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(54) Title: A MICRO-CHANNEL HEAT EXCHANGER SUITABLE FOR HEAT PUMP WATER HEATER AND THE MANUFACTURING METHOD

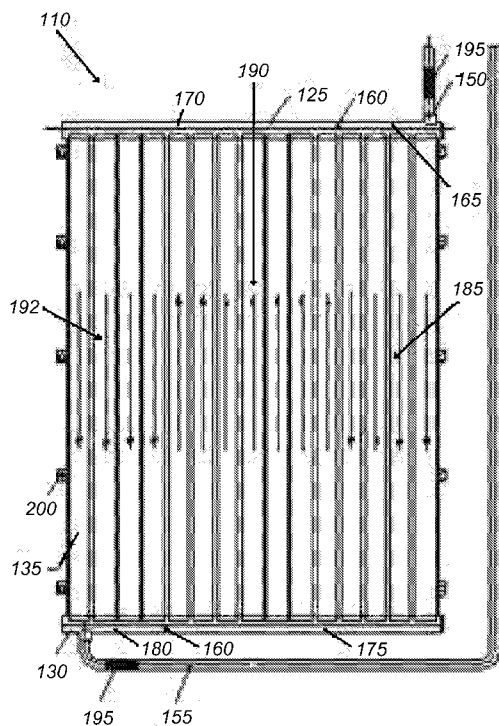


Figure 1

(57) Abstract: A heat exchanger for use with a heat pump water heater, the heat exchanger including a first header, a second header, multiple heat exchange tubes extending between the first header and the second header, an inlet pipe connected to the first header, a discharge pipe connected to at least one of the first header and the second header, and a bulkhead positioned in the first header. Each of the heat exchange tubes is curved and includes a flat surface. The bulkhead is positioned such that a circuitous flow path is formed between the first header and the second header. The flow path is configured so that refrigerant flows from the first header to the second header through a first set of heat exchange tubes and then from the second header to the first header through a second set of heat exchange tubes.



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A Micro-channel Heat Exchanger Suitable for Heat Pump Water Heater and the Manufacturing Method

BACKGROUND

[0001] This invention relates to a heat exchanger, in particular to a heat exchanger suitable for use with a heat pump water heater as well as its manufacturing method, a combination heat exchanger and water storage tank for use with a heat pump water heater, and a heat pump water heater.

SUMMARY

[0002] Because a heat pump water heater utilizes the air's heat energy, it has energy saving advantages compared to traditional electrical water heaters and gas water heaters. As investigated by the applicant, typical heat exchangers of existing heat pump water heaters use circular tubes which are wound around the water storage tank. Because the contact between the circular tube and the water storage tank is line contact in theory, the heat exchange efficiency is not high. Additionally, because special equipment to wind the tube must be manufactured, the manufacturing technology is complicated and the production efficiency is low and so it can't satisfy the mass production requirement.

[0003] Searching found that the China Patent application number 00920300520.9 disclosed a heat exchanger used for heat pump water heater which adopts micro-channel flat tube. However, this technology proposal still has the following problems to be solved: 1) its flat tube adopts single-wrap or double-wrap mode, which still needs special production equipment and the production efficiency is very low; 2) the flat tube is rather long and will lose rather high pressure; 3) it requires manual aluminum welding so the welding reliability is difficult to be ensured.

[0004] The goal of this invention is to address the above-mentioned shortcomings of existing technology, by putting forward a micro-channel heat exchanger suitable for heat pump water heater which has low pressure loss, high heat exchange efficiency, a simple manufacturing process and to provide the manufacturing method.

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[0005] To achieve the above goals, the micro-channel heat exchanger suitable for heat pump water heater of this invention includes the first and second headers and the said first and second headers are generally connected by parallel micro-channel tubes with flat cross section; the said heat exchanger is shaped to contain the water heater's water storage tank; during assembling, the said first and second headers are respectively connected to the circulation loop of the heat pump by the inlet pipe and discharge pipe; there is at least one bulkhead in the said first and/or second header to form the circuitous flow path from the first header to the second header through the first set of micro-channel tubes and then from the second header to the first header through the second set of micro-channel tubes, which is connected to the said discharge pipe in the end.

[0006] The further improvement of this invention is that after the said micro-channel tube is shaped, its surface is attached to the water heater's water storage tank.

[0007] The further improvement of this invention is that in the micro-channel tubes of flat cross section, the total flow area of the former set of micro-channel tubes is always larger than the total flow area of the latter set of tubes. It is not only coincident to the decreasing trend of the heat exchange medium volume in the heat exchange process, but also beneficial to produce turbulence of the medium in the flow process and increase heat exchange efficiency.

[0008] There are mainly three kinds of detailed structures of the micro-channel heat exchanger of this invention: horizontal micro-channel heat exchanger structure with even number of flow paths (for example, the number of tubes forming the flow paths is 8-6-4-4) and so both the heat exchanger's inlet and outlet are on the same header; horizontal micro-channel heat exchanger structure with odd number of flow paths (for example, the number of tubes forming flow paths is 10-10-3) and so the heat exchanger's inlet and outlet are installed on the left and right headers; and vertical micro-channel heat exchanger structure whose inlet and outlet are always on the two headers. Such kinds of heat exchanger structures effectively solve the phenomena of layered water temperature and can bear rather high pressure. Because the heat exchange area of the micro-channel heat exchanger is rather large, the required refrigerant volume is effectively reduced and because aluminum is relatively cheaper, the cost is saved.

[0009] The manufacturing may be done as the following steps: Step 1: Length calculating and blanking of the first and second headers and the micro-channel tubes with flat cross section; Step

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2: Fixing even-distributed bulkheads at the desired positions in the first and second headers; Step 3: Punching slotted holes at the corresponding positions in the first and second headers whose shape is matched with the profile of the said flat cross section, in particular, the slotted holes shall have depressed flange; Step 4: Plug the two ends of the micro-channel tubes into the corresponding depressed-flanged slotted holes of the first and second headers and then fix by welding; Step 5: Shape the heat exchanger to the shape which may contain the water heater's water storage tank.

[0010] In service, to form the heat pump heat exchange system, it needs only to wrap the heat exchanger of this invention onto the water storage tank of the heat pump water heater and connect to the heat pump circulation loop by the inlet pipe and discharge pipe. Because the surface of the micro-channel tubes is flat, they may contact with the water storage tank's surface by surface contact and multi micro-channels may work at the same time as required which therefore effectively increase the heat exchanger's heat exchange efficiency. The manufacturing technology is simple; the quality may be ensured; the working hours of manufacturing is remarkably shortened; the product efficiency is increased; the required refrigerant volume is reduced; and its pressure bearing capacity is better than existing circular heat exchanger so it is safer and more reliable under high pressure working conditions.

[0011] The present invention provides, in one aspect, a combination heat exchanger and water storage tank for use with a heat pump water heater. The heat exchanger includes a first header, a second header, multiple heat exchange tubes extending between the first header and the second header, an inlet pipe connected to the first header, a discharge pipe connected to at least one of the first header and the second header, and a bulkhead positioned in the first header between a first set of heat exchange tubes and a second set of heat exchange tubes. Each of the heat exchange tubes is curved and includes a flat surface. The heat exchange tubes are divided into at least two sets of heat exchange tubes. The inlet pipe is configured to receive refrigerant. The discharge pipe is configured to discharge refrigerant. The bulkhead is positioned such that a circuitous flow path is formed between the first header and the second header. The flow path is configured so that refrigerant flows from the first header to the second header through the first set of heat exchange tubes and then from the second header to the first header through the second set of heat exchange tubes. The water storage tank includes a curved outer surface. The heat

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exchanger is secured to the water storage tank such that the flat surfaces of the heat exchange tubes are in contact with the curved outer surface in a heat exchange relationship.

[0012] The present invention provides, in another aspect, a heat exchanger for use with a heat pump water heater. The heat exchanger includes a first header, a second header, multiple heat exchange tubes extending between the first header and the second header, an inlet pipe connected to the first header, a discharge pipe connected to at least one of the first header and the second header, and a bulkhead positioned in the first header between a first set of heat exchange tubes and a second set of heat exchange tubes. Each of the heat exchange tubes is curved and includes a flat surface. The heat exchange tubes are divided into at least two sets of heat exchange tubes. The inlet pipe is configured to receive refrigerant. The discharge pipe is configured to discharge refrigerant. The bulkhead is positioned such that a circuitous flow path is formed between the first header and the second header. The flow path is configured so that refrigerant flows from the first header to the second header through the first set of heat exchange tubes and then from the second header to the first header through the second set of heat exchange tubes.

[0013] The present invention provides, in another aspect, a method of manufacturing a heat exchanger for use with a heat pump water heater. The method includes the following steps. Forming a first header and a second header. Forming multiple heat exchange tubes with each tube including a flat surface. Securing a bulkhead within one of the first header and the second header to divide the one of the first header and the second header into two parts. Forming first holes in the first header with the first holes configured to receive the heat exchange tubes. Forming second holes in the second header with the second holes positioned in the second header to correspond to the first holes and the second holes configured to receive the heat exchange tubes. Inserting each of the heat exchange tubes into a corresponding first hole and second hole so that the heat exchange tubes extend between the first header and the second header. Securing each heat exchange tube to the first header and to the second header. Shaping the heat exchange tubes into a curved shape so that the heat exchange tubes are configured to be secured to a water storage tank having a curved outer surface such that the flat surfaces of the heat exchange tubes are in contact with the curved outer surface in a heat exchange relationship.

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[0014] The present invention provides, in another aspect, a heat pump water heater including a compressor, a water storage tank having a curved outer surface, a heat exchanger secured to the water storage tank, an expansion device, and an evaporator. The compressor, the heat exchanger, the expansion device, and the evaporator are connected in series. The heat exchanger includes a first header, a second header, multiple heat exchange tubes extending between the first header and the second header, an inlet pipe connected to the first header, a discharge pipe connected to at least one of the first header and the second header, and a bulkhead positioned in the first header between a first set of heat exchange tubes and a second set of heat exchange tubes. Each of the heat exchange tubes is curved and includes a flat surface. The heat exchange tubes are divided into at least two sets of heat exchange tubes. The inlet pipe is configured to receive refrigerant from the compressor. The discharge pipe is configured to discharge refrigerant to the expansion device. The bulkhead is positioned such that a circuitous flow path is formed between the first header and the second header. The flow path is configured so that refrigerant flows from the first header to the second header through the first set of heat exchange tubes and then from the second header to the first header through the second set of heat exchange tubes. The heat exchanger is secured to the water storage tank such that the flat surfaces of the heat exchange tubes are in contact with the curved outer surface in a heat exchange relationship.

[0015] Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Fig. 1 is a front view of a heat exchanger before bending the heat exchange tubes.

[0017] Fig. 2 is a front view of a second embodiment of a heat exchanger before bending the heat exchange tubes.

[0018] Fig. 3 is side view of a header of Fig. 1.

[0019] Fig. 4 is a sectional view of the header of Fig. 3 along line 4-4.

[0020] Fig. 5 is a sectional view of the header of Fig. 3 including a limit core rod.

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[0021] Fig. 6 is a sectional view of the header of Fig. 3 including a limit core rod and a heat exchange tube.

[0022] Fig. 7 is a sectional view of the header of Fig. 3 including a heat exchange tube.

[0023] Fig. 8 is a front view of a third embodiment of a heat exchanger before bending the heat exchange tubes.

[0024] Fig. 9 is a front view of a fourth embodiment of a heat exchanger before bending the heat exchange tubes.

[0025] Fig. 10 is a front view of a fifth embodiment of a heat exchanger before bending the heat exchange tubes.

[0026] Fig. 11 is a side view of the heat exchanger of Fig. 10 after bending of the heat exchange tubes and secured to a water storage tank.

[0027] Fig. 12 is a front view of the heat exchanger and water storage tank of Fig. 11.

[0028] Fig. 13 is a schematic view of a heat pump water heater.

DETAILED DESCRIPTION

[0029] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways.

[0030] Figure 13 illustrates a heat pump water heater 100 that includes a compressor 105, a heat exchanger or condenser 110, an expansion device 115, and an evaporator 120 connected in series. The heat pump water heater 100 functions according to a vapor-compression heat pump cycle.

[0031] Figure 1 illustrates the unfolded structure of the micro-channel heat exchanger 110 suitable for use with the heat pump water heater 100. The heat exchanger 110 includes a first

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header 125 and the second header 130 and the first and second headers are connected by parallel heat exchange tubes 135, each having a flat cross section created by at least one flat surface (for example, micro-channel flat tubes). As shown, the heat exchange tubes 135 are vertical to the headers 125, 130. In shaping, the heat exchanger 110 is bent to a shape which may contain a water storage tank 140 having a curved outer surface 145 (as shown in Figs. 11-12). The curved outer surface 145 can be, for example, a cylinder. This shaping bends the heat exchange tubes 135 so that each heat exchange tube 135 is curved. During assembling, the first header 125 and the second header 130 are respectively connected to the rest of the heat pump water heater 100 through an inlet pipe 150 and a discharge pipe 155. A bulkhead 160 positioned in the first header 125 separates the first header 125 into a first part 165 and a second part 170. A second bulkhead 160 separates the second header 130 into a first part 175 and a second part 180. A circuitous flow path is formed through the heat exchanger 110 so that refrigerant flows from the first part 165 of the first header 125 to the first part 175 of the second header 130 through a first set 185 of micro-channel tubes 135, and then from the first part 175 of the second header 130 to the second part 170 of the first header 125 through a second set 190 of micro-channel tubes 135, and then from the second part 170 of the first header 125 to the second part 180 of the second header 130 through a third set 192 of micro-channel tubes 135, and finally to the discharge pipe 155. An adapter or connector 195 is provided on the inlet pipe 150 and the discharge pipe 155 as needed. Installation supports 200 are provided as needed.

[0032] The heat exchanger 110 adopting micro-channel flat tubes 135 can be welded in a furnace thanks to its design structure, which may effectively ensure the welding quality and increase the manufacturing rate of finished products. Welding can also encompass brazing and soldering. The micro-channel flat tubes 135 may effectively reduce the material consumption of the heat exchanger 110 under the same amount of heat exchange, lower manufacturing cost, reduce required refrigerant volume, and improve pressure bearing capacity over known heat exchangers having circular heat exchange tubes, which makes the heat exchanger 110 is safer and more reliable under high pressure working conditions.

[0033] The manufacturing may be done as the following steps. Step 1: Calculate the needed length of the first header 125, the second header 130, and the micro-channel tubes 135 with flat cross section and then form these components (for example by blanking; and make flux rings

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205 (shown in Fig. 6) whose inner bore shape matches with the outside profile of the micro-channel flat tubes 135 (the fit clearance ought to be within 0.1mm (0.003937 inch) $\pm 0.02\text{mm}$ (0.0007874 inch)). The flux rings 205 shall have suitable fusion temperature and fluidity and the potential difference between it and the base metal shall be as small as possible.

[0034] Step 2: Fix bulkheads 160 at the desired positions in the first header 125 and the second header 130 as needed.

[0035] Step 3: Form holes 210 (for example, with a stamping die) with depressed flange 215 (or holes 210 without flange 215) at positions in the first header 125 and the second header 130 so that the holes 210 in the first header 125 mirror or correspond to the holes 210 in the second header 130. The shape of each hole 210 shall match with the cross sectional profile of the micro-channel tubes 135.

[0036] Step 4: First, clean the base metal of the heat exchange tubes 135, the first header 125, and the second header 130 with a cleanout fluid to totally remove the grease, dust and other impurities on the surface of the base metal. If there is oxidation layer on the surfaces to be welded, it shall be polished and then cleaned. Next, insert a limit core rod 220 with arched cross section into the header 125, 130 (as shown in Fig. 5). The length of the core rod is calculated based on the number of holes 210 in the header 125, 130 and the thickness of the core rod 220 is determined by the required insertion depth of the flat tubes 135. The core rod 220 ensures the insertion depth of the flat tubes 135 and also ensures a consistent height of all the micro-channel flat tubes 135 in the header 125, 130. Next, fasten the header 125, 130 on a fixture with the holes 210 facing upward, put the flux rings 205 onto the micro-channel flat tubes 135, and then insert an end of each tube 135 into the holes 210 of the first header 125 and the second header 130 respectively until the tubes 135 contact the limit core rod 220 (as shown in Fig. 6). Fasten the other end of the micro-channel flat tubes 135 in a similar manner in a second fixture and ensure the tubes 135 and the headers 125, 130 to be a whole and have been fixed reliably. Finally, put the headers 125, 130 which are assembled with micro-channel flat tubes 135 and flux rings 205 into a vacuum high temperature furnace to be welded. Based on the base metal and soldering flux's melting point, by adjusting the furnace temperature to appropriate temperature, the work piece and the soldering flux may be heated to the temperature higher than the soldering flux's

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melting point but lower than the work piece's melting point. In favor of capillarity, the flux rings 205 will melt and permeate into the gap between the heat exchange tubes 135 and the header 125, 130 to form welds 207 as shown in Fig. 7. The welding position of the flat tubes 135 and the header 125, 130 is heated from two directions which are 180 degrees apart in the vacuum high temperature furnace to ensure even heating of the welding position.

[0037] Step 5: Bend the heat exchanger 110 to the shape which may contain the water storage tank 140 of the water heater 100, sand blast the welding positions, and then seal the welding positions with epoxy resin to protect the welding seams.

[0038] In step 1, if a layer of flux is covered on the surface of the header 125, 130, the flux ring 205 may be cancelled but the cost will be higher. In step 5, if the welding positions on the micro-channel tubes 135 are covered by insulation provided between the water storage tank and a jacket so that the welding positions are not exposed to the air, the welding positions need not to be sealed by epoxy resin, which may lower cost.

[0039] The micro-channel heat exchanger 110 produced by the above-mentioned technology has fewer welding points, the welding seam width is more uniform and the welding seam strength is higher than known heat exchangers for use with heat pump water heaters, so the heat exchanger 110 may bear high system pressure and can satisfy the service requirement of condensation heat exchange for a heat pump water heater 100. Additionally, the heat exchanger 110 is easy to mass produce by automatic production line so that quality can be ensured and the production efficiency may be remarkably increased.

[0040] Figure 2 illustrates the unfolded structure of a second embodiment of the micro-channel heat exchanger 110 suitable for heat pump water heater 100. In the embodiment of Fig. 1, there is a single bulkhead 160 in the first header 125, which therefore forms an odd number of flow paths through the heat exchange tubes 130 and requires the inlet pipe 150 and the discharge pipe 155 be secured to different headers 125, 130. In the second embodiment (Fig. 2) there are two bulkheads 160 in the first header 125 this embodiment, which therefore forms an even number of flow paths through the heat exchange tubes 135 and requires the inlet pipe 150 and the discharge pipe 155 be secured to the first header 125.

[0041] Figure 8 illustrates the unfolded structure of a third embodiment of the micro-channel heat exchanger 110 suitable for heat pump water heater 100. The third embodiment (Fig. 8) is similar to the second embodiment (Fig. 2), with a difference being that the parallel micro-channel tubes 135 connecting the headers 125, 130 are oriented horizontally. The inlet pipe 150 and discharge pipe 155 are secured to the first header 125. In shaping, the heat exchanger 110 is bent to the shape which may contain a horizontally oriented water storage tank 140. In particular, in the micro-channel tubes 135 with flat cross section, the number of tubes 135 which form each of the flow paths is 4-3-2-1, so the total flow area of the first set of tubes 135 is always larger than the total flow area of the last set of tubes 135. By means of bulkheads 160 in the headers 125, 130, a circuitous flow path having multiple sets of tubes 135 is created. The flow area of each set of tubes 135 decreases as refrigerant passes through the sets in the circuitous flow path. This decrease in flow area is not only coincident to the decreasing trend of the heat exchange medium volume in the heat exchange process, but also beneficial to produce turbulence of the medium in the flow process and increase heat exchange efficiency.

[0042] Figure 9 illustrates the unfolded structure of a fourth embodiment of the micro-channel heat exchanger 110 suitable for heat pump water heater 100. The fourth embodiment (Fig. 9) is similar to the third embodiment (Fig. 8) with a difference being that number of flow paths is odd, so that the inlet pipe 150 and the discharge pipe 155 are secured to different headers 125, 130.

[0043] Figure 10 illustrates the unfolded structure of a fifth embodiment of the micro-channel heat exchanger 110 suitable for heat pump water heater 100. Figures 11-12 illustrate the heat exchanger 110 shaped in semicircular arc and wrapped around the water storage tank 140 of the water heater 100. Because the flat surfaces of the heat exchange tubes 135 are in contact with the curved outer surface 145 of the water storage tank 140 by being curved in a semicircular arc, a heat-exchange relationship is established between the water storage tank 140 and the heat exchange tubes 135. Because the heat exchange tubes 135 extend about halfway around the curved outer surface 145, the heat exchange tubes are in contact with the middle and lower part of the curved outer surface 145 such that the water in the water storage tank 140 can be evenly heated and counter flow heat exchange is strengthened.

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[0044] As shown in Figs. 11-12, the heat exchanger 110 includes aluminum headers 125, 130 and micro-channel flat tubes 135. The inlet pipe 150 is secured to the first header 125 and the discharge tube 155 is secured to the second header 130. Bulkheads 160 in the headers 125, 130 separate the refrigerant into several flow paths, which solves the uneven distribution problem of the refrigerant. The micro-channel heat exchanger 110 is installed at the lower half of the water storage tank 140 and the heat exchange tubes 135 are closely attached to the curved outer surface 145 by fixture. Because the cold water enters from the wall of the water storage tank 140, the counter flow heat exchange is effectively strengthened compared with known spiral single path heat exchangers, which makes the hot water to be heated very uniformly and the layered temperature effect will not happen.

[0045] The first headers 125 of the first embodiment (Fig. 1) and the second embodiment (Fig. 2) are connected with the second headers 130 by vertical micro-channel tubes 135 and the micro-channel tubes are shaped to contain the water storage tank 140 of a vertical water heater. The first headers 125 of the third embodiment (Fig. 8), the fourth embodiment (Fig. 9), and the fifth embodiment (Fig. 10) are connected with the second headers 130 by horizontal micro-channel tubes 135 and the micro-channel tubes are shaped to totally or locally contain the water storage tank 140 of a horizontal water heater.

[0046] Besides above-mentioned embodiments, this invention also has other implementation modes. For example, the heat exchanger 110 may also be shaped to in a complete or nearly-complete circular arc. Additionally, the heat exchanger 110 may be locally wrapped around a water storage tank from the bottom up. Any technology adopting identical substitution or equivalent alteration belongs to the protection domain claimed by this invention.

[0047] Various features and advantages of the invention are set forth in the following claims.

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CLAIMS

What is claimed is:

1. A combination heat exchanger and water storage tank for use with a heat pump water heater, comprising:

a heat exchanger including,

a first header,

a second header,

a plurality of heat exchange tubes extending between the first header and the second header, each of the plurality of heat exchange tubes is curved and includes a flat surface, and the plurality of heat exchange tubes is divided into at least two sets of heat exchange tubes,

an inlet pipe connected to the first header, the inlet pipe configured to receive refrigerant,

a discharge pipe connected to at least one of the first header and the second header, the discharge pipe configured to discharge refrigerant, and

a bulkhead positioned in the first header between a first set of heat exchange tubes and a second set of heat exchange tubes such that a circuitous flow path is formed between the first header and the second header, the flow path configured so that refrigerant flows from the first header to the second header through the first set of heat exchange tubes and then from the second header to the first header through the second set of heat exchange tubes; and

a water storage tank including a curved outer surface;

wherein the heat exchanger is secured to the water storage tank such that the flat surfaces of the heat exchange tubes are in contact with the curved outer surface in a heat exchange relationship.

2. The combination heat exchanger and water storage tank of claim 1, wherein the curved outer surface is cylindrical and the heat exchange tubes extend about halfway around the curved outer surface.

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3. The combination heat exchanger and water storage tank of claim 1, wherein a cross-sectional flow area of the first set of heat exchange tubes is greater than a cross-sectional flow area of the second set of heat exchange tubes.

4. The combination heat exchanger and water storage tank of claim 1, wherein the heat exchanger further includes a second bulkhead positioned in the second header between the second set of heat exchange tubes and a third set of heat exchange tubes;

wherein the plurality of heat exchange tubes is divided into an odd number of sets of heat exchange tubes such that the circuitous flow path is configured so that refrigerant flows from the first header to the second header through the first set of heat exchange tubes, then from the second header to the first header through the second set of heat exchange tubes, and then from the first header to the second header through the third set of heat exchange tubes; and

wherein the discharge pipe is connected to the second header.

5. The combination heat exchanger and water storage tank of claim 1, wherein the plurality of heat exchange tubes is divided into an even number of sets of heat exchange tubes; and wherein the discharge pipe is connected to the first header.

6. The combination heat exchanger and water storage tank of claim 1, wherein substantially the entire flat surface of each of the heat exchange tubes is in contact with the curved outer surface.

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7. A heat exchanger for use with a heat pump water heater, the heat exchanger comprising:
 - a first header;
 - a second header;
 - a plurality of heat exchange tubes extending between the first header and the second header, each of the plurality of heat exchange tubes is curved and includes a flat surface, and the plurality of heat exchange tubes is divided into at least two sets of heat exchange tubes;
 - an inlet pipe connected to the first header, the inlet pipe configured to receive refrigerant;
 - a discharge pipe connected to at least one of the first header and the second header, the discharge pipe configured to discharge refrigerant; and
 - a bulkhead positioned in the first header between a first set of heat exchange tubes and a second set of heat exchange tubes such that a circuitous flow path is formed between the first header and the second header, the flow path configured so that refrigerant flows from the first header to the second header through the first set of heat exchange tubes and then from the second header to the first header through the second set of heat exchange tubes.
8. The heat exchanger of claim 7, wherein a cross-sectional flow area of the first set of heat exchange tubes is greater than a cross-sectional flow area of the second set of heat exchange tubes.
9. The heat exchanger of claim 7, further comprising:
 - a second bulkhead positioned in the second header between the second set of heat exchange tubes and a third set of heat exchange tubes;
 - wherein the plurality of heat exchange tubes is divided into an odd number of sets of heat exchange tubes such that the circuitous flow path is configured so that refrigerant flows from the first header to the second header through the first set of heat exchange tubes, then from the second header to the first header through the second set of heat exchange tubes, and then from the first header to the second header through the third set of heat exchange tubes; and
 - wherein the discharge pipe is connected to the second header.

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10. The heat exchanger of claim 7,
wherein the plurality of heat exchange tubes is divided into an even number of sets of heat exchange tubes; and wherein the discharge pipe is connected to the first header.
11. The heat exchanger of claim 7, wherein the plurality of heat exchange tubes are configured to be secured to a water storage tank having a curved outer surface such that the flat surfaces of the heat exchange tubes are in contact with the curved outer surface in a heat exchange relationship.
12. The heat exchanger of claim 11, wherein the plurality of heat exchange tubes are configured such that substantially the entire flat surface of each of the heat exchange tubes is in contact with the curved outer surface.

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13. A method of manufacturing a heat exchanger for use with a heat pump water heater, comprising:

- forming a first header and a second header;
- forming a plurality of heat exchange tubes, each tube including a flat surface;
- securing a bulkhead within one of the first header and the second header to divide the one of the first header and the second header into two parts;
- forming first holes in the first header, the first holes configured to receive the heat exchange tubes;
- forming second holes in the second header, the second holes positioned in the second header to correspond to the first holes, and the second holes configured to receive the heat exchange tubes;
- inserting each of the heat exchange tubes into a corresponding first hole and second hole so that the heat exchange tubes extend between the first header and the second header;
- securing each heat exchange tube to the first header and to the second header;
- shaping the heat exchange tubes into a curved shape so that the heat exchange tubes are configured to be secured to a water storage tank having a curved outer surface such that the flat surfaces of the heat exchange tubes are in contact with the curved outer surface in a heat exchange relationship.

14. The method of claim 13, further comprising:

- inserting a first limit core rod into the first header to limit the depth of insertion of the heat exchange tubes into the first header.

15. The method of claim 14, further comprising:

- inserting a second limit core rod into the second header to limit the depth of insertion of the heat exchange tubes into the second header.

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16. The method of claim 13, further comprising:
- providing a plurality of flux rings, each flux ring having an inner bore shape that matches an outside profile of the heat exchange tubes;
 - positioning a flux ring on each heat exchange tube prior to inserting the heat exchange tube into a first hole;
 - after inserting each heat exchange tube into a first hole, positioning the flux ring against the first header;
 - then heating the first header, the heat exchange tubes, and the flux rings so that the flux rings melt to weld the heat exchange tubes to the first header.

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17. A heat pump water heater comprising:

a compressor;

a water storage tank including a curved outer surface;

a heat exchanger secured to the water storage tank, the heat exchanger including,

a first header.

a second header,

a plurality of heat exchange tubes extending between the first header and the second header, each of the plurality of heat exchange tubes is curved and includes a flat surface, and the plurality of heat exchange tubes is divided into at least two sets of heat exchange tubes,

an inlet pipe connected to the first header, the inlet pipe configured to receive refrigerant from the compressor,

a discharge pipe connected to at least one of the first header and the second header, the discharge pipe configured to return refrigerant to the expansion device, and

a bulkhead positioned in the first header between a first set of heat exchange tubes and a second set of heat exchange tubes such that a circuitous flow path is formed between the first header and the second header, the flow path configured so that refrigerant flows from the first header to the second header through the first set of heat exchange tubes and then from the second header to the first header through the second set of heat exchange tubes;

an expansion device; and

an evaporator;

wherein the compressor, the heat exchanger, the expansion device, and the evaporator are connected in series; and

wherein the heat exchanger is secured to the water storage tank such that the flat surfaces of the heat exchange tubes are in contact with the curved outer surface in a heat exchange relationship.

18. The heat pump water heater of claim 17, wherein the heat exchange tubes extend about halfway around the curved outer surface.

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19. The heat pump water heater of claim 17, wherein a cross-sectional flow area of the first set of heat exchange tubes is greater than a cross-sectional flow area of the second set of heat exchange tubes.

20. The heat pump water heater of claim 17, wherein substantially the entire flat surface of each of the heat exchange tubes is in contact with the curved outer surface.

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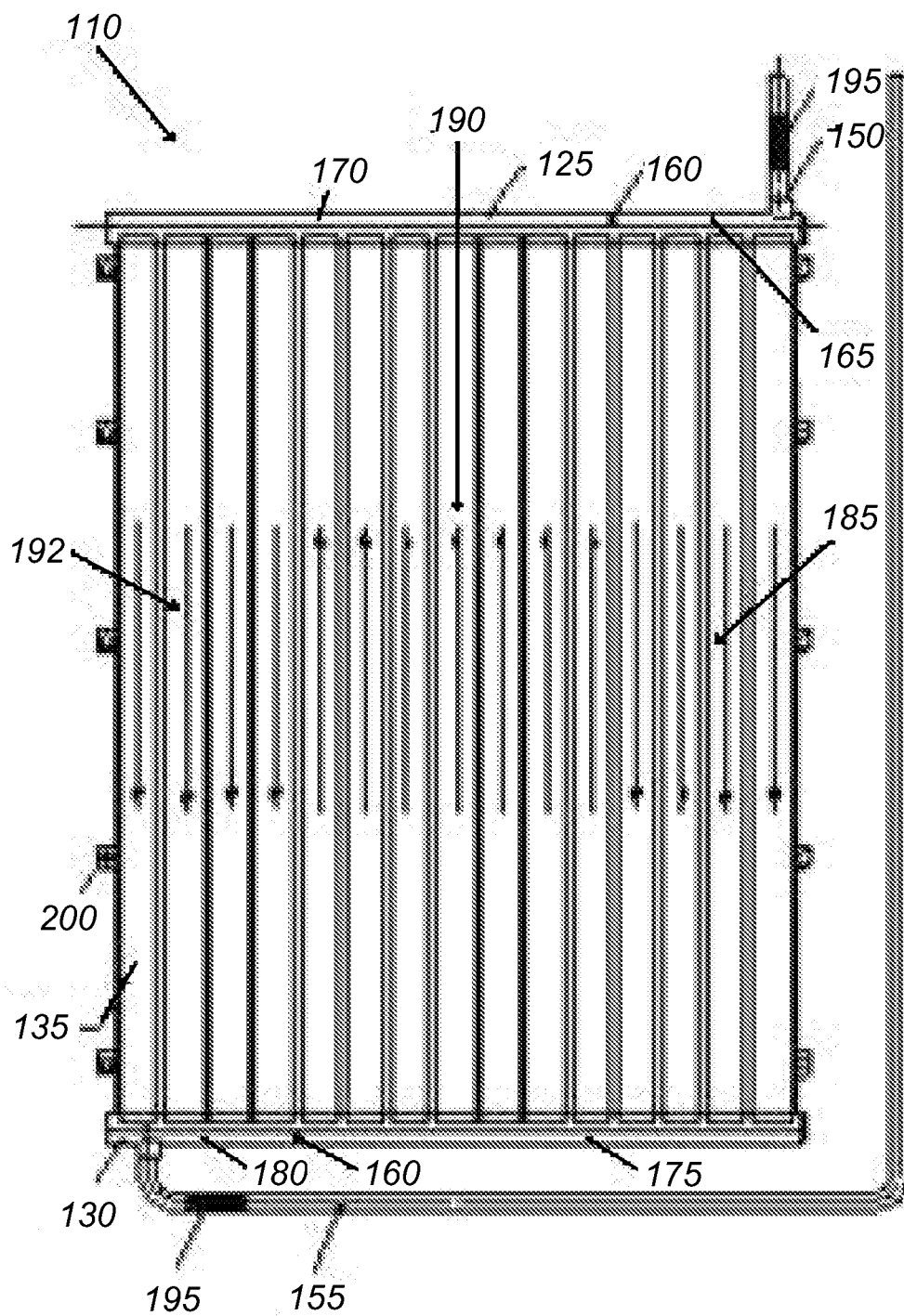


Figure 1

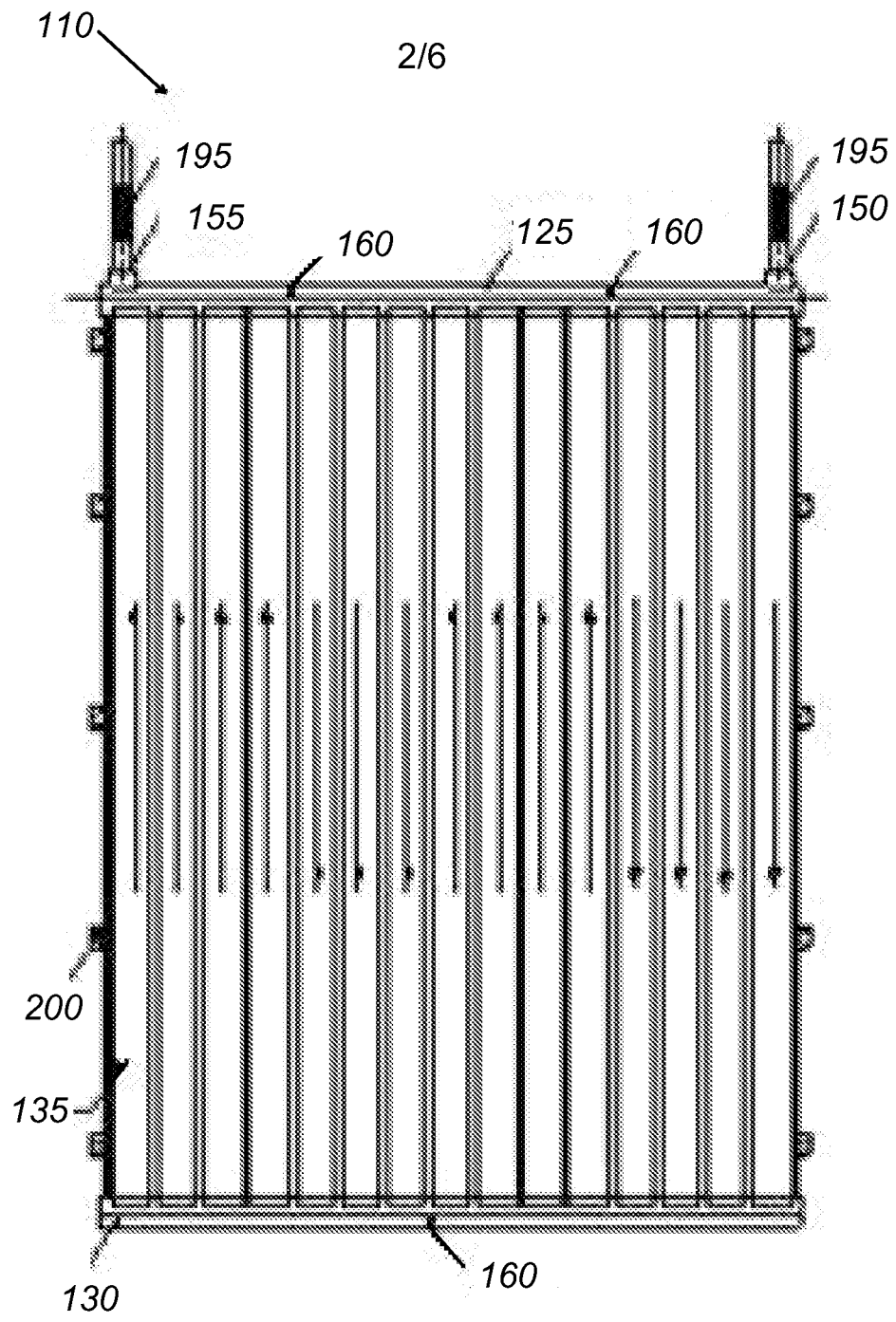
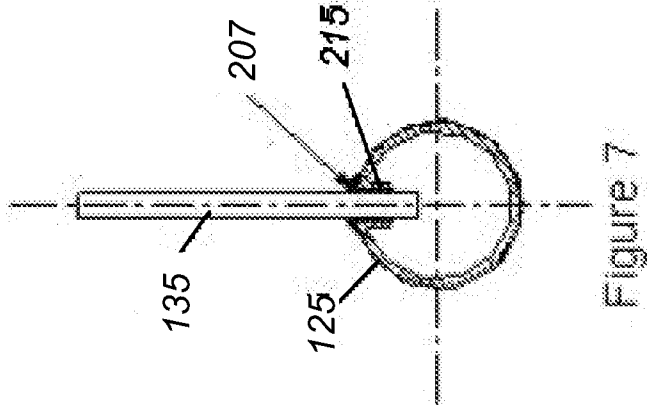
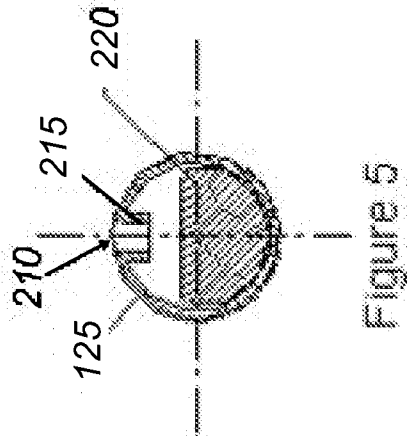
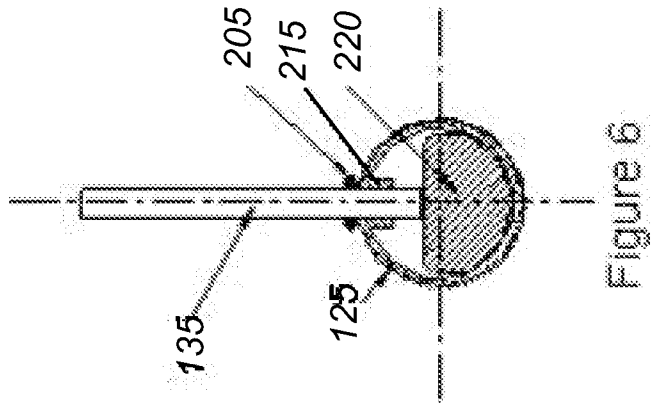
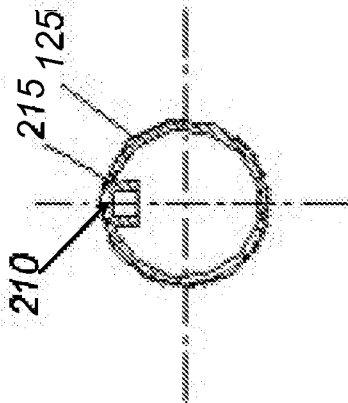
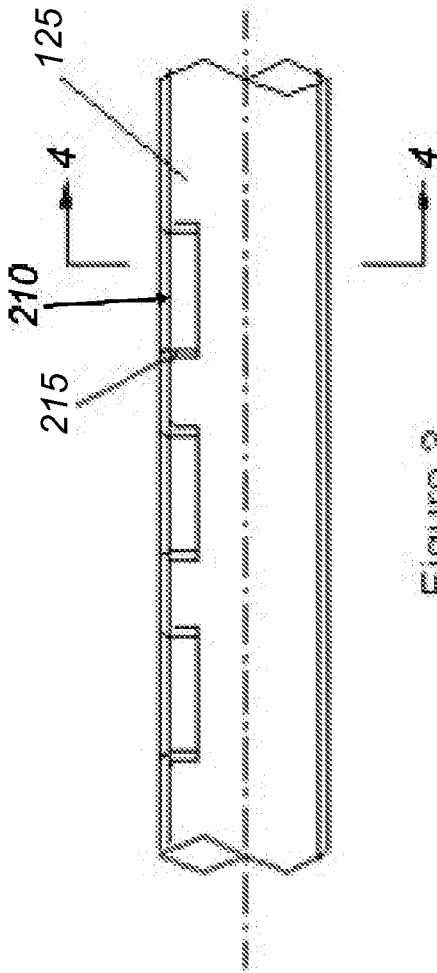


Figure 2



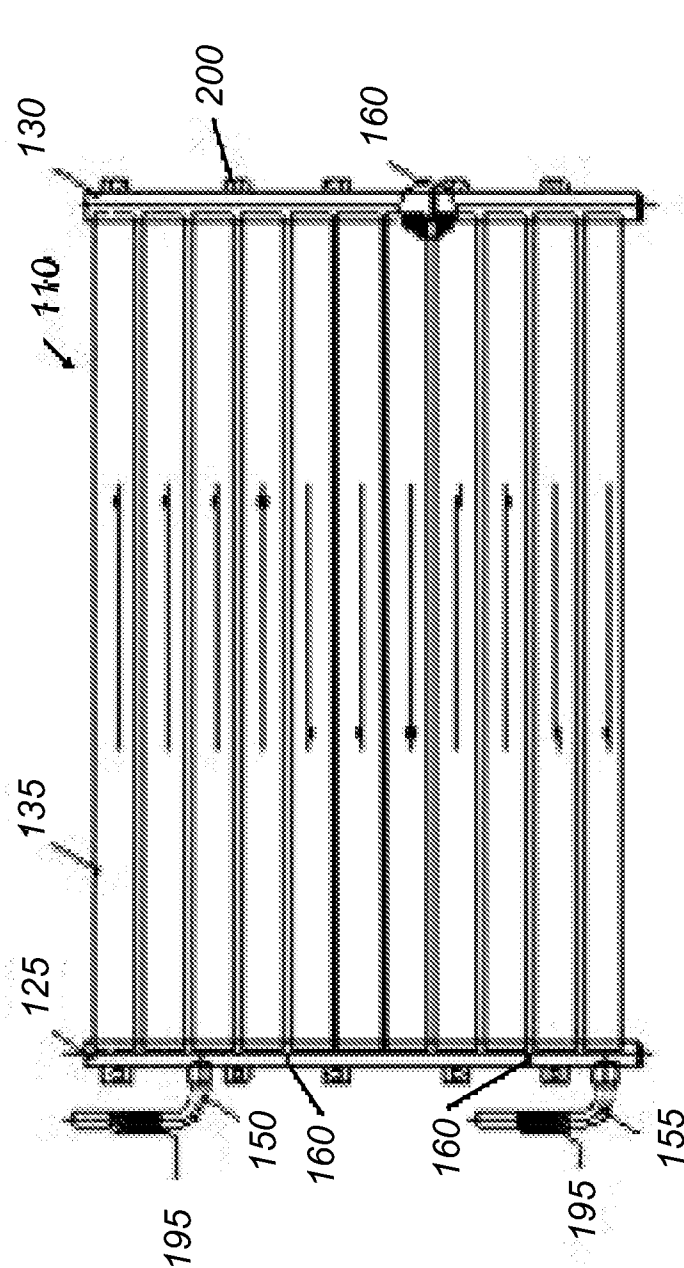


Figure 8

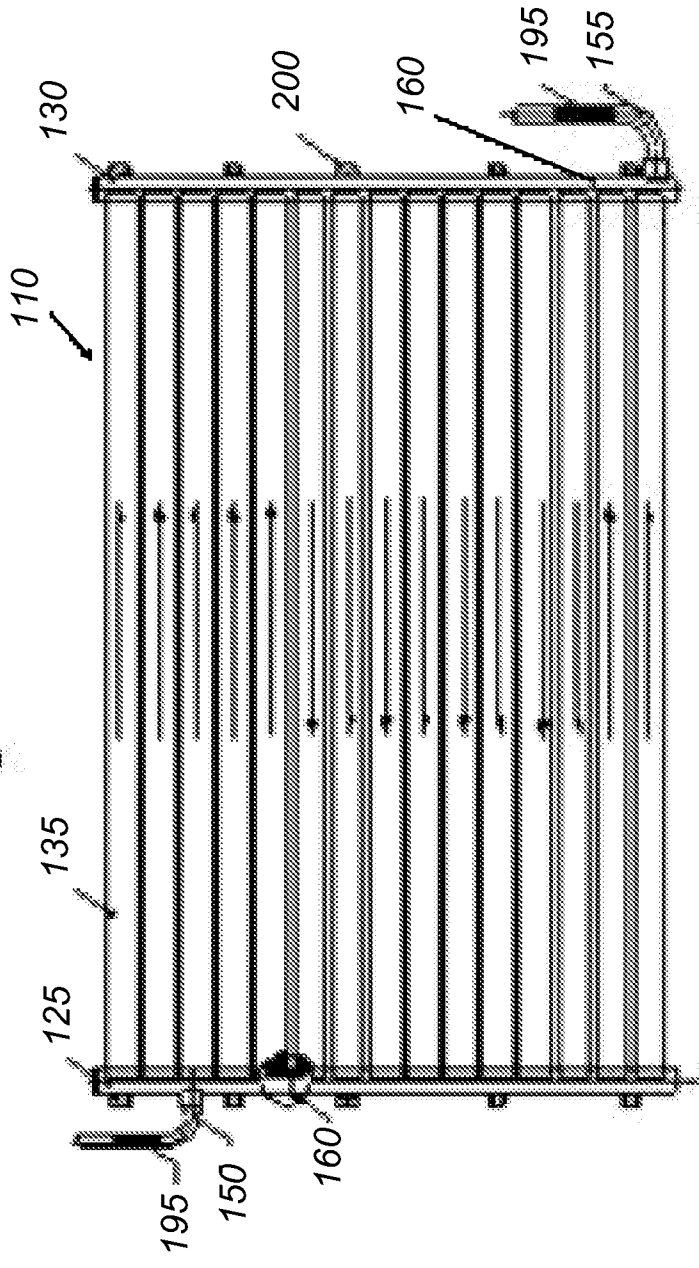


Figure 9

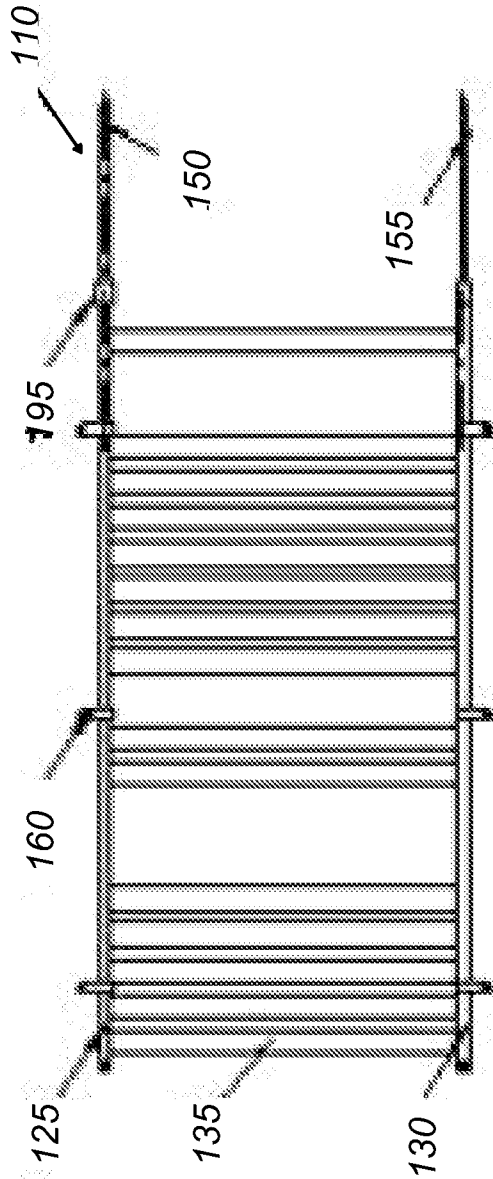


Figure 10

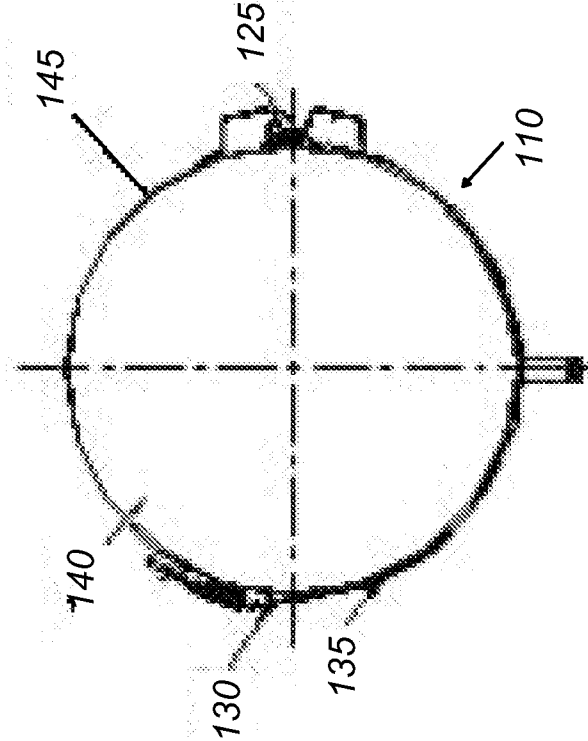


Figure 11

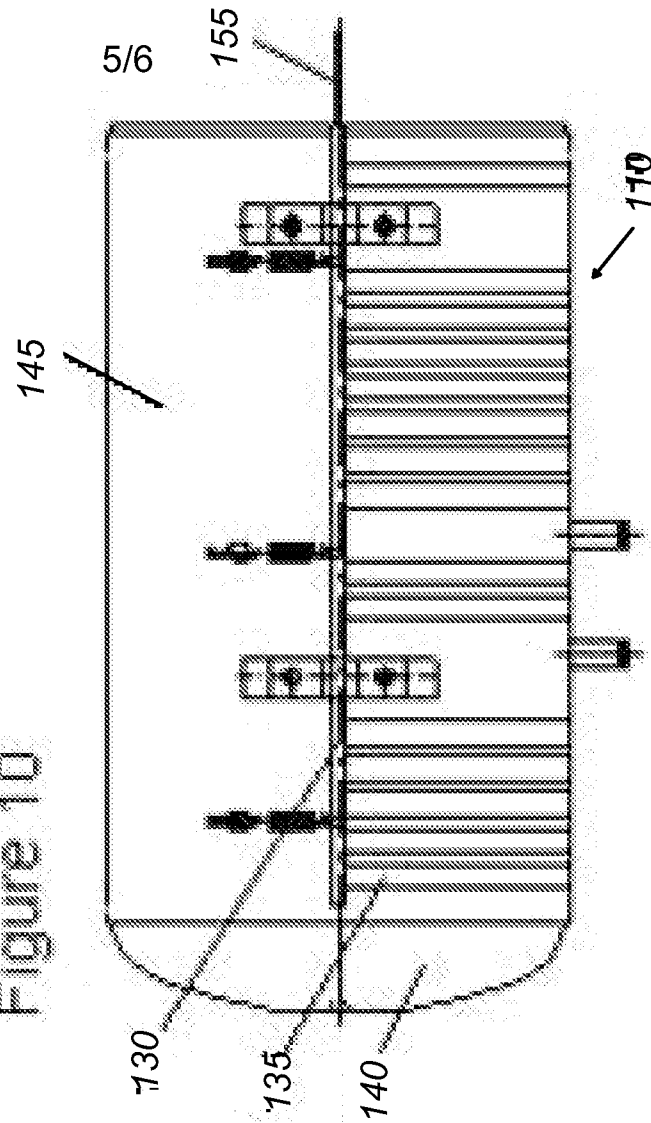


Figure 12

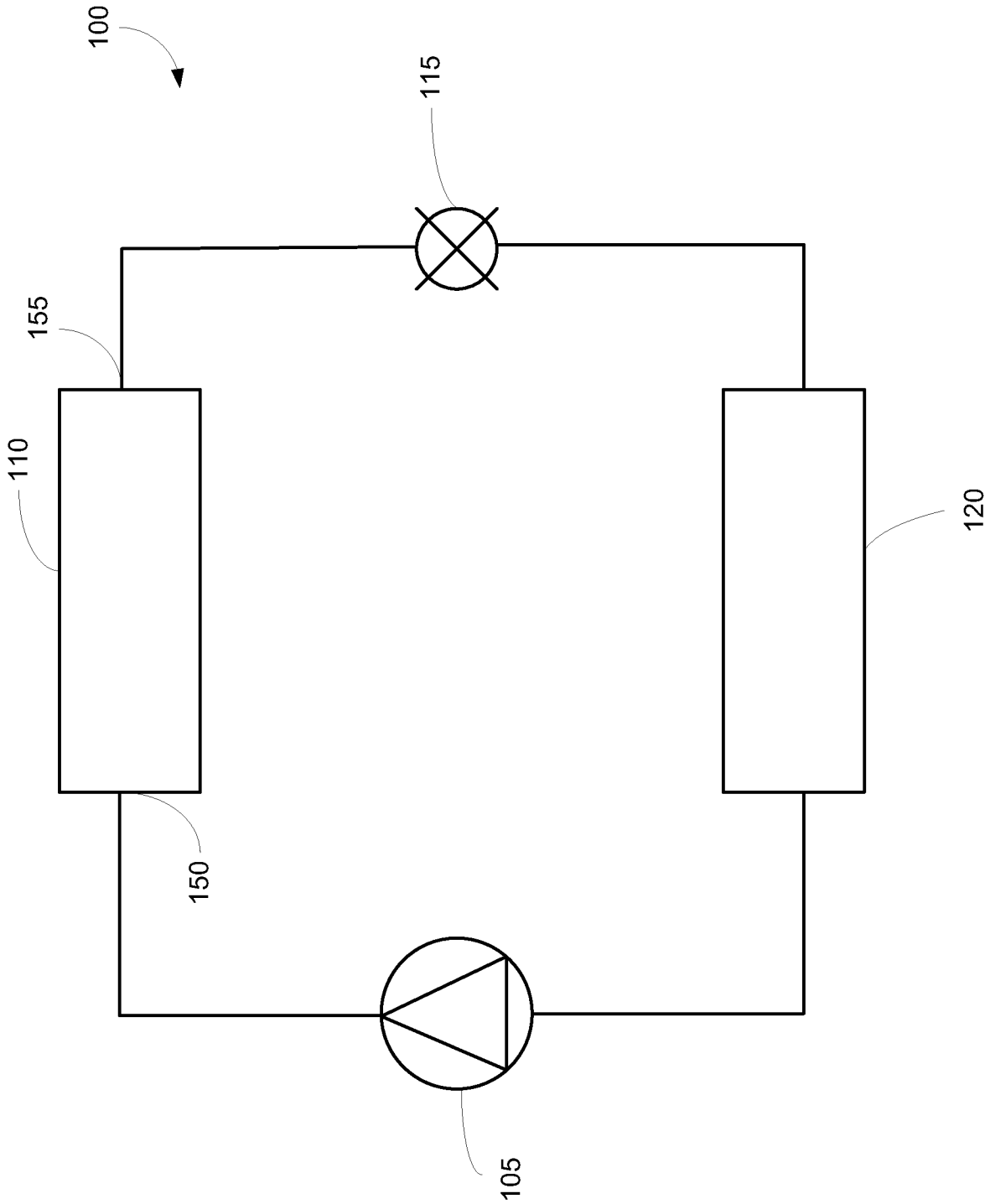


Figure 13