Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2851781 A1 2015/11/13

(21) 2 851 781

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(22) Date de dépôt/Filing Date: 2014/05/13

(41) Mise à la disp. pub./Open to Public Insp.: 2015/11/13

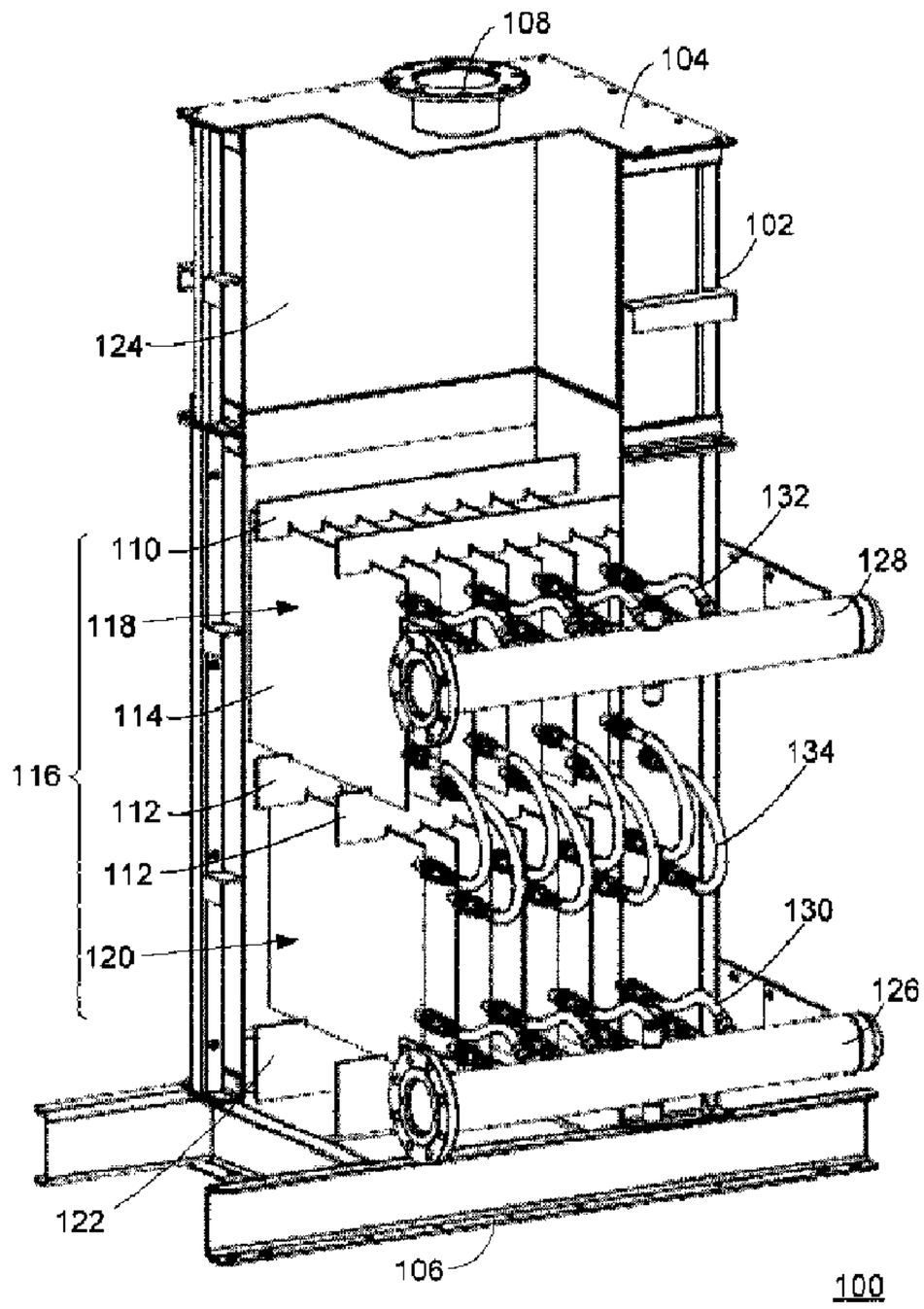
(51) Cl.Int./Int.Cl. *F28D 19/02* (2006.01)

(71) Demandeur/Applicant:
SOLEX THERMAL SCIENCE INC., CA

(72) Inventeurs/Inventors:
BYMAN, ASHLEY DEAN, CA;
CHARLES, THOMAS LAYNE, CA;
HUANG, XINGCUN, CA

(74) Agent: BORDEN LADNER GERVAIS LLP

(54) Titre : ECHANGEUR DE CHALEUR SERVANT A REFROIDIR OU RECHAUFFER LES SOLIDES EN VRAC
(54) Title: HEAT EXCHANGER FOR COOLING OR HEATING BULK SOLIDS




(57) Abrégé/Abstract:
A heat exchanger includes a housing that includes an inlet for receiving bulk solids and an outlet for discharging the bulk solids. A first heat transfer plate bank is disposed between the inlet and the outlet. The first heat transfer plate bank includes a plurality of

(21) 2 851 781

(13) A1

(57) Abrégé(suite)/Abstract(continued):
horizontally spaced apart, substantially parallel heat transfer plates for cooling the bulk solids that flow from the inlet, through spaces between adjacent plates. A second heat transfer plate bank is disposed between the first bank and the outlet. The second bank includes plurality of horizontally spaced apart, substantially parallel heat transfer plates for cooling or heating the bulk solids that flow from the spaces between adjacent plates of the first bank, through spaces between adjacent plates of the second bank, to the outlet. The plates of the second bank are horizontally offset from the plates of the first bank such that the plates of the second bank are not in vertically aligned with the plates of the first bank.

## ABSTRACT

A heat exchanger includes a housing that includes an inlet for receiving bulk solids and an outlet for discharging the bulk solids. A first heat transfer plate bank is disposed between the inlet and the outlet. The first heat transfer plate bank includes a plurality of horizontally spaced apart, substantially parallel heat transfer plates for cooling the bulk solids that flow from the inlet, through spaces between adjacent plates. A second heat transfer plate bank is disposed between the first bank and the outlet. The second bank includes plurality of horizontally spaced apart, substantially parallel heat transfer plates for cooling or heating the bulk solids that flow from the spaces between adjacent plates of the first bank, through spaces between adjacent plates of the second bank, to the outlet. The plates of the second bank are horizontally offset from the plates of the first bank such that the plates of the second bank are not in vertically aligned with the plates of the first bank.

# HEAT EXCHANGER FOR COOLING OR HEATING BULK SOLIDS

## FIELD OF THE INVENTION

**[0001]** The present disclosure relates to a heat exchanger for cooling and heating bulk solids.

## BACKGROUND

**[0002]** Heat exchangers use heat transfer plates to indirectly cool or heat bulk solids that continuously flow, under the force of gravity, through the heat exchanger. Bulk solids are cooled or heated as they flow through spaces between adjacent heat transfer plates. The spacing of the plates may be set to facilitate the flow of the bulk solid being cooled or heated. As the spacing of the plates increases, however, the heat exchanged decreases. An improved heat exchanger that facilitates flow of bulk solids, including bulk solids that have a relatively large size, is desirable.

## SUMMARY

**[0003]** According to one aspect, a heat exchanger is provided. The heat exchanger includes a housing that includes an inlet for receiving bulk solids and an outlet for discharging the bulk solids. A first heat transfer plate bank is disposed between the inlet and the outlet. The first heat transfer plate bank includes a plurality of spaced apart, substantially parallel heat transfer plates for cooling the bulk solids that flow from the inlet, through spaces between adjacent heat transfer plates. A second heat transfer plate bank is disposed between the first heat transfer plate bank and the outlet. The second heat transfer plate bank includes plurality of spaced apart, substantially parallel heat transfer plates for cooling the bulk solids that flow from the spaces between adjacent heat transfer plates of the first bank, through spaces between adjacent heat transfer plates of the second heat transfer plate bank, to the outlet. The heat transfer plates of the second heat transfer plate bank are horizontally offset from the heat transfer plates of the first heat transfer plate bank such that the heat transfer plates of the second heat transfer plate bank are not in vertical alignment with the heat transfer plates of the first heat transfer plate bank. The heat transfer plates of the second heat transfer

plate bank may be horizontally offset relative to the heat transfer plates of the first heat transfer plate bank by about half of a distance between adjacent heat transfer plates of the first heat transfer plate bank.

**[0004]** According to another aspect, the heat exchanger includes a third heat transfer plate bank disposed in the housing, between the second heat transfer plate bank and the outlet. The third heat transfer plate bank may include a plurality of horizontally spaced apart, substantially parallel heat transfer plates for cooling or heating the bulk solids that flow from the spaces between adjacent heat transfer plates of the second heat transfer plate bank, through spaces between heat transfer plates of the third heat transfer plate bank, to the outlet. The heat transfer plates of the third heat transfer plate bank may be horizontally offset from the heat transfer plates of the first heat transfer plate bank and the second heat transfer plate bank such that the heat transfer plates of the third heat transfer plate bank are not vertically aligned with the heat transfer plates of the first heat transfer plate bank and are not vertically aligned with the heat transfer plates of the second heat transfer plate bank. The heat transfer plates of one of the second heat transfer plate bank and the third heat transfer plate bank may be horizontally offset by about a third of a distance between adjacent heat transfer plates of the first heat transfer plate bank. The heat transfer plates of the other of the second heat transfer plate bank and the third heat transfer plate bank may be horizontally offset by about two thirds of the distance. The heat transfer plates of the second heat transfer plate bank may be horizontally offset by about a third of the distance, and the heat transfer plates of the third heat transfer plate bank may be horizontally offset by about two thirds of the distance. The heat transfer plates of the third heat transfer plate bank may be horizontally offset by about one third of the distance, and the heat transfer plates of the second heat transfer plate bank may be horizontally offset by about two thirds of the distance.

**[0005]** According to another aspect, the heat exchanger includes a fourth heat transfer plate bank disposed in the housing, between the third heat transfer plate bank and the outlet. The fourth heat transfer plate bank may include a plurality of horizontally spaced apart, substantially parallel heat transfer plates for cooling or

heating the bulk solids that flow from the spaces between adjacent heat transfer plates of the third heat transfer plate bank, through spaces between heat transfer plates of the fourth heat transfer plate bank, to the outlet. The heat transfer plates of the fourth bank may be horizontally offset from the heat transfer plates of the first heat transfer plate bank, the second heat transfer plate bank, and third heat transfer plate bank such that the heat transfer plates of the fourth heat transfer plate bank are not vertically aligned with the heat transfer plates of the first heat transfer plate bank, are not vertically with the heat transfer plates of the second heat transfer plate bank, and are not vertically aligned with the heat transfer plates of the third heat transfer plate bank. The heat transfer plates of one of the second heat transfer plate bank, the third heat transfer plate bank, and the fourth heat transfer plate bank may be horizontally offset by about a half of a distance between adjacent heat transfer plates of the first heat transfer plate bank. The heat transfer plates of the second heat transfer plate bank may be horizontally offset by about a quarter of a distance between adjacent heat transfer plates of the first heat transfer plate bank. The heat transfer plates of the third heat transfer plate bank may be horizontally offset by about half the distance and the heat transfer plates of the fourth bank may be horizontally offset by about three quarters of the distance.

**[0006]** According to another aspect, the heat exchanger includes a first fluid inlet manifold in fluid communication with a fluid inlet of each heat transfer plate of the first heat transfer plate bank for providing cooling fluid or heating fluid to each heat transfer plate of the first heat transfer plate bank. A first fluid discharge manifold may be in fluid communication with a fluid outlet of each heat transfer plate of the first heat transfer plate bank for receiving cooling fluid or heating fluid discharged from each heat transfer plate of the first heat transfer plate bank.

**[0007]** According to another aspect, the heat exchanger includes a second fluid inlet manifold in fluid communication with a fluid inlet of each heat transfer plate of the second heat transfer plate bank to provide cooling fluid or heating fluid to each heat transfer plate of the second heat transfer plate bank. A second fluid discharge manifold may be in fluid communication with a fluid outlet of each heat transfer plate of the second heat transfer plate bank to receive cooling fluid or

heating fluid discharged from each heat transfer plate of the second heat transfer plate bank.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0008]** Embodiments of the present invention will be described, by way of example, with reference to the drawings and to the following description, in which:

**[0009]** FIG. 1 is a partially cut away perspective view of a heat exchanger for cooling bulk solids in accordance with an embodiment;

**[0010]** FIG. 2 is a top view of an example of a top bank of heat transfer plates of the heat exchanger of FIG. 1;

**[0011]** FIG. 3 is an end view of the stack of banks of heat transfer plates of the heat exchanger of FIG. 1;

**[0012]** FIG. 4 is a sectional side view of an example of a heat transfer plate of the heat exchanger of FIG. 1;

**[0013]** FIG. 5 is a simplified end view of the stack of banks of heat transfer plates of a heat exchanger in accordance with another embodiment;

**[0014]** FIG. 6 is a simplified end view of the stack of banks of heat transfer plates of a heat exchanger in accordance with still another embodiment.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0015]** For simplicity and clarity of illustration, reference numerals may be repeated among the figures to indicate corresponding or analogous elements. Numerous details are set forth to provide an understanding of the embodiments described herein. The embodiments may be practiced without these details. In other instances, well-known methods, procedures, and components have not been described in detail to avoid obscuring the embodiments described. The description is not to be considered as limited to the scope of the embodiments described herein.

**[0016]** The disclosure generally relates to heat exchangers for cooling or heating bulk solids that have a large particle size, or large pieces, for example, bulk solids that have a diameter between ¼ inch and 4 inches. Examples of bulk solids include wood chips, fertilizers, and other solids that may have a large particle size and that flow under the force of gravity.

**[0017]** A partially cutaway perspective view of an embodiment of a heat exchanger for cooling bulk solids is shown in FIG. 1. The heat exchanger 100 includes a housing 102 with a generally rectangular cross-section. The housing 102 has a top 104 and a bottom 106. The top 104 of the housing 102 includes an inlet 108 for introducing bulk solids into the heat exchanger 100. The bottom 106 of the housing 102 is open to provide an outlet (not shown) for discharging cooled bulk solids from the housing 102 to an optional discharge hopper, and out of the heat exchanger 100. A vertical axis extends from a center of the inlet 108 to a center of the outlet. A plurality of heat transfer plates 114 are disposed within the housing 102, between the inlet 108 and the outlet. The plurality of heat transfer plates 114 are horizontally spaced apart along axes that extends transverse to the vertical axis and the heat transfer plates 114 are arranged generally parallel to each other in rows, referred to herein as banks. In the example shown in FIG. 1, the heat exchanger 100 includes two banks of heat transfer plates 114. The two banks are arranged in a stack 116. The stack 116 includes a top bank 118 and a bottom bank 120. For the purpose of the present example, each heat transfer plate bank includes eight heat transfer plates 114. Although the heat exchanger 100 of FIG. 1 includes two banks, other suitable numbers of banks may be utilized. Also, other suitable numbers of heat transfer plates 114 in each heat transfer plate bank may be utilized.

**[0018]** The two banks 118, 120 of heat transfer plates 114, also referred to herein as heat transfer plate banks 118, 120, are spaced apart. The heat transfer plates 114 of the bank 118 are spaced apart by spacers 110 and by the spacers 112, which also support the bank 118 of heat transfer plates 114. The heat transfer plates 114 of the bank 120 are spaced apart by spacers 112 and by the supports 122. The bank 120 of heat transfer plates 114 is supported on the

supports 122 at the bottom of the stack 116. The supports 122 support the bank and the weight of the bulk solids introduced into the heat exchanger 100 as the weight of the bulk solids is transferred to the heat transfer plates 114 via friction.

**[0019]** The top bank 118 of the stack 116, which is the bank that is located closest to the inlet 108, is sufficiently spaced from the inlet 108 to provide a hopper 124 in the housing 102, between the inlet 108 and the top bank 118. The hopper 124 facilitates distribution of bulk solids that flow from the inlet 108, as a result of the force of gravity, over the heat transfer plates 114 of the top bank 118 and into spaces between adjacent heat transfer plates 114 of the top bank 118. The bottom bank 120 of the stack 116, which is the bank that is located closest to the outlet, is sufficiently spaced from the outlet to facilitate the flow of bulk solids through the outlet. The optional discharge hopper may be utilized at the outlet to create a mass flow or "choked flow" of bulk solids and to regulate the flow rate of the bulk solids through the heat exchanger 100. An example of a discharge hopper is described in U.S. Patent 5,167,274, the entire content of which is incorporated herein by reference. The term "choked flow" is utilized herein to refer to a flow other than a free fall of the bulk solids as a result of the force of gravity.

**[0020]** The heat exchanger 100 also includes a fluid inlet manifold 126 that provides cooling fluid or heating fluid to the stack 116, and a fluid discharge manifold 128 that receives cooling fluid or heating fluid from the stack 116. The fluid inlet manifold 126 is coupled to the housing 102 and is in fluid communication with each heat transfer plate 114 of the bottom bank 120 of the stack 116. A respective fluid line 130 extends from each heat transfer plate 114 of the bottom bank 120 to the fluid inlet manifold 126. The fluid discharge manifold 128 is coupled to the housing 102 and is in fluid communication with each heat transfer plate 114 of the top bank 118 of the stack 116. A respective fluid line 132 extends from each heat transfer plate 114 of the top bank 118 to the fluid inlet manifold 126.

**[0021]** In the embodiment shown in FIG. 1, the heat transfer plates 114 of the bottom bank 120 are disposed between the heat transfer plates 114 of the top

bank 118 and the outlet. Each heat transfer plate 114 of the top bank 118 is in fluid communication with a respective heat transfer plate 114 of the bottom bank 120. For example, a respective fluid line 134 extends from each heat transfer plate 114 of the top bank 118 to a respective heat transfer plate 114 of the bottom bank 120.

**[0022]** Referring to FIG. 2, a top view of the top bank 118 of heat transfer plates 114 of the heat exchanger 100 of FIG. 1 is shown. Each heat transfer plate 114 of the top bank 118 generally extends the width of the housing 102, between a first sidewall 202 of the housing 102 and an opposing second sidewall 204 of the housing 102. The heat transfer plates 114 are horizontally spaced apart and arranged generally parallel to each other such that spaces are provided between adjacent heat transfer plates 114.

**[0023]** Referring to FIG. 3, an end view of the stack 116 of heat transfer plates 114 of the heat exchanger 100 of FIG. 1 is shown. In the example shown in FIG. 3, the bottom bank 120 is horizontally offset from the top bank 118 such that the heat transfer plates 114 of the top bank 118 are not vertically aligned with the heat transfer plates 114 of the bottom bank 120. A bottom end 302 of each heat transfer plate 114 of the top bank 118 is vertically spaced from a top end 304 of each heat transfer plate 114 of the bottom bank 120 such that the bottom end 302 of the heat transfer plates 114 of the top bank 118 do not vertically overlap with the top end 304 of the heat transfer plates 114 of the bottom bank 120. Alternatively, the bottom end 302 of each heat transfer plate 114 of the top bank 118 is not vertically spaced and from a top end 304 of each heat transfer plate 114 of the bottom bank 120 to reduce the vertical spacing between the top and bottom banks 118, 120. In the example shown in FIG. 3, the bottom end 302 of each heat transfer plate 114 of the top bank 118 does not vertically overlap with the top end 304 of each heat transfer plate 114 of the bottom bank 120. Passageways are provided between the heat transfer plates 114 of the top bank 118 and the heat transfer plates 114 of the bottom bank 120 for bulk solids to flow through.

**[0024]** In the example shown in FIG. 3, the bottom bank 120 is horizontally offset from the top bank 118 such that each heat transfer plate 114 of the bottom

bank 120 is horizontally spaced relative to a respective heat transfer plate 114 of the top bank 118 by a distance that is half of the distance between adjacent heat transfer plates 114 of the top bank 118 to reduce a peak temperature when cooling the bulk solid, or increase a low temperature when heating the bulk solids, that flow in the center of the space between adjacent heat transfer plates 114 of the top bank 118. Alternatively, each heat transfer plate 114 of the bottom bank 120 may be horizontally spaced from a respective heat transfer plate 114 of the top bank by a suitable distance that facilitates the flow of bulk solids that have a large particle size through the passageways.

**[0025]** Horizontally offsetting the bottom bank 120 from the top bank 118 facilitates the flow of bulk solids that have a large particle size through the passageways between adjacent heat transfer plates 114 of the top and bottom banks 118, 120, and facilitates the exchange of heat between the bulk solids and the heat transfer plates 114 of the bottom bank 120.

**[0026]** The terms top, bottom, horizontal, and vertical are utilized generally to refer to the orientation of the heat exchanger 100 when assembled for use, as shown in FIG. 1 and are not otherwise limiting.

**[0027]** A sectional side view of an example of a heat transfer plate 114 is shown in FIG. 4. The heat transfer plate 114 includes a pair of metal sheets 402. The sheets 402 may be made from stainless steel, such as 316L stainless steel. The sheets 402 are arranged generally parallel to each other. The sheets 402 are welded together at locations that are spaced from the edges of the sheets 402 and are seam welded along the edges of the sheets 402. After the two sheets 402 are welded together, slots are cut for insertion of nozzles that are welded to the sheets 402 and are utilized as a fluid inlet 406 and a fluid outlet 408. The sheets 402 are inflated utilizing the nozzles such that generally circular depressions 404 are formed on each sheet at the welded locations. The generally circular depressions 404 are distributed throughout each sheet 402 and may be located at complementary locations on each sheet 402 such that the generally circular depressions 404 on one of the sheets 402 are aligned with the generally circular depressions 404 on the

other of the sheets 402. When the sheets 402 are inflated, spaces are formed between the sheets 402, in areas where the sheets 402 are not welded together.

**[0028]** The fluid inlet 406 extends from a front edge 414, near a bottom 410 of the heat transfer plate 114. The fluid outlet 408 extends from the front edge 414, near a top 412 of the heat transfer plate 114. The fluid inlet 406 and the fluid outlet 408 both extend substantially perpendicular to and away from the front edge 414 of the heat transfer plate 114.

**[0029]** The flow of cooling or heating fluid through the stack 116 is now described with reference to FIG. 1 and FIG. 4. The flow of the cooling or heating fluid through a heat transfer plate 114 is illustrated by the arrows in FIG. 4. In operation, cooling or heating fluid flows from the fluid inlet manifold 126 through the respective fluid lines 130, through the fluid inlet 406 and into the respective heat transfer plates 114. For the purposes of explanation, the flow of cooling or heating fluid through one of the heat transfer plates 114 is described with reference to FIG. 4.

**[0030]** The cooling or heating fluid flows through the fluid inlet 406 and into the heat transfer plate 114. The generally circular depressions 404 distributed throughout the heat transfer plate 114 facilitate the flow of the cooling fluid throughout the heat transfer plate 114. The cooling fluid then flows from the heat transfer plate 114 into the fluid outlet 408.

**[0031]** Referring again to FIG. 1 and FIG. 4, the cooling or heating fluid flows from the fluid outlet 408 of each heat transfer plate 114 of the bottom bank 120, through the respective fluid lines 134, and into the respective fluid inlets 406 of the heat transfer plates 114 of the top bank 118. The cooling or heating fluid flows through each heat transfer plate 114 of the top bank 118 in a similar manner as described above.

**[0032]** The cooling or heating fluid then flows from the fluid outlet 408 of each heat transfer plate 114 of the top bank 118 through the respective fluid lines 134, and into the fluid discharge manifold 128.

**[0033]** Although the flow of cooling or heating fluid is described herein as flowing in an upward direction through the stack 116, in an alternative embodiment the fluid inlet manifold 126 may be a fluid discharge manifold, the fluid discharge manifold 128 may be a fluid inlet manifold 126, and the direction of flow of cooling or heating fluid through the stack 116 and the heat transfer plate 114 may be in an opposite direction to that described such that the cooling fluid flows downwardly through the stack 116.

**[0034]** The operation of the heat exchanger 100 is now described with reference to FIG. 1 to FIG. 4. When bulk solids are fed into the housing 102 through the inlet 108, the bulk solids flow downwardly as a result of the force of gravity from the inlet 108 into the hopper 124. The hopper 124 facilitates distribution of the bulk solids to the top bank 118 of the stack 116 of heat transfer plates 114. The bulk solids flow through passageways between the heat transfer plates 114, to the outlet (not shown). Bulk solids that contact the heat transfer plates 114 are deflected into the passageways between adjacent heat transfer plates 114.

**[0035]** As bulk solids flow through the passageways between adjacent heat transfer plates 114 of the top and bottom banks 118, 120, the bulk solids are cooled as the heat from the bulk solids is transferred to the heat transfer plates 114 and to the cooling fluid that flows through the heat transfer plates 114. The cooling fluid that flows through the heat transfer plates 114 indirectly cools the bulk solids. Alternatively, the bulk solids are heated as the heat from the heat transfer plates 114 is transferred to the bulk solids and from the heating fluid. The heating fluid that flows through the heat transfer plates 114 indirectly heats the bulk solids.

**[0036]** The bulk solids then flow from the passageways between adjacent heat transfer plates 114 of the bottom bank 120, through the outlet, and into the discharge hopper, where the cooled or heated bulk solids are discharged under a "choked" flow. Horizontally offsetting the heat transfer plates 114 of the top bank 118 from the heat transfer plates 114 of the bottom bank 120 increases the

thermal efficiency of the heat exchanger 100 while reducing the number of heat transfer plates 114 in each bank.

**[0037]** Although the embodiment described with reference to FIG. 1 and FIG. 3 includes a single stack 116 of heat transfer plate banks 118, 120, in an alternative embodiment, the heat exchanger 100 may include multiple stacks 116. When the heat exchanger 100 includes multiple stacks 116, the stacks 116 are arranged in the housing 102, between the inlet 108 and the outlet such that the top bank 118 of each stack 116 is horizontally aligned. The top bank 118 and the bottom bank 120 of a stack 116 are horizontally offset as described above with reference to FIG. 3.

**[0038]** A fluid inlet manifold 126 and a fluid discharge manifold 128 may be coupled to each stack 116. Each stack may have a respective fluid discharge manifold 128 in fluid communication with the heat transfer plates 114 of the top bank 118 of the stack 116. Fluid lines may extend from each heat transfer plate 114 of the stacks 116 to the fluid discharge manifolds 128. Each stack may have a respective fluid inlet manifold 126 in fluid communication with the heat transfer plates 114 of the bottom bank 120 of the stack 116. Fluid lines may extend from the heat transfer plates 114 of the stacks 116 to the fluid inlet manifolds 126.

**[0039]** Alternatively, a fluid discharge manifold 128 may be coupled to the top bank 118 of the top stack and a fluid inlet manifold 126 may be coupled to the bottom bank 120 of the bottom stack. Fluid lines may extend from each heat transfer plate 114 of the top bank 118 of the top stack to the fluid discharge manifold 128. Fluid lines may also extend from each heat transfer plate 114 of the bottom bank 120 of the bottom stack 116 to the fluid inlet manifold.

**[0040]** Although the heat transfer plates 114 in the top and bottom banks 118, 120 are shown in FIG. 1 and 3 as having the same vertical height, the heat transfer plates 114 in the top bank 118 may have a different vertical height than the heat transfer plates 114 of the bottom bank 120.

**[0041]** Referring to FIG. 5, a simplified end view of another example of a stack of heat transfer plates 114 of a heat exchanger is shown. In the example shown in FIG. 5, the stack 500 includes three banks of heat transfer plates 114 disposed within a housing. The stack 500 includes a top bank 502 of heat transfer plates 114, an intermediate bank 504 of heat transfer plates 114, and a bottom bank 506 of heat transfer plates 114. The top bank 502 is disposed in the housing 102 of the heat exchanger 100, between the inlet 108 and the outlet. The intermediate bank 504 is disposed in the housing 102, between the top bank 502 and the outlet. The bottom bank 506 is disposed in the housing 102, between the intermediate bank 504 and the outlet.

**[0042]** The top bank 502, the intermediate bank 504, and the bottom bank 506 each include eight horizontally spaced apart heat transfer plates 114 that are arranged generally parallel to each other in rows. The bottom bank 506 is horizontally offset from the top bank 502 and horizontally offset from the intermediate bank 504 such that the heat transfer plates 114 of the bottom bank 506, the intermediate bank 504, and the top bank 502 are not vertically aligned. Each heat transfer plate 114 of the bottom bank 506 is horizontally spaced relative to respective heat transfer plates 114 of the top bank 502 by a distance that is about two thirds of the distance between adjacent heat transfer plates 114 of the top bank 502. Each heat transfer plate 114 of the intermediate bank 504 is horizontally spaced relative to respective heat transfer plates 114 of the top bank 502 by a distance that is about one third of the distance between adjacent heat transfer plates 114 of the top bank 502. Alternatively, each heat transfer plate 114 of the bottom bank 506 may be horizontally spaced relative to respective heat transfer plates 114 of the top bank 502 by a distance that is about one third of the distance between adjacent heat transfer plates 114 of the top bank 502, and each heat transfer plate 114 of the intermediate bank 504 may be horizontally spaced relative to respective heat transfer plates 114 of the top bank 502 by a distance that is about two thirds of the distance between adjacent heat transfer plates 114 of the top bank 502. Passageways are provided between the heat transfer plates 114 of the top bank 502, the intermediate bank 504, and the bottom bank 506 for bulk solids to flow through the housing 102, from the inlet 108 to the outlet.

**[0043]** A bottom end 508 of each heat transfer plate 114 of the top bank 502 is vertically spaced from a top end 510 of each heat transfer plate 114 of the intermediate bank 504 such that the heat transfer plates 114 of the top bank 502 and the heat transfer plates 114 of the intermediate bank 504 do not vertically overlap. Similarly, a bottom end 512 of each heat transfer plate 114 of the intermediate bank 504 is vertically spaced from a top end 514 of each heat transfer plate 114 of the bottom bank 506 such that the heat transfer plates 114 of the intermediate bank 504 and the heat transfer plates 114 of the bottom bank 506 do not vertically overlap.

**[0044]** Horizontally offsetting the top bank 502, the intermediate bank 504, and the bottom bank 506 facilitates the flow of bulk solids that have a large particle size through the passageways between adjacent heat transfer plates 114 of the top bank 502, the intermediate bank 504, and the bottom bank 506, and facilitates the exchange of heat between the bulk solids and the heat transfer plates 114 of the intermediate bank 504, and the bottom bank 506.

**[0045]** Referring to FIG. 6, a simplified end view of another example of a stack of heat transfer plates 114 of a heat exchanger is shown. In the embodiment shown in FIG. 6, the stack 600 includes four banks of heat transfer plates 114 disposed within the housing 102. The stack 600 includes a top bank 602 of heat transfer plates 114, a first intermediate bank 604 of heat transfer plates 114, a second intermediate bank 606 of heat transfer plates 114, and a bottom bank 608 of heat transfer plates 114. The top bank 602 is disposed in the housing 102 of the heat exchanger 100 between the inlet 108 and the outlet. The first intermediate bank 604 is disposed in the housing 102 of the heat exchanger 100, between the top bank 602 and the outlet. The second intermediate bank 606 is disposed in the housing 102, between the first intermediate bank 604 and the outlet. The bottom bank 608 is disposed in the housing 102, between the second intermediate bank 606 and the outlet.

**[0046]** The top bank 602, the first intermediate bank 604, the second intermediate bank 606, and the bottom bank 608 each include eight horizontally

spaced apart heat transfer plates 114 that are arranged generally parallel too each other in rows. The bottom bank 608 is horizontally offset from the top bank 602, horizontally offset from the first intermediate bank 604, and horizontally offset from the second intermediate bank 606 such that the heat transfer plates 114 of the bottom bank 608, the first intermediate bank 604, the second intermediate bank 606, and the top bank 602 are not vertically aligned.

**[0047]** The heat transfer plates 114 of the bottom bank 608 are horizontally offset relative to the heat transfer plates 114 of the top bank 602 by a distance that is about three quarters of the distance between adjacent heat transfer plates 114 of the top bank 602. The heat transfer plates 114 of the second intermediate bank 606 are horizontally spaced relative to the heat transfer plates 114 of the top bank 602 by a distance that is about one half of the distance between adjacent heat transfer plates 114 of the top bank 602. The heat transfer plates 114 of the first intermediate bank 604 are horizontally spaced relative to heat transfer plates 114 of the top bank 602 by a distance that is about one quarter of the distance between adjacent heat transfer plates 114 of the top bank 602.

**[0048]** Alternatively, the heat transfer plates 114 of the bottom bank 608 may be horizontally spaced relative to heat transfer plates 114 of the top bank 602 by a distance that is about one quarter of the distance between adjacent heat transfer plates 114 of the top bank 602, the heat transfer plates 114 of the second intermediate bank 606 may be horizontally spaced relative to the heat transfer plates 114 of the top bank 602 by a distance that is about three quarters of the distance between adjacent heat transfer plates 114 of the top bank 602 , and the heat transfer plates 114 of the first intermediate bank 604 may be horizontally spaced relative to the heat transfer plates 114 of the top bank 602 by a distance that is about one half of the distance between adjacent heat transfer plates 114 of the top bank 602.

**[0049]** Alternatively, the heat transfer plates 114 of the bottom bank 608 may be horizontally spaced relative to the heat transfer plates 114 of the top bank 602 by a distance that is about one half of the distance between adjacent heat transfer

plates 114 of the top bank 602, the heat transfer plates 114 of the second intermediate bank 606 may be horizontally spaced relative to the heat transfer plates 114 of the top bank 602 by a distance that is about one quarter of the distance between adjacent heat transfer plates 114 of the top bank 602 , and the heat transfer plates 114 of the first intermediate bank 604 may be horizontally spaced relative to the heat transfer plates 114 of the top bank 602 by a distance that is about three quarters of the distance between adjacent heat transfer plates 114 of the top bank 602.

**[0050]** Alternatively, the heat transfer plates 114 of the bottom bank 608 may be horizontally spaced relative to the heat transfer plates 114 of the top bank 602 by a distance that is about three quarters of the distance between adjacent heat transfer plates 114 of the top bank 602, the heat transfer plates 114 of the second intermediate bank 606 may be horizontally spaced relative to the heat transfer plates 114 of the top bank 602 by a distance that is about one quarter of the distance between adjacent heat transfer plates 114 of the top bank 602, and the heat transfer plates 114 of the first intermediate bank 604 may be horizontally spaced relative to the heat transfer plates 114 of the top bank 602 by a distance that is about one half of the distance between adjacent heat transfer plates 114 of the top bank 602.

**[0051]** In the example shown in FIG. 6, passageways are provided between the heat transfer plates 114 of the top bank 602, the first intermediate bank 604, the second intermediate bank 606, and bottom bank 608 for bulk solids to flow through the housing 102, from the inlet 108 to the outlet. A bottom end 610 of each heat transfer plate 114 of the top bank 602 is vertically spaced from a top end 612 of each heat transfer plate 114 of the first intermediate bank 604 so that the heat transfer plates 114 of the top bank 602 and the heat transfer plates 114 of the first intermediate bank 604 do not vertically overlap. Similarly, a bottom end 614 of each heat transfer plate 114 of the first intermediate bank 604 is vertically spaced from a top end 616 of each heat transfer plate 114 of the second intermediate bank 606 such that the heat transfer plates 114 of the first intermediate bank 604 and the heat transfer plates 114 of the second intermediate

bank 606 do not vertically overlap. Similarly, a bottom end 618 of each heat transfer plate 114 of the second intermediate bank 606 is vertically spaced from a top end 620 of each heat transfer plate 114 of the bottom bank 608 such that the heat transfer plates 114 of the second intermediate bank 606 and the heat transfer plates 114 of the bottom bank 608 do not vertically overlap.

**[0052]** For cooling bulk solids, the height of the heat transfer plates 114, which is the dimension of the plates in the vertical direction, can be reduced by comparison to a heat exchanger with vertically aligned plates while still resulting in a bulk solid that is cooled to a desired temperature. Similarly, heat exchange is increased when heating a bulk solid utilizing the offset heat transfer plates. With reduced plate height, supports that are utilized to support one bank of heat transfer plates 114, may be utilized to support two or more banks of heat transfer plates 114. Alternatively, the supports and spacers may be smaller to support less weight. For example, the supports and spacers may be thinner or may be shorter. With smaller supports and spacers, catching or clogging of bulk solid on the supports is reduced. Furthermore, utilizing heat transfer plates of less height, the total change in dimension as a result of thermal expansion of heat transfer plates 114 is reduced, facilitating sealing of fluid lines such as the fluid lines 130 and 132 that are coupled to the heat transfer plates 114. Additionally, doors in the heat exchanger that are utilized to provide access to banks of heat transfer plates 114 may be reduced in size or a single door may be utilized to access more than one bank of heat transfer plates 114.

**[0053]** Alternatively, for cooling bulk solids utilizing the same number of plates and utilizing plates of the same height, a heat exchanger with horizontally offset plates may result in a cooler bulk solid.

**[0054]** Advantageously, horizontally offsetting the banks of heat transfer plates in a heat exchanger such that the heat transfer plates of each bank are not vertically aligned facilitates the flow of bulk solids that have a large particle size through the passageways between adjacent heat transfer plates of each bank, and

facilitates the exchange of heat between bulk solids and the heat transfer plates of the heat exchanger.

**[0055]** The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the claims should not be limited by the preferred embodiments set forth in the examples, but should be given the broadest interpretation consistent with the description as a whole. All changes that come with meaning and range of equivalency of the claims are to be embraced within their scope.

**Claims:**

1. A heat exchanger comprising:

a housing including an inlet for receiving bulk solids, and an outlet for discharging the bulk solids;

a first heat transfer plate bank disposed between the inlet and the outlet, the first heat transfer plate bank comprising a plurality of horizontally spaced apart, substantially parallel heat transfer plates for cooling the bulk solids that flow substantially vertically from the inlet through spaces between adjacent heat transfer plates;

a second heat transfer plate bank disposed between the first heat transfer plate bank and the outlet, the second heat transfer plate bank comprising a plurality of horizontally spaced apart, substantially parallel heat transfer plates for cooling or heating the bulk solids that flow from the spaces between adjacent heat transfer plates of the first heat transfer plate bank, through spaces between adjacent heat transfer plates of the second heat transfer plate bank, to the outlet;

wherein the heat transfer plates of the second heat transfer plate bank are horizontally offset from the heat transfer plates of the first heat transfer plate bank such that the heat transfer plates of the second heat transfer plate bank are not vertically aligned with the heat transfer plates of the first heat transfer plate bank.

2. The heat exchanger of claim 1, wherein the heat transfer plates of the second heat transfer plate bank are horizontally offset relative to the heat transfer plates of the first heat transfer plate bank by about half of a distance between adjacent heat transfer plates of the first heat transfer plate bank.

3. The heat exchanger of claim 1, comprising:

a third heat transfer plate bank disposed in the housing, between the second heat transfer plate bank and the outlet, the third heat transfer plate bank comprising a plurality of horizontally spaced apart, substantially parallel heat transfer plates for

cooling or heating the bulk solids that flow from the spaces between adjacent heat transfer plates of the second heat transfer plate bank, through spaces between heat transfer plates of the third heat transfer plate bank, to the outlet;

wherein the heat transfer plates of the third heat transfer plate bank are horizontally offset from the heat transfer plates of the first heat transfer plate bank and the second heat transfer plate bank such that the heat transfer plates of the third heat transfer plate bank are not vertically aligned with the heat transfer plates of the first heat transfer plate bank and are not vertically aligned with the heat transfer plates of the second heat transfer plate bank.

4. The heat exchanger of claim 3, wherein the heat transfer plates of one of the second heat transfer plate bank and the third heat transfer plate bank are horizontally offset by about a third of a distance between adjacent heat transfer plates of the first heat transfer plate bank, and the heat transfer plates of the other of the second heat transfer plate bank and the third heat transfer plate bank are horizontally offset by about two thirds of the distance.

5. The heat exchanger of claim 4, wherein the heat transfer plates of the second heat transfer plate bank are horizontally offset by about a third of the distance, and the heat transfer plates of the third heat transfer plate bank are horizontally offset by about two thirds of the distance.

6. The heat exchanger of claim 4, wherein the heat transfer plates of the third heat transfer plate bank are horizontally offset by about one third of the distance, and the heat transfer plates of the second heat transfer plate bank are horizontally offset by about two thirds of the distance.

7. The heat exchanger of claim 3, comprising:

a fourth heat transfer plate bank disposed in the housing, between the third heat transfer plate bank and the outlet, the fourth heat transfer plate bank comprising a plurality of horizontally spaced apart, substantially parallel heat transfer plates for cooling or heating the bulk solids that flow from the spaces between adjacent heat

transfer plates of the third heat transfer plate bank, through spaces between heat transfer plates of the fourth heat transfer plate bank, to the outlet;

wherein the heat transfer plates of the fourth bank are horizontally offset from the heat transfer plates of the first heat transfer plate bank, the second heat transfer plate bank, and third heat transfer plate bank such that the heat transfer plates of the fourth heat transfer plate bank are not vertically aligned with the heat transfer plates of the first heat transfer plate bank, are not vertically with the heat transfer plates of the second heat transfer plate bank, and are not vertically aligned with the heat transfer plates of the third heat transfer plate bank.

8. The heat exchanger of claim 7, wherein the heat transfer plates of one of the second heat transfer plate bank, the third heat transfer plate bank, and the fourth heat transfer plate bank are horizontally offset by about a half of a distance between adjacent heat transfer plates of the first heat transfer plate bank.

9. The heat exchanger of claim 7, wherein the heat transfer plates of the second heat transfer plate bank are horizontally offset by about a quarter of a distance between adjacent heat transfer plates of the first heat transfer plate bank, the heat transfer plates of the third heat transfer plate bank are horizontally offset by about half the distance, and the heat transfer plates of the fourth bank are horizontally offset by about three quarters of the distance.

10. The heat exchanger according to claim 1, comprising a first fluid inlet manifold in fluid communication with a fluid inlet of each heat transfer plate of the first heat transfer plate bank for providing cooling fluid or heating fluid to each heat transfer plate of the first heat transfer plate bank, and a first fluid discharge manifold in fluid communication with a fluid outlet of each heat transfer plate of the first heat transfer plate bank for receiving cooling fluid or heating fluid discharged from each heat transfer plate of the first heat transfer plate bank.

11. The heat exchanger according to claim 10, comprising a second fluid inlet manifold in fluid communication with a fluid inlet of each heat transfer plate of the second heat transfer plate bank to provide cooling fluid or heating fluid to each heat transfer plate of the second heat transfer plate bank, and a second fluid discharge

manifold in fluid communication with a fluid outlet of each heat transfer plate of the second heat transfer plate bank to receive cooling fluid or heating fluid discharged from each heat transfer plate of the second heat transfer plate bank.

12. The heat exchanger according to claim 1, comprising a fluid inlet manifold in fluid communication with a fluid inlet of each heat transfer plate of the second heat transfer plate bank for providing cooling fluid or heating fluid to each heat transfer plate of the second heat transfer plate bank, and a fluid discharge manifold in fluid communication with a fluid outlet of each heat transfer plate of the first heat transfer plate bank to receive cooling fluid or heating fluid discharged from each heat transfer plate of the first heat transfer plate bank.

13. The heat exchanger according to claim 12, wherein a fluid outlet of each heat transfer plate of the second heat transfer plate bank is in fluid communication with a fluid inlet of each heat transfer plate of the first heat transfer plate bank to provide cooling fluid or heating fluid from each heat transfer plate of the second heat transfer plate bank to the respective heat transfer plates of the first heat transfer plate bank.

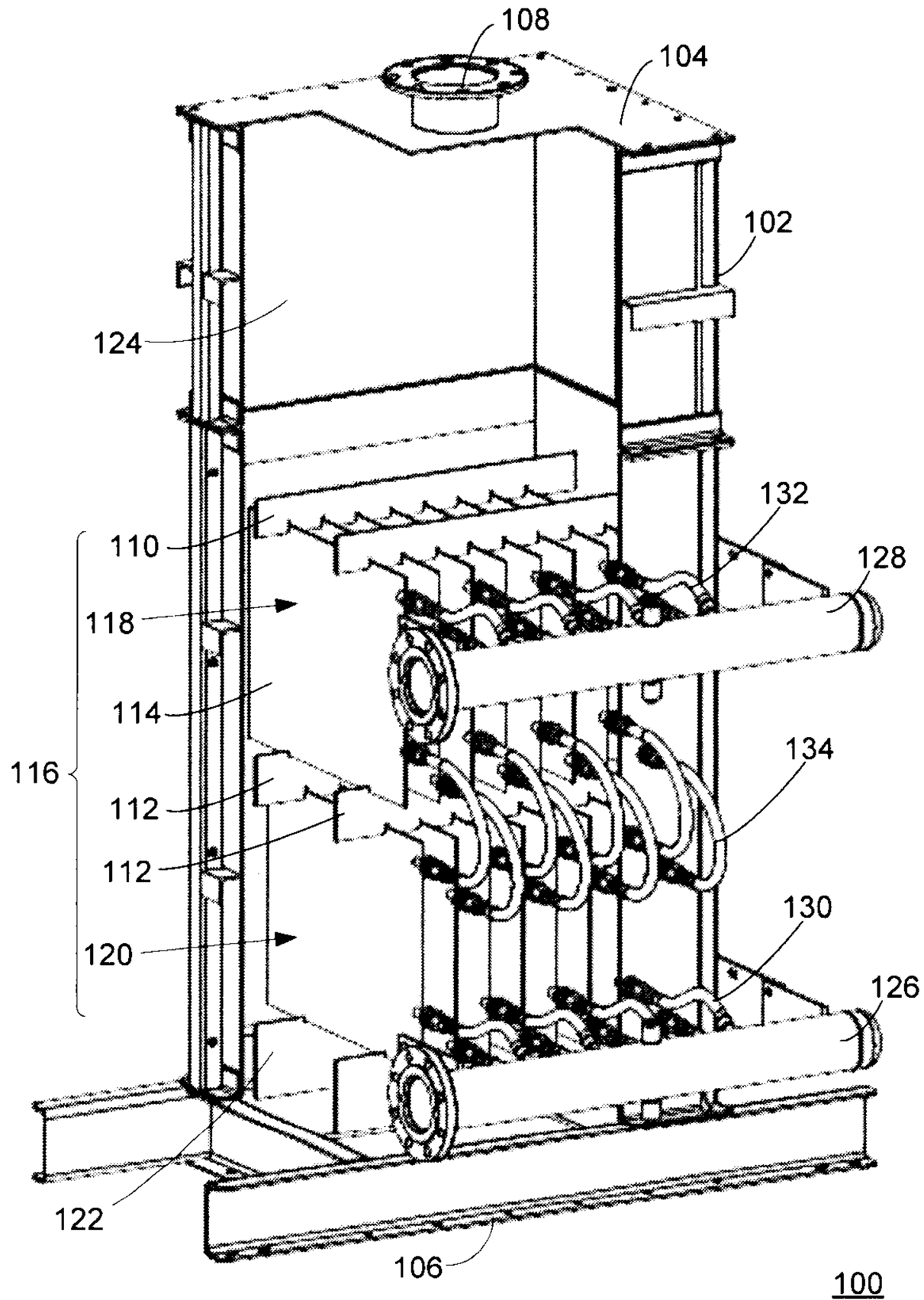

108
104
102
124
132
110
128
118
114
116
134
112
112
130
120
126
122
106
100

FIG. 1

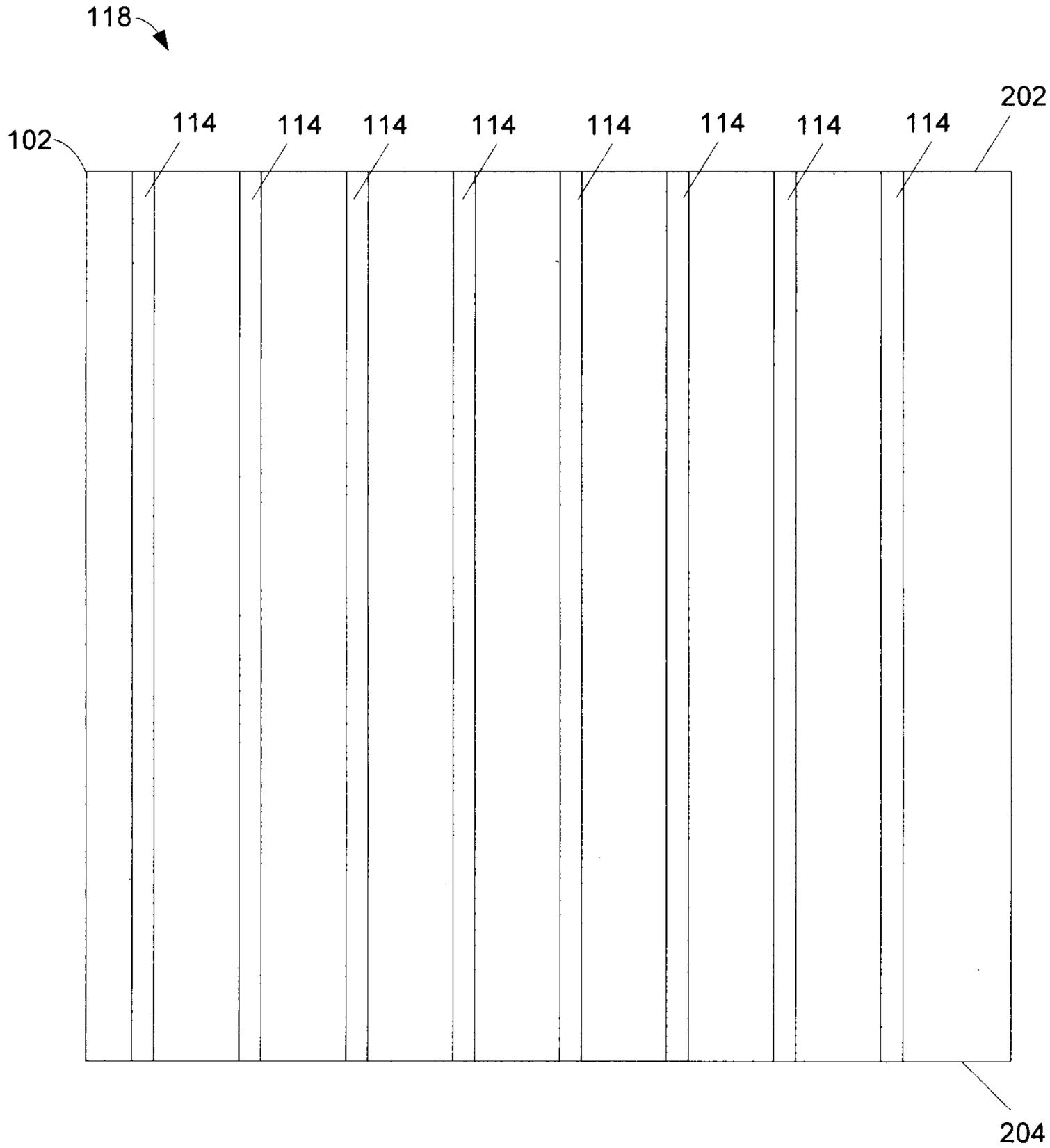



FIG. 2

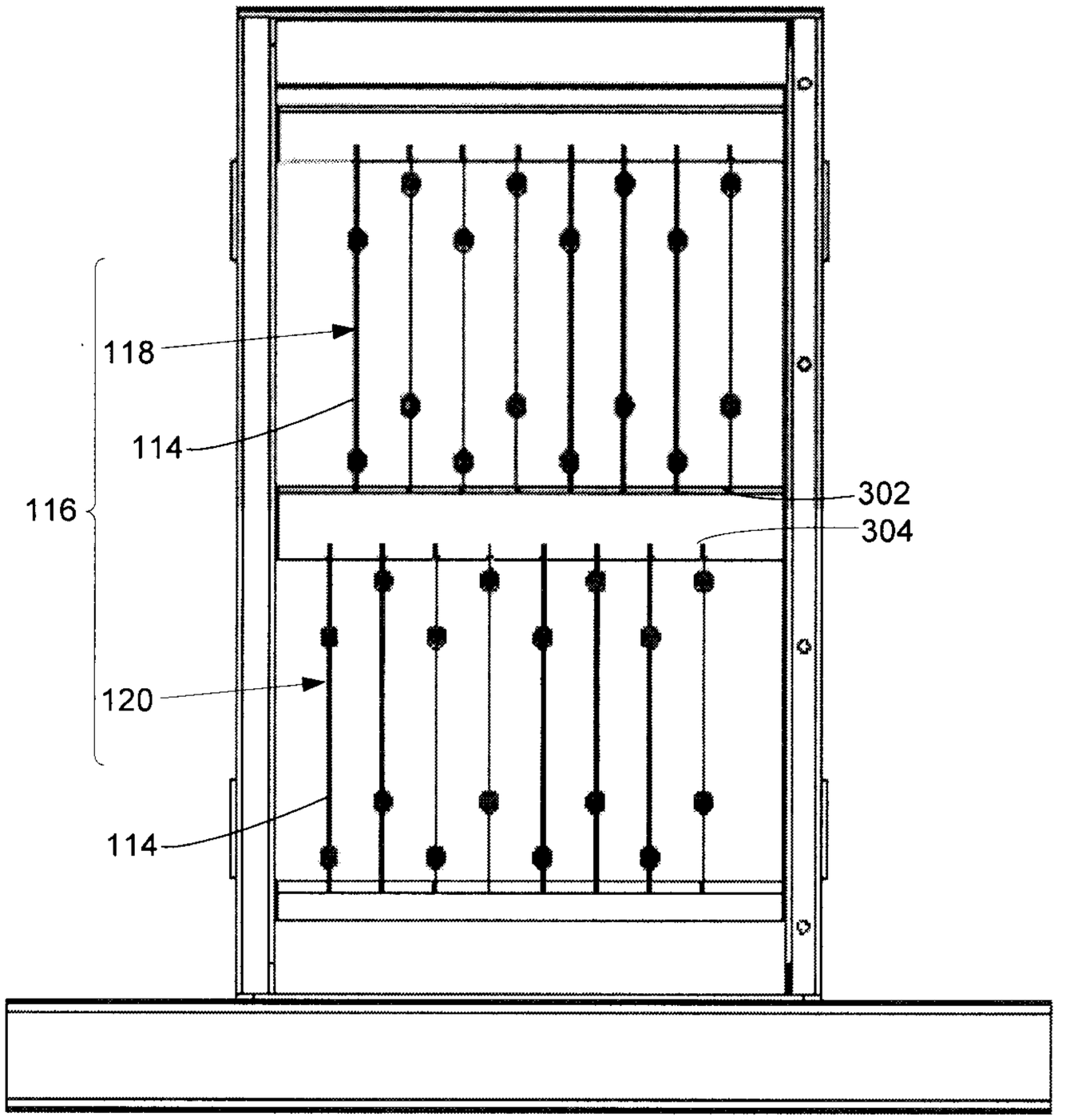



FIG. 3

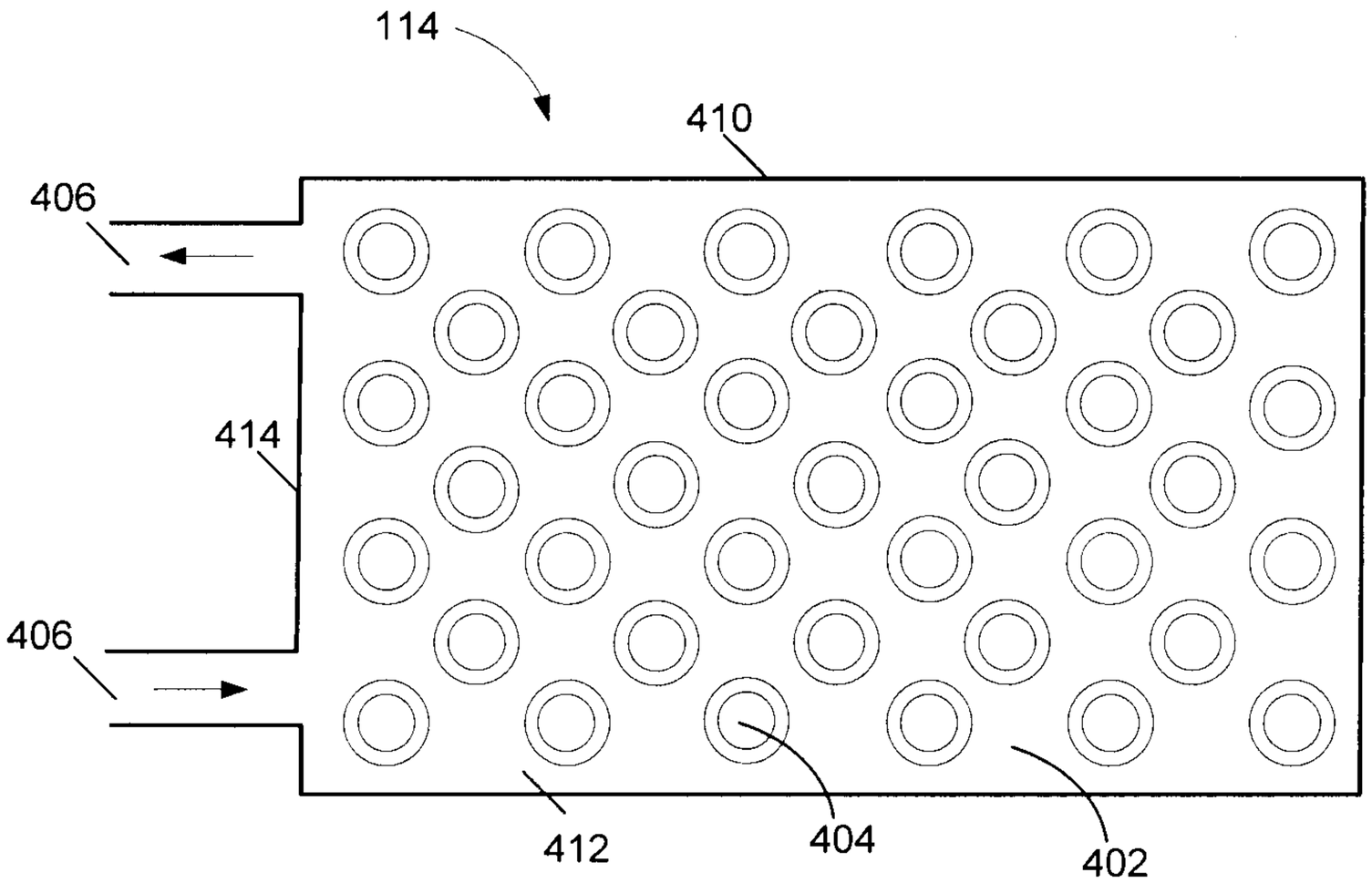



FIG. 4

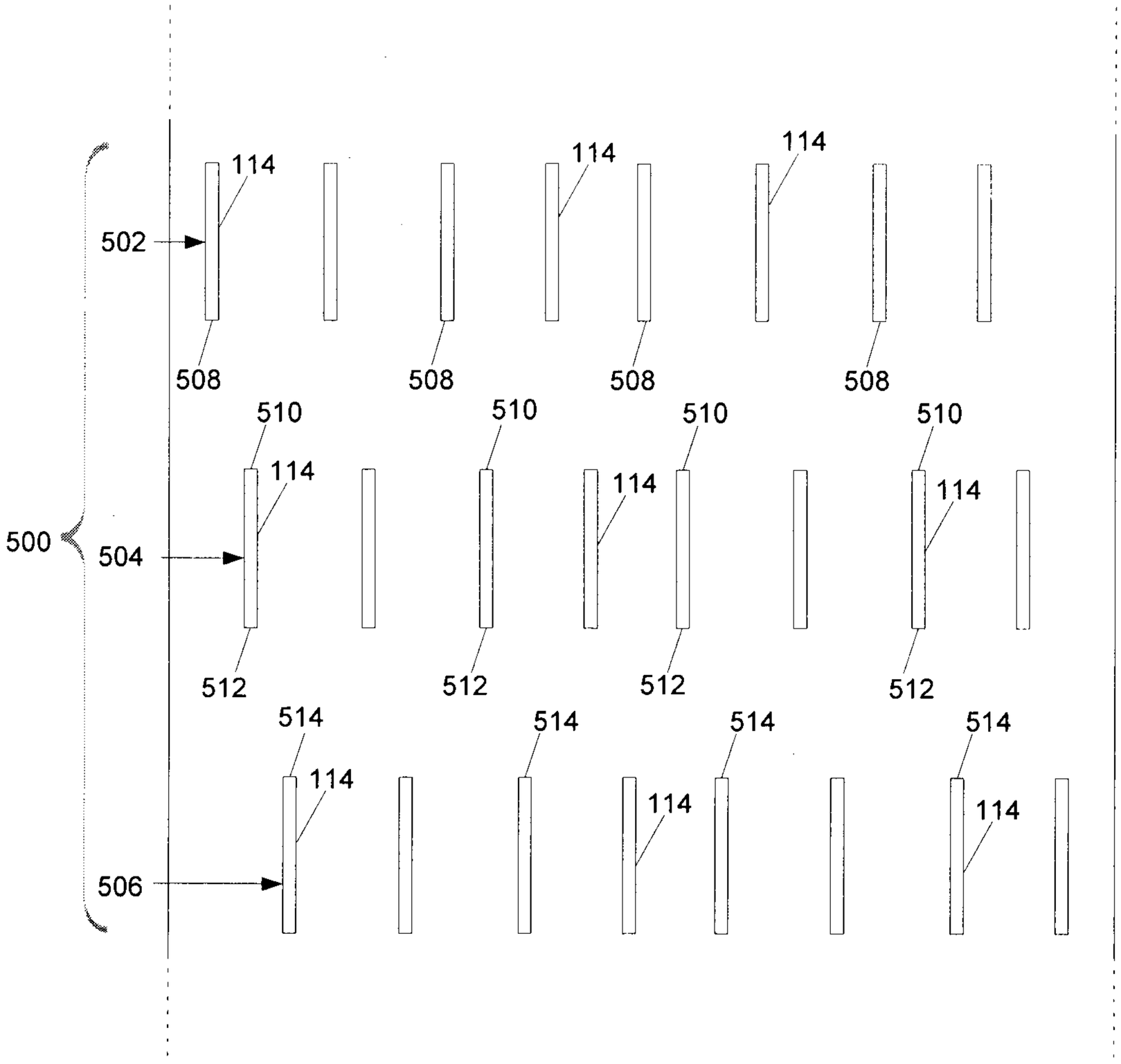



FIG. 5

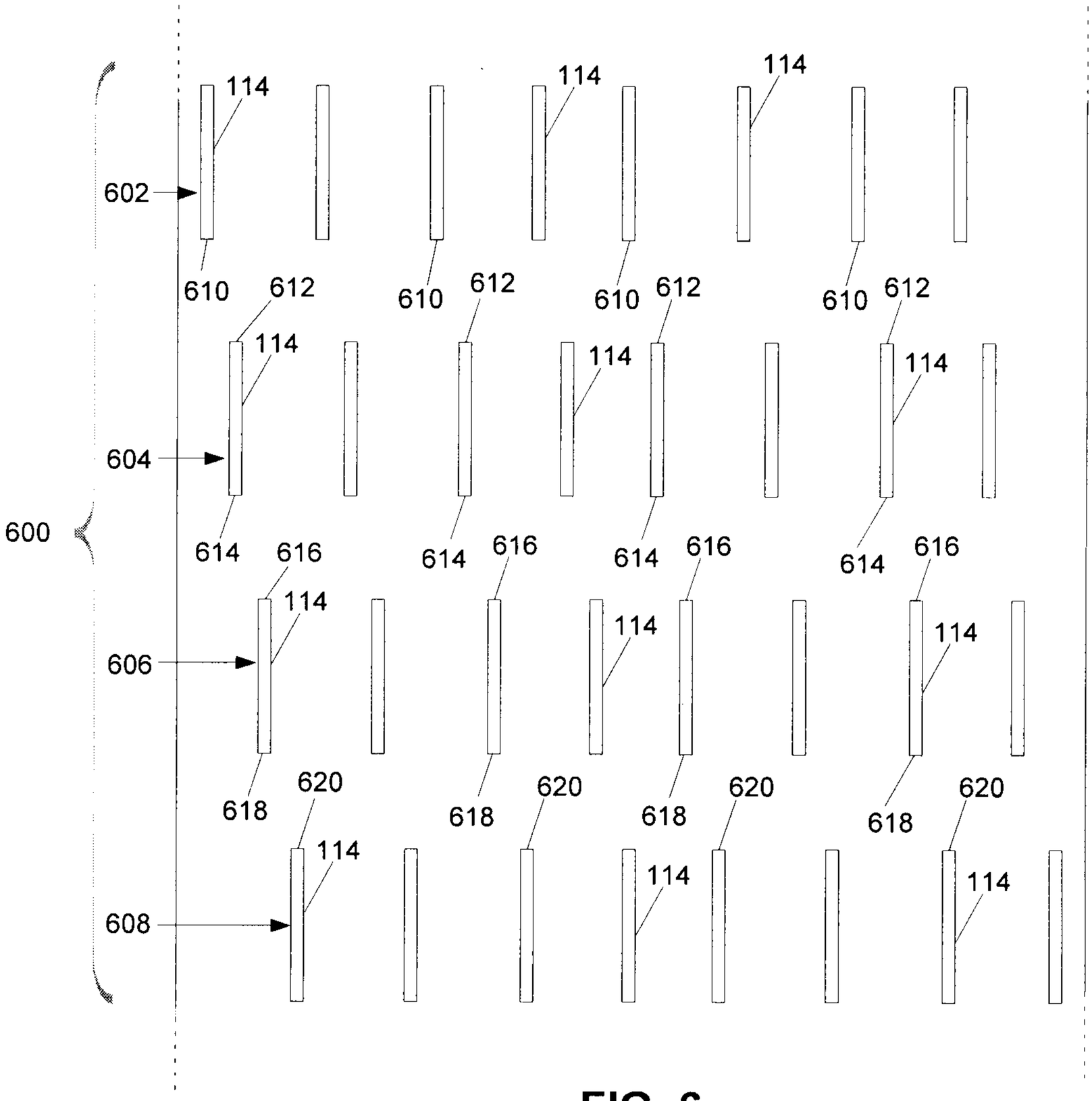
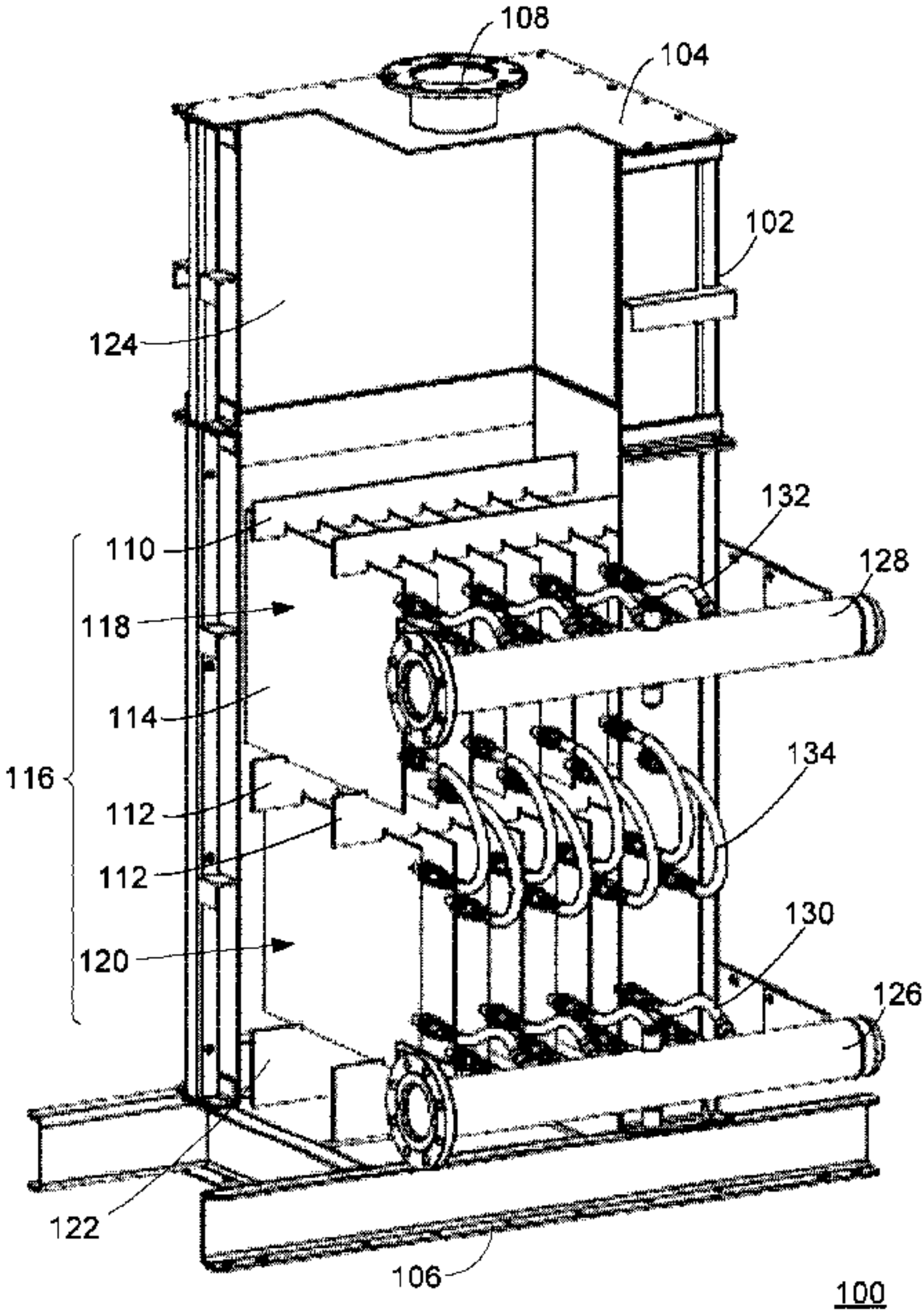



FIG. 6


108
104
102
124
132
110
128
118
114
134
116
112
112
130
120
126
122
106
100