company, the disclosure of which is incorporated by reference herein. This bottom-to-top flow path directs the hottest refrigerant toward the bottom of the tank, flowing up toward the top of the tank, and has proven to deliver a small gradient in the tank.

[0008] However, in some designs, if cold water is introduced into the bottom of a hot tank of water (via the cold inlet dip tube), the lowest portion of the condenser is exposed to the coldest water. Refrigerant in the condenser migrates toward the coolest point, thus tending to accumulate in the lower portion of the condenser, where the refrigerant changes phase from gas to a liquid. This liquid has a hard time making the gradual climb up the spiral condenser path toward the restriction (thermal expansion valve (TXV) or other), as gravity tends to pull it toward the bottom of the tank. A mental image of this phenomenon can be pictured as liquid refrigerant settling to the bottom of the tube, slowly getting pulled back toward the bottom of the tank by gravity, while refrigerant in vapor phase continues to make the gradual climb, but is also condensing as it travels. Thus, the refrigerant flow rate drops until the compressor has no refrigerant to pump/move, and the system enters what has been called "vapor lock," which can loosely be compared to a pump losing its prime. In this condition, the heat pump is no longer able to do work, and the heating process stalls.

[0009] The return-flow coil condenser described in the above-referenced U.S. Patent Application Publication No. 2010/0209084 addresses the vapor lock issue by looping from the bottom-to-top cylinder coil back to the bottom/underside of the tank.

BRIEF DESCRIPTION OF THE INVENTION

[0010] As described herein, the exemplary embodiments of the present invention overcome one or more disadvantages known in the art.

[0011] In one embodiment, a water heater comprises a tank, a cylinder coil section and a return-flow coil section. The cylinder coil section is in a heat transfer relationship with the tank and encircles a first portion of the tank. The return-flow coil section is in a heat transfer relationship with the tank and encircles a second portion of the tank. The cylinder coil section and the return-flow coil section are continuous over at least the first and second portions of the tank.

[0012] In another embodiment, a method for assembling a condenser of a heat pump water heater comprises winding a first section of a coil around a first portion of a tank of the water heater and winding a second section of the coil around a second portion of the tank of the water heater. The first section of the coil comprises a cylinder coil section of the condenser and the second section of the coil comprises a return-flow coil section of the condenser. The first section and the second section are continuous over at least the first and second portions of the tank.

[0013] In yet another embodiment, a condenser for a heat pump water heater comprises a cylinder coil section and a return-flow coil section. The cylinder coil section is configured to be in a heat transfer relationship with and encircle a first portion of a tank of the water heater. The return-flow coil section is configured to be in a heat transfer relationship and encircle a second portion of the tank of the water heater. The cylinder coil section and the return-flow coil section form a continuous coil structure over at least the first and second portions of the tank.

[0014] In a further embodiment, a heat pump water heater comprises a tank and a condenser comprising a cylinder coil section in a heat transfer relationship with and encircling a first portion of the tank and a return-flow coil section in a heat transfer relationship with the tank and encircling a second portion of the tank, wherein the cylinder coil section and the return-flow coil section are continuously formed.

[0015] Advantageously, embodiments of the invention reduce costs associated with manufacturing and maintaining a water heater. Embodiments also allow for improved water heater performance.

[0016] These and other aspects and advantages of the present invention 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 solely for purposes of illustration and not as a definition of the limits of the invention, for which reference should be made to the appended claims. Moreover, the drawings are not necessarily drawn to scale and, unless otherwise indicated, they are merely intended to conceptually illustrate the structures and procedures described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] In the drawings:

[0018] FIG. **1** is a cross-sectional view of a conventional heat pump water heater having a copper jointed conventional return-flow condenser;

[0019] FIG. **2** is a side cross-sectional view of an improved heat pump water heater having an aluminum or steel return-flow condenser, according to one embodiment of the invention;

[0020] FIG. **3** is a cross-sectional plan view of the improved heat pump water heater of FIG. **2**;

[0021] FIGS. **4** and **5** are each side views of a bottom section of the improved heat pump water heater **200** of FIG. **2**;

[0022] FIG. **6** is a perspective view of a clip as shown in FIG. **4**;

[0023] FIG. **7** is a cross-sectional view of the clip of FIG. **6** taken along line A-A;

[0024] FIG. **8** is a perspective view of a spool as shown in FIG. **4**; and

[0025] FIG. **9** is a side view of the spool of FIG. **8**.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS OF THE INVENTION

[0026] One or more of the embodiments of the invention will be described below in the context of an exemplary HPWH. However, it is to be understood that the embodiments of the invention are not intended to be limited solely to the HPWHs described herein. Rather, embodiments of the invention may be applied to and deployed in other suitable environments in which it would be desirable to reduce the manufacturing costs and/or improve the performance of water heaters.

[0027] Embodiments of a water heater described herein address at least the vapor lock issue, described above, by providing a jointless condenser coil in the form of a one-piece (unitary) structure. The jointless design eliminates the need for the brazing or other joining operation between the cylinder coil section and the return-flow coil section, because the cylinder coil section and return-flow coil section of the condenser coil are wound in a single, continuous operation. While the cylinder coil section is wound up the tank, the return-flow coil section is wound down to the coolest part of the tank, near its bottom, to fully condense a refrigerant that flows through the condenser. In some embodiments, the return-flow coil section is wound around the bottom surface of the tank. The return-flow coil section can be wound with a flow path of outside to inside, starting from the outer edge of the bottom surface of the tank and winding inside towards the center of the bottom surface of the tank. In other embodiments, the return-flow coil section is wound with a flow path of inside to outside, starting at the center of the bottom surface of the tank and winding towards an outer edge of the bottom surface of the tank. The flow path of outside to inside or opposite is determined at least in part by the tank bottom shape and desired performance of the water heater. One skilled in the art would recognize that various other winding patterns and condenser arrangements are possible, such as winding the return-flow coil in an upward direction. While illustrative embodiments may be described with the particular winding patterns described above, the invention is not limited solely to these winding patterns but is instead more generally applicable to a variety of winding patterns and condenser arrangements.

[0028] Benefits of this type of condenser include, but are not limited to, lower manufacturing cost and improved heat exchange performance. This approach also avoids the above-mentioned larger issues associated with other types of condensers. Moreover, embodiments of the improved condenser described herein advantageously use features, such as, but not limited to, improved attachment clips to tension the aluminum tubing and non-kink spools to bend aluminum or steel tubing without kinking or crushing.

[0029] Where steel is used as the condenser tubing material, embodiments of the invention help reduce/minimize condenser corrosion due to moisture from external sources or condensation forming on the tank, by using anti-corrosion coatings on the steel condenser tubing and/or the tank. Additionally, embodiments of the invention prevent water from accessing or contacting the condenser. This also helps prevent general and/or galvanic types of corrosion. The condensers described herein may be used in conjunction with various water seepage abatement techniques, such as those disclosed in the U.S. patent application identified by Attorney Docket No. GE 254601, entitled "Water Seepage Abatement in Water Heaters," and the U.S. patent application identified by Attorney Docket No. GE 253942, entitled "Foam Dam for Appliance," which are filed concurrently herewith and incorporated by reference herein.

[0030] FIG. **1** is a cross-sectional view of a prior art heat pump water heater having a prior art copper jointed return-flow condenser. In this arrangement, the condenser has a separate cylindrical coil structure that is joined to a separate return-flow coil structure. Since the two separate structures must be joined, the joined structure does not form a one-piece, jointless structure and is thus not considered continuous.

[0031] The coil condenser **100** retains a bottom-to-top flow path, which begins near the bottom of the cylindrical tank **102**, as originally intended, and forms a cylinder coil **104**; but after progressing toward the top **106** of the tank **102**, it then returns back to the bottom/underside **107** of the tank **102**, and the tubing of the condenser **100** forms a spiral coil **108** that is put in contact with the bottom of the tank **102**. The purpose of this configuration is to bring the last path of the condenser comprising return-flow coil **108** into thermal contact with the coldest part of the tank/water. By this arrangement, the refrigerant has the greatest opportunity to condense from gas to liquid before making the final vertical path to the TXV/restrictor **112** and evaporator **110**.

[0032] With copper tubing for the condenser **100**, a two-piece condenser design is typically used. This design requires a brazing operation or other operation **114** to connect the cylinder coil **104** of the condenser **100** to the return-flow coil **108**. The return-flow coil **108** is a spiral shaped coil mounted on the bottom of tank **102**. The return-flow coil **108** passes refrigerant along the coolest part of the tank to fully condense refrigerant. While FIG. **1** shows a tank **102** with a bottom configuration that is concave, the tank bottom may also be convex. Return-flow condensers concepts apply to both concave and convex arrangements.

[0033] The type of material used to form a condenser and how the condenser is wound are important. For example, material cost, as well as the manufacturing cost to wind a condenser on the outside of a tank is the largest disadvantage of an externally wound condenser. Copper is the most common material used for almost all heat pump water heater condensers types described above, but its cost tends to be volatile and rising. Accordingly, it would be advantageous to use other materials that are less costly. The problem with doing so however is that many of such materials have historically been deemed unsuitable for use in heat pump water heater condensers, which get wet. For example, steel has been used in refrigeration products. However, in that application, the condenser does not get wet. Additionally, in the refrigeration application, the condenser is post-painted to prevent corrosion due to ambient humidity and incidental wetting. Accordingly, the corrosion properties of steel are a significant obstacle to using it as a heat pump condenser material.

[0034] Disclosed herein are embodiments of a condenser for a water heater, which condenser may be formed of copper or of an alternative material to copper, such as aluminum, steel, cross-linked polyethylene, etc. If steel is used, it may be coated with an anti-corrosion material.

[0035] A discussion of the obstacles to using alternative materials such as aluminum and steel is provided below, along with identification and discussion of solutions to such obstacles which are utilized in various embodiments of the invention. Following this discussion is a detailed description of specific embodiments, with reference to FIGS. **2-9**.

[0036] As briefly mentioned above, several obstacles have hitherto prevented the successful application of aluminum or steel as a condenser material. Embodiments of the invention overcome these obstacles, thus allowing the use of aluminum or steel as a viable material for heat pump condensers, regardless of the flow-path. In one embodiment, either aluminum or coated steel is used to form an externally wound condenser for a water heater.

[0037] There are several factors which should be taken into account when choosing a material for a condenser in sealed systems for a HPWH. These factors include, but are not limited to, cost, coefficient of heat transfer, coefficient of thermal expansion (CTE) versus an adjacent mating material, galvanic potential versus an adjacent mating material, return-flow condenser considerations, material strength, manufacturing processes to join components, manufacturing processes to route tube on a tank, and manufacturing methods to secure or attach the condenser tube to a tank.

[0038] Embodiments of the invention use aluminum as a condenser material. The cost of aluminum is typically lower than copper, and thus provides no obstacle for cost concerns. Similarly, the coefficient of heat transfer of aluminum to steel conduction is acceptable for most water heaters.

[0039] The CTE of aluminum is greater than the CTE of steel, which is typically the adjacent material for tanks of water heaters. Consequently, an aluminum tube will tend to separate from the tank as temperature increases. In order to overcome this obstacle, embodiments of the invention utilize higher tension when winding the aluminum condenser on the tank as compared to the tension used when winding a steel or copper condenser. Some embodiments will also use thermal mastic which provides an expansion joint between the coil and the tank wall to prevent voids during expansion. Thermal mastic is a heat transfer compound applied to the coils/tubing of the condenser at points where the coils/tubing make metal-to-metal contact. Thermal mastic greatly increases the heat transfer ability of the condenser.

[0040] The galvanic potential of aluminum is not an obstacle to the use of aluminum as a condenser material. There is a possible galvanic coupling between an aluminum tube and a steel tank, but the aluminum tube wall thickness is greater than that required to service ten years of the corrosion rate of aluminum.

[0041] Return-flow condenser considerations present a problem for the use of aluminum. Aluminum is difficult to join, and so a brazing or other operation (**114** as shown in FIG. **1**) may become prohibitively difficult and expensive for separate cylinder coil and return-flow coil arrangements. To overcome this obstacle, embodiments use a one-piece, jointless (hereinafter referred to as "continuous" or "continuously formed") condenser comprising a cylinder coil section and a return-flow coil section with a transition section there between on the tank cylinder.

[0042] The material strength of aluminum provides an obstacle for the use of aluminum as a condenser material. Material strength considerations include characteristics of the material as a pressure vessel such as the resistance to crush, collapse or kink of tubing during handling. Aluminum tubes can easily collapse or kink when secured to a tank for winding. Embodiments overcome this obstacle through the use of clips which support the tube shape. The clips maintain the shape of the aluminum tube while continuing to hold the tube securely during the high-tension winding process required to address the CTE obstacle discussed above. The clips also avoid stress concentrations such as those caused by thermal expansion by spreading contact load, and radii at bracket edges that contact the tube. The inlet tube is clamped with a leader length to allow winding, then the tube is formed to the inlet.

[0043] Manufacturing processes to route aluminum tubes on a tank provide a further obstacle to the use of aluminum. Currently, there is no method to wind a return-flow condenser without a joint. Embodiments of the invention overcome this obstacle by winding primary (cylindrical coil section) and return-flow (return-flow coil section) condenser portions in a single pass, utilizing non-kink spools at points were tubing direction changes. The spool design provides a minimum radius for the tube bend to prevent kinking of tube necking

The spool design additionally cradles the tube to prevent stress concentrations. The spool design can also provide an insulator function between return line and heating coil windings. For example, the spool may be designed such that it forces the condenser tube to be positioned outboard of the original coil.

[0044] Thus, embodiments of the invention provide techniques for the use of an aluminum condenser on a water heater tank. No brazing or other joining of the condenser tube under the foam in a tank assembly is required by using a continuous operation to wind the cylinder coil section and return-flow coil section of the aluminum condenser. An improved clip attaches to the aluminum tube start and stop points without crushing/kinking the aluminum tube. The improved clip also allows the aluminum tubing to be wound with higher tension than that used to wind copper to steel to minimize gaps through the full heating range of the water heater. Spools are provided at tube direction change points. The spools are non-kink spools which permit the creation of an aluminum return-flow condenser with no joints and not pinching or crushing of the aluminum tube.

[0045] Steel presents a different set of obstacles to its use as a condenser material. The cost of steel is presently lower than that of copper, and thus cost is no obstacle to the use of steel as a condenser material. The coefficient of heat transfer for steel-to-steel conduction is acceptable, and thus similarly presents no obstacle to the use of steel. The CTE of steel tubing is the same as the CTE of steel tanks used for water heaters, and as such presents no obstacle to the use of steel. The strength of steel tubing is greater than the strength of copper tubing, and thus there are no obstacles relating to material strength or manufacturing methods to attach steel tubing to the tank of a water heater.

[0046] There is a possible galvanic coupling between a coated steel tube and a steel tank. This presents a significant obstacle to the use of steel as a condenser material. Small defects in steel tube coating can lead to a concentrated galvanic cell at the defect, leading to a potential failure. Corrosion, however, must have a source of water to progress. Also, general corrosion in a humid environment may cause failure before the end of the useful life of the product, which is about ten years. Embodiments of the invention overcome this obstacle through the use of the continuous condenser coil, which avoids water seepage or other leaks at a joint between the cylinder coil section and the return-flow coil section of the condenser coil. Embodiments may also use a tube coating capable of preventing corrosion even if water accesses the condenser. Zinc/aluminum/chromium type coatings such as are commercially available under the GALVALUME® trademark, have been tested and found acceptable. Embodiments may also remove any galvanic coupling that negatively impacts the condenser, such as by placing a barrier such as aluminum between the tank and the steel condenser. For example, the entire condenser area may be wrapped with a thin aluminum foil before the steel condenser is wound on the tank. Embodiments may also wind the steel condenser and coat the entire tank/condenser assembly with paint or another sealant.

[0047] Return-flow condenser considerations with respect to the use of steel present similar obstacles as in the case of the use of aluminum. Steel-to-steel brazing is less robust than copper-to-copper brazing. Thus, a continuous condenser is utilized, as described above.

[0048] There are manufacturing processes to join steel to copper components such as an evaporator or compressor. Current methods include brazing. Embodiments may also utilize brazing, but perform the brazing in a nitrogen (oxygen-free) environment, which requires greater operator skill to ensure a proper joint. Embodiments of the invention overcome this obstacle by utilizing a continuous condenser on at least the tank cylinder, thus eliminating the need to join steel in the foamed/tank assembly. As a result, only joints which exist above the foam assembly are brazed and accessible for service.

[0049] Manufacturing processes to route steel tubing on the tank present similar obstacles as aluminum, as discussed above. Similar techniques are used to overcome this obstacle for steel condensers. In accordance with embodiments of the invention, the primary and return-flow condenser sections are wound in a single pass, utilizing non-kink spools at points where tubing direction changes. The spool design provides a minimum radius for the tube bend to prevent kinking or tube necking The spools also cradle the tubing to prevent stress concentrations. The spool design can also provide an insulator function between return line and heating coil windings.

[0050] Thus, embodiments of the invention provide techniques for the use of a steel condenser on a water heater tank. No brazing or other joining of the condenser tube under the foam in a tank assembly is required. Corrosion due to galvanic coupling between the condenser tubing the tank and coating of the steel tubing is reduced or minimized by preventing water or humidity from accessing or contacting the condenser and using spools at tube direction change points, which non-kink spools permit creation of a steel return-flow condenser with no joints.

[0051] Copper, aluminum and steel tubing of the condenser for a water heater should be tensioned to mate the condenser coils snugly against the water heater tank so that the condenser coils are in a heat transfer relationship with the tank. Aluminum tubing is placed under greater tension than copper, which tension is also greater than steel.

[0052] FIG. **2** is a cross-sectional view of an improved heat pump water heater **200** having a continuous aluminum or steel condenser **202**. FIG. **3** is a cross-sectional plan view of the improved heat pump water heater **200** of FIG. **2**. FIGS. **4** and **5** are each side views of a bottom section of the improved heat pump water heater **200** of FIG. **2**.

[0053] As previously described, the heat pump water heater **200** includes a cylindrical tank **204**, which may include a concave or a convex bottom. The condenser **202** wraps around the exterior of the tank **200** and includes a cylinder coil section **206**, a return-flow coil section **208**, and a transition section **209** which extends between cylinder coil section **206** and return-flow coil section **208**. Condenser **202** is a continuous coil which may be formed of any suitable material. For example, depending on the embodiment, the condenser **202** can be formed of cross-linked polyethylene (PEX), copper, aluminum, steel, or other suitable material. A layer of foam **203** surrounds the tank and condenser.

[0054] The condenser **202** may be attached to the tank **204** with one or more clips **220** and/or spools **222**, as shown in FIG. **4**. The clips **220** are elongated and secure the tubing at the beginning and endpoint of the condenser **202**. Each clip **220** is configured to cradle the condenser tubing to prevent its collapse (e.g., kinking), while creating sufficient grip to prevent slipping of the tensioned winding. If aluminum tubing is used as the condenser material, the tension applied to it will be greater than the tension used to wind copper (or steel) tubing. Each clip **220** has a channel **226** that cradles the condenser tubing against the tank **204** and prevents the condenser tubing from collapsing. FIG. **6** is a perspective view of a clip **220**. FIG. **7** is a side view of the clip **220** taken along the line A-A. The clip **220** has the channel **226** formed therein. The clip **220** also has a hole **227** formed therein, which may be used to couple the clip **220** to the tank **204**. While FIG. **7** shows an unthreaded hole **227**, the hole may be threaded in other embodiments.

[0055] As best seen in FIG. **5**, the spools **222** are positioned at points where the condenser flow path changes direction. In some embodiments, the condenser flow path changes direction at the transition section **209** between the cylinder coil section **206** and the return-flow coil section **208**. The transition section **209** is a portion of the coil that extends between the end of the cylindrical coil section and the beginning of the return-flow coil section. As shown in FIGS. **4** and **5**, spools **222** are placed at ends of the transition section **209**. The spools **222** are dimensioned to ensure that a minimum bend radius of the condenser tubing is not exceeded. Each spool **222** also includes a channel **228** that cradles the condenser tubing to prevent the tubing from collapsing. FIG. **8** is a perspective view of a spool **222**. FIG. **9** is a side view of the spool **222**. FIGS. **8** and **9** show the channel **228** formed in the spool which is used to cradle the condenser tubing and prevent the tubing from collapsing. While FIGS. **8** and **9** show a semi-circular spool **222**, the spool may be a full circle, ellipse, or other shape with an appropriate channel **228** which is desired for a given condenser arrangement.

[0056] The clips **220** and spools **222** may be metal, or molded of a suitable polymer or plastic material. One or more fasteners and/or adhesives are used to attach the clips **220** and the spools **222** to the tank **204**. In one embodiment, the fasteners are weld studs that secure the clips **220** and/or spools **222** to the tank **204**.

[0057] As shown in FIG. **5**, a strip of foam **224** may be used to insulate the return coil transition from contacting the cylinder coils **206** between spools **222** shown in FIGS. **4** and **5**. The foam strip **224** provides insulation between the cylinder coils and the return coil, as any thermal communication between the cylinder coils and the return coil reduces efficiency of the water heater. In FIG. **5**, strips of foam **224** are placed at both ends of the transition section **209** around the spools **222**. It is important to note that while FIG. **5** shows strips of foam **224** along the length of the spools **222**, in other embodiments, foam strips may extend over the entire transition section **209**. In addition, in some embodiments, the coil may not change direction at the transition section, such that strips of foam are not placed over the length of a spool.

[0058] In use, a controller **218** as shown in FIG. **3**, coupled with one or more sensors, such as a thermostat, determines when water in the tank **204** has dropped below a predetermined temperature. The controller **218** then activates the compressor **212** to move refrigerant through the condenser **202** and activates the fan **216** to draw air through the evaporator **210**. Heat from the ambient air is transferred to the refrigerant, which vaporizes and travels through the cylinder coil section **206**. The compressor **212** adds heat by pressurizing the refrigerant. As the refrigerant travels through the cylinder coil section **206**, heat is transferred to the water in the tank **204**, and some of the refrigerant begins to cool (and change state into a liquid). After passing through the cylinder coil section **206**, the refrigerant enters the return-flow coil section **208** and imparts heat to the cool water entering the tank **204** at the bottom. Thereafter, the refrigerant passes through the TXV/restrictor **214**, where it is depressurized (and thus cooled) before again entering the evaporator **210**.

[0059] Thus, in one or more embodiments, a heat pump water heater has a tank and includes a condenser coil comprising a continuously formed cylinder coil section and return-flow coil section with a transition section extending there between. The cylinder coil section is in a heat transfer relationship with the tank and encircles (or is positioned around) an upper portion of the tank. The return-flow coil section encircles (or is positioned around) a lower portion of the tank and is in a heat transfer relationship therewith. As mentioned above, the condenser coil may be formed of any suitable material. However, in one embodiment, the condenser coil is formed of a metal that is not copper (e.g., aluminum or steel).

[0060] As used herein, an element or function recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural said elements or functions, unless such exclusion is explicitly recited. Furthermore, references to "one embodiment" of the claimed invention should not be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

[0061] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to make and use the invention. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

[0062] Although specific features of the invention are shown in some drawings and not in others, this is for convenience only as each feature may be combined with any or all of the other features in accordance with the invention. The words "including", "comprising", "having", and "with" as used herein are to be interpreted broadly and comprehensively and are not limited to any physical interconnection. Moreover, any embodiments disclosed in the subject application are not to be taken as the only possible embodiments. Other embodiments will occur to those skilled in the art and are within the scope of the following claims.

What is claimed is:

1. A water heater comprising:

a tank;

a cylinder coil section in a heat transfer relationship with and encircling a first portion of the tank; and

a return-flow coil section in a heat transfer relationship with the tank and encircling a second portion of the tank;

wherein the cylinder coil section and the return-flow coil section are continuous over at least the first and second portions of the tank.

2. The water heater of claim **1**, wherein the second portion of the tank is below the first portion of the tank.

3. The water heater of claim **1**, wherein a thermal mastic compound is applied to at least one of the cylinder coil section and the return-flow coil section where the at least one of the cylinder coil section and the return-flow coil section make metal-to-metal contact with the tank.

4. The water heater of claim **1**, wherein at least one of the cylinder coil section and the return-flow coil section is subject to a tension, wherein the tension is controlled as a function of the coefficient of thermal expansion between a material of the tank and a material of the at least one of the cylinder coil section and the return-flow coil section.

5. The water heater of claim **1**, further comprising one or more clips which support a shape of a tube of at least one of the cylinder coil section and the return-flow coil section.

6. The water heater of claim **5**, wherein a given one of the one or more clips has a length sufficient to distribute a contact stress of a bracket connecting the tube and the tank.

7. The water heater of claim **1**, further comprising at least one spool placed at a point where a tube of at least one of the cylinder coil section and the return-flow coil section changes direction.

8. The water heater of claim **7**, wherein the at least one spool has a radius controlled as a function of a minimum radius for preventing at least one of kinking and necking of the tube.

9. The water heater of claim **1**, further comprising a foam layer surrounding the tank and at least a given portion of the cylinder coil section and the return-flow coil section.

10. The water heater of claim **9**, wherein the cylinder coil section and return-flow coil section are continuous over the given portion.

11. The water heater of claim **1**, wherein the cylinder coil section and return-flow coil section are formed of a non-copper material.

12. The water heater of claim **11**, wherein the non-copper material is aluminum.

13. The water heater of claim **11**, wherein the non-copper material is steel.

14. The water heater of claim **13**, wherein at least a part of at least one of the cylinder coil section and the return-flow coil section are coated with a zinc/aluminum/chromium type coating.

15. The water heater of claim **1**, wherein the tank, the cylinder coil section and the return-flow coil section are coated with a sealant.

16. The water heater of claim **1**, further comprising a transition section extending between the cylinder coil section and the return-flow coil section, wherein a strip of foam separates at least a portion of the transition section and the cylinder coil section.

17. A method for assembling a condenser of a heat pump water heater, comprising:

winding a first section of a coil around a first portion of a tank of the heat pump water heater; and

winding a second section of the coil around a second portion of the tank of the heat pump water heater,

wherein the first section of the coil comprises a cylinder coil section of the condenser and wherein the second section of the coil comprises a return-flow coil section of the condenser;

wherein the first section and the second section are continuous over at least the first and second portions of the tank.

18. The method of claim **17**, wherein the first section of the coil is wound upwards around the tank and the second section is wound downwards around the tank.

19. A condenser for a heat pump water heater, comprising:

a cylinder coil section configured to be in a heat transfer relationship with and encircle a first portion of a tank of the heat pump water heater; and

a return-flow coil section configured to be in a heat transfer relationship and encircle a second portion of the tank of the water heater,

wherein the cylinder coil section and the return-flow coil section form a continuous coil structure over at least the first and second portions of the tank.

20. A heat pump water heater comprising:

a tank; and

a condenser comprising a cylinder coil section in a heat transfer relationship with and encircling a first portion of the tank and a return-flow coil section in a heat transfer relationship with the tank and encircling a second portion of the tank,

wherein the cylinder coil section and the return-flow coil section are continuously formed.

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