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(12) **United States Patent**
McCarthy

(10) **Patent No.: US 11,519,403 B1**
(45) **Date of Patent: Dec. 6, 2022**

(54) **COMPRESSOR FOR PUMPING FLUID HAVING CHECK VALVES ALIGNED WITH FLUID PORTS**

(71) Applicant: **I-JACK TECHNOLOGIES INCORPORATED**, Moosomin (CA)

(72) Inventor: **Dan McCarthy**, Moosomin (CA)

(73) Assignee: **I-JACK TECHNOLOGIES INCORPORATED**, Moosomin (CA)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/483,452**

(22) Filed: **Sep. 23, 2021**

(51) **Int. Cl.**
F04B 5/02 (2006.01)
F04B 39/12 (2006.01)
F04B 9/109 (2006.01)

(52) **U.S. Cl.**
CPC ***F04B 39/123*** (2013.01); ***F04B 5/02*** (2013.01); ***F04B 9/109*** (2013.01)

(58) **Field of Classification Search**
CPC .. F04B 5/02; F04B 39/10; F04B 39/12; F04B 39/123; F04B 47/02; F04B 47/04; F04B 53/10; F04B 53/16; F04B 7/0266; F04B 9/109; F04B 15/02; F04B 39/125
USPC 417/442
See application file for complete search history.

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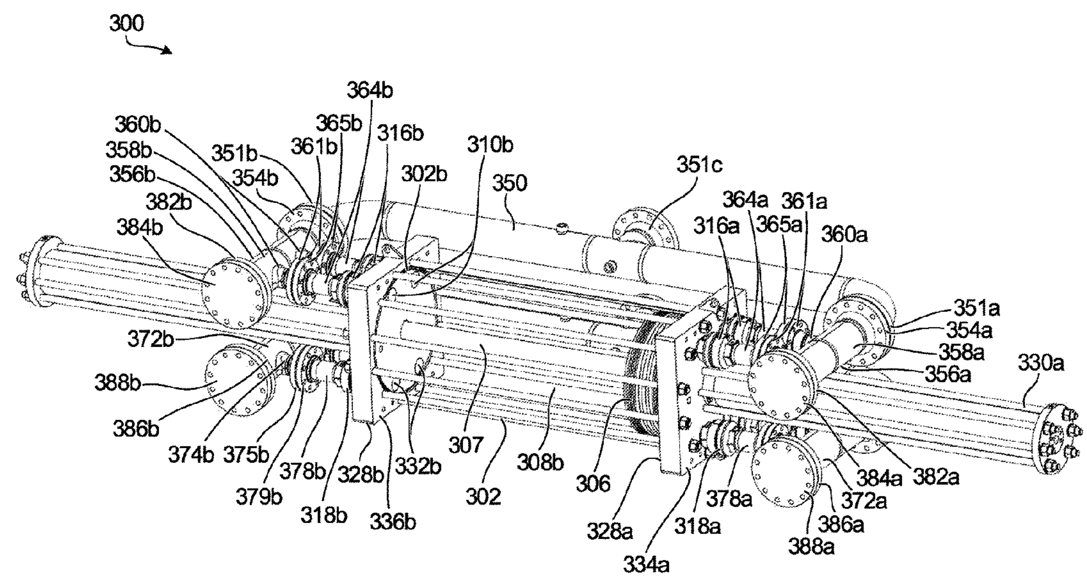
Primary Examiner — Thomas Fink

(57) **ABSTRACT**

A compressor comprises a first cylinder for compressing a fluid and a second cylinder for driving a piston in the first cylinder. The first cylinder comprises a chamber with first and second ends. The piston is reciprocally movable along an axial direction of the chamber for compressing a fluid. Three or more first ports at the first end include at least one first inlet port and at least one first outlet port. Three or more second ports at the second end include at least one second inlet port and at least one second outlet port. Each port has an axial direction parallel to the axial direction of the chamber. A check valve is connected inline with each port along the axial direction of the port.

5 Claims, 30 Drawing Sheets



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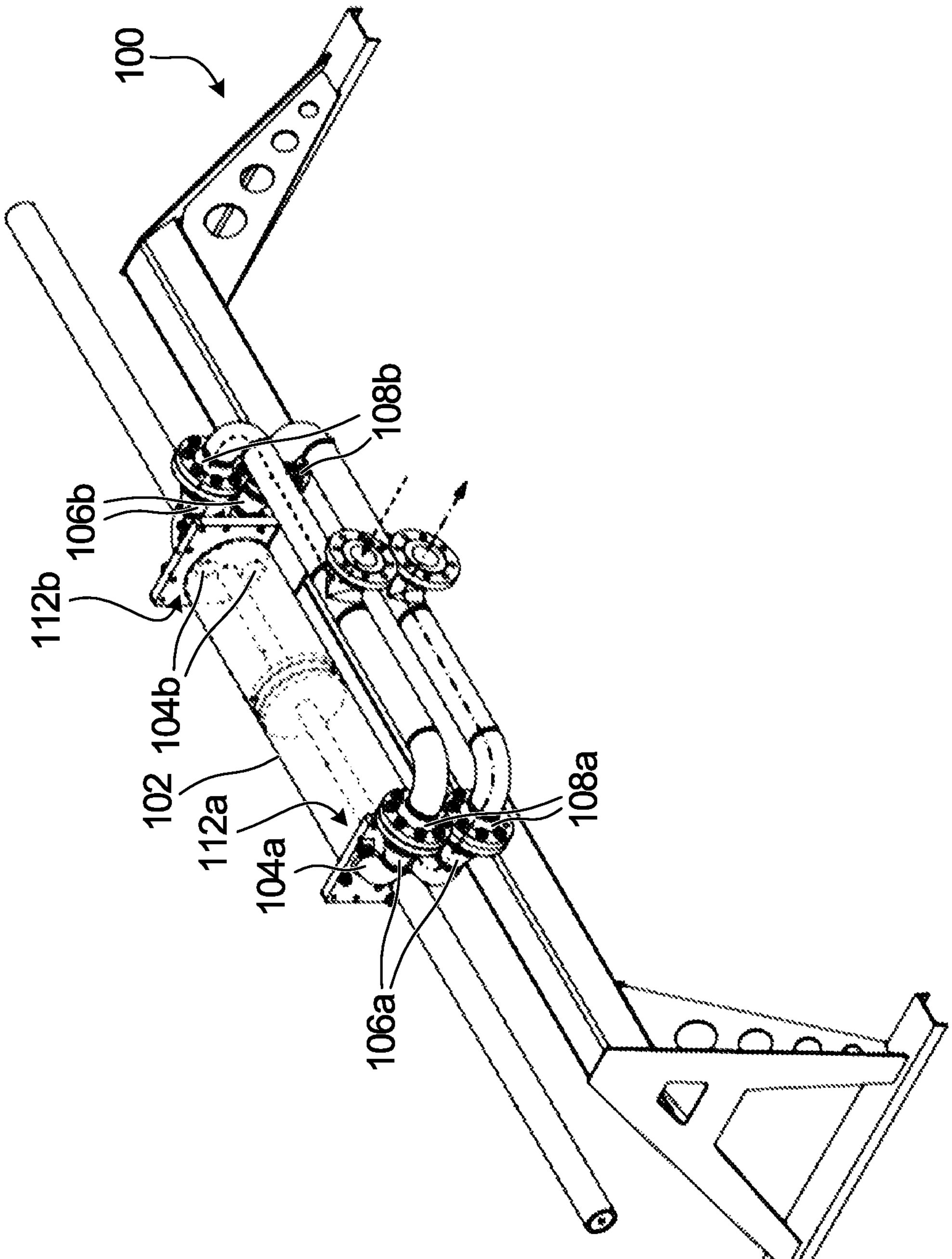
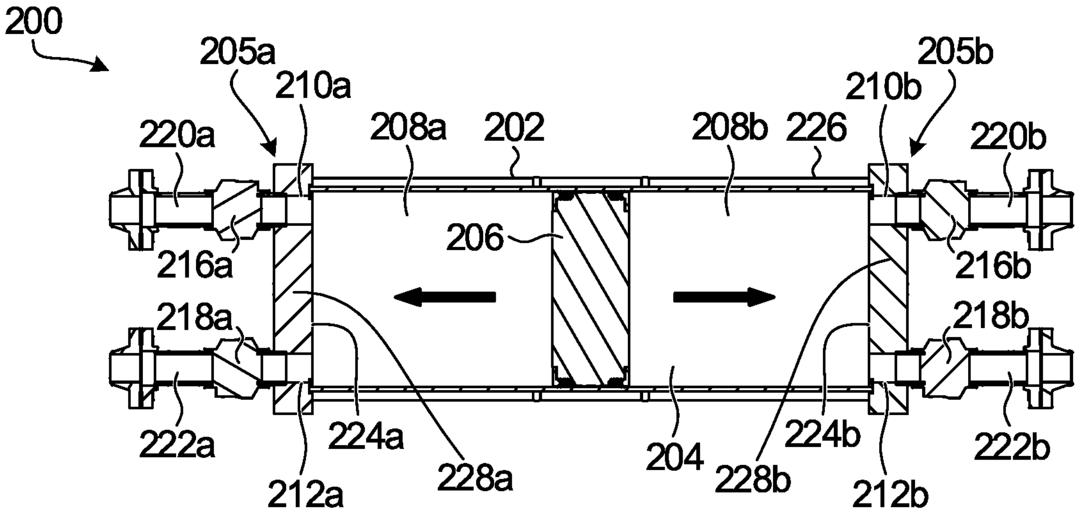


FIG. 1 PRIOR ART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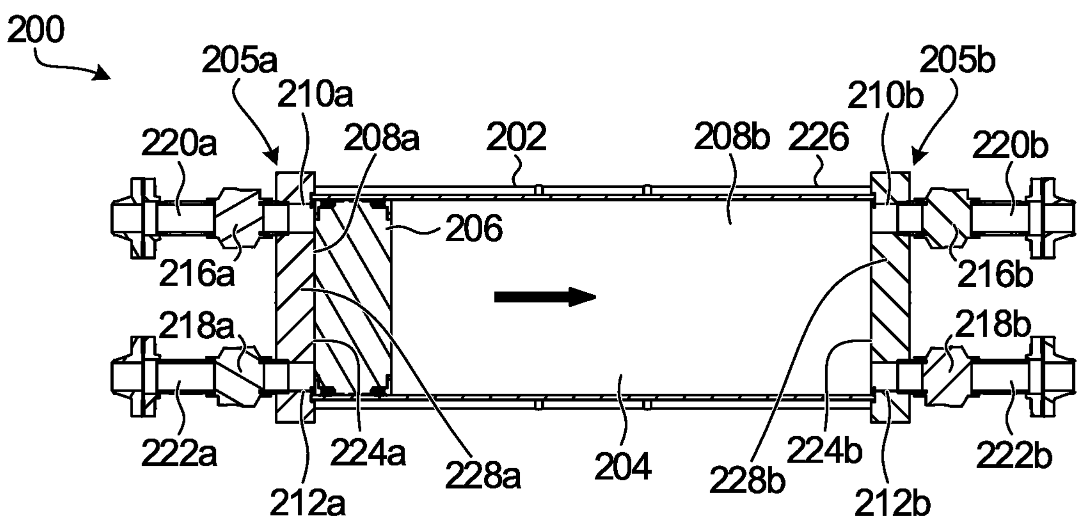
204
228b
224b
212a
212b
222b

FIG. 2A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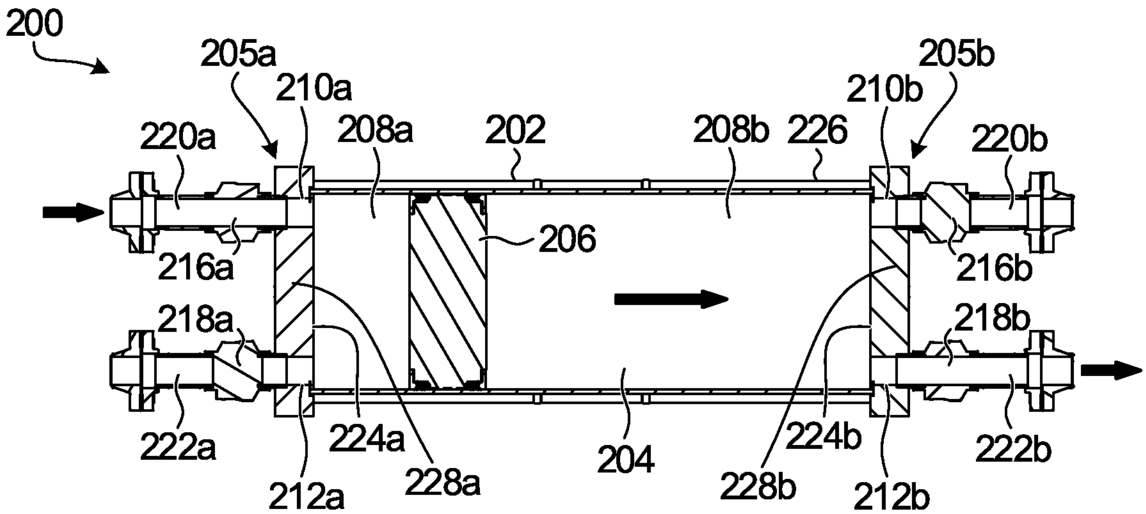
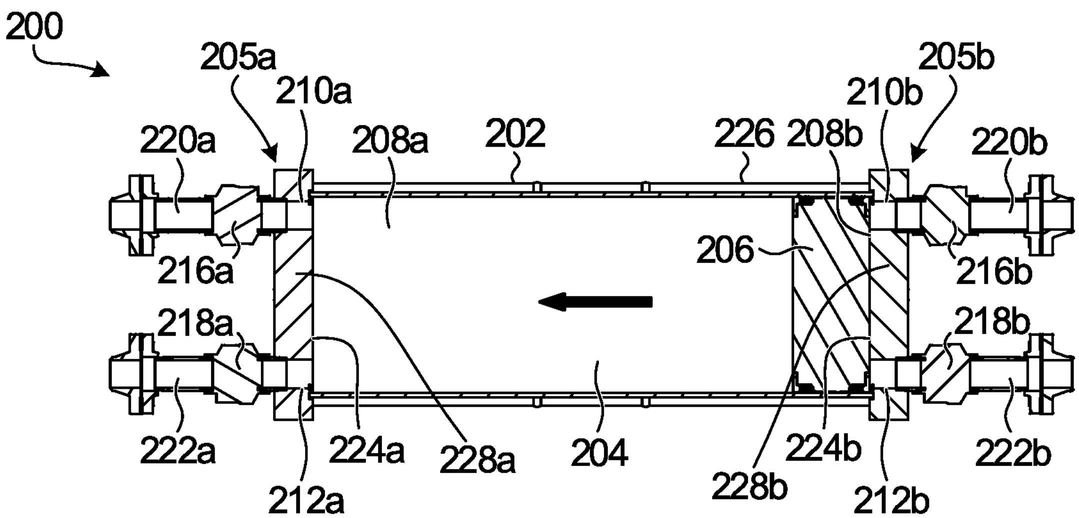
212b
222b

FIG. 2B



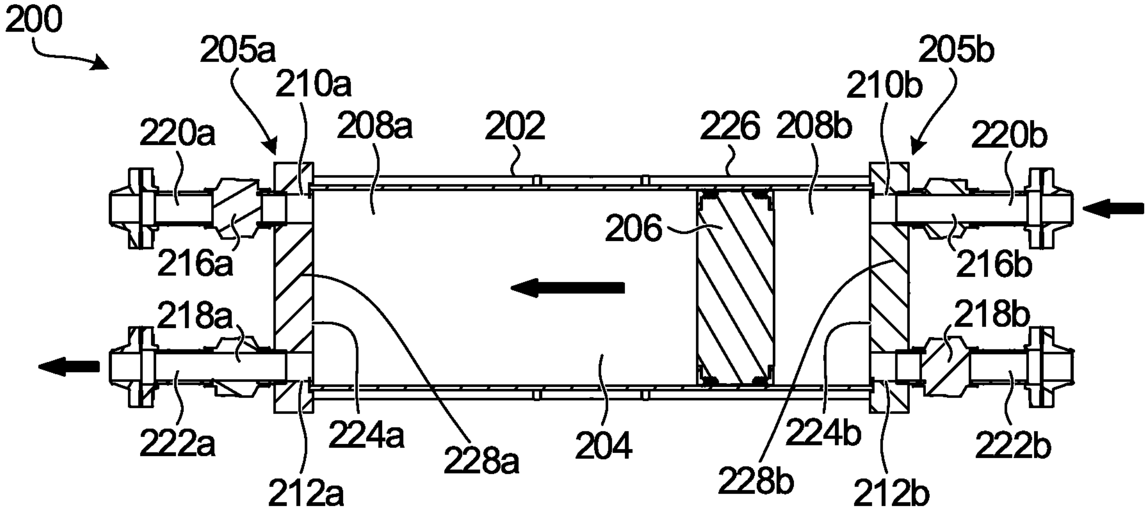
200
205a
210a
220a
208a
202
208b
226
210b
205b
220b
206
216a
216b
218a
218b
222a
224a
228a
204
228b
224b
212a
212b
222b

FIG. 2C



200
205a
210a
220a
208a
202
226
208b
210b
205b
220b
206
216a
216b
218a
218b
222a
224a
228a
204
228b
224b
212a
212b
222b

FIG. 2D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202
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220b
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222a
224a
228a
204
224b
228b
212a
212b
222b

FIG. 2E

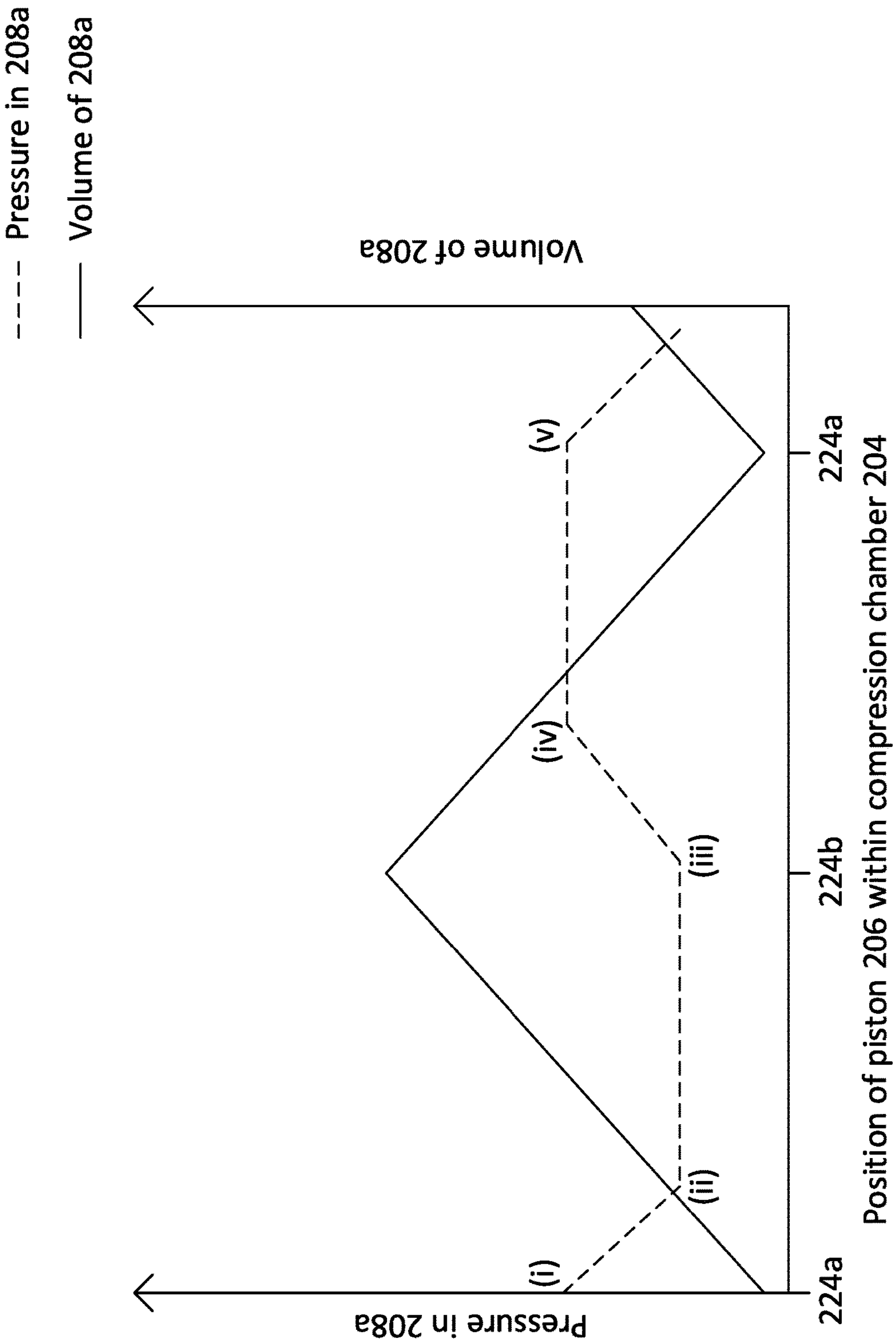

Pressure in 208a
Volume of 208a
Volume of 208a
Pressure in 208a
(i)
(ii)
(iii)
(iv)
(v)
224a
224b
224a
Position of piston 206 within compression chamber 204

FIG. 3A

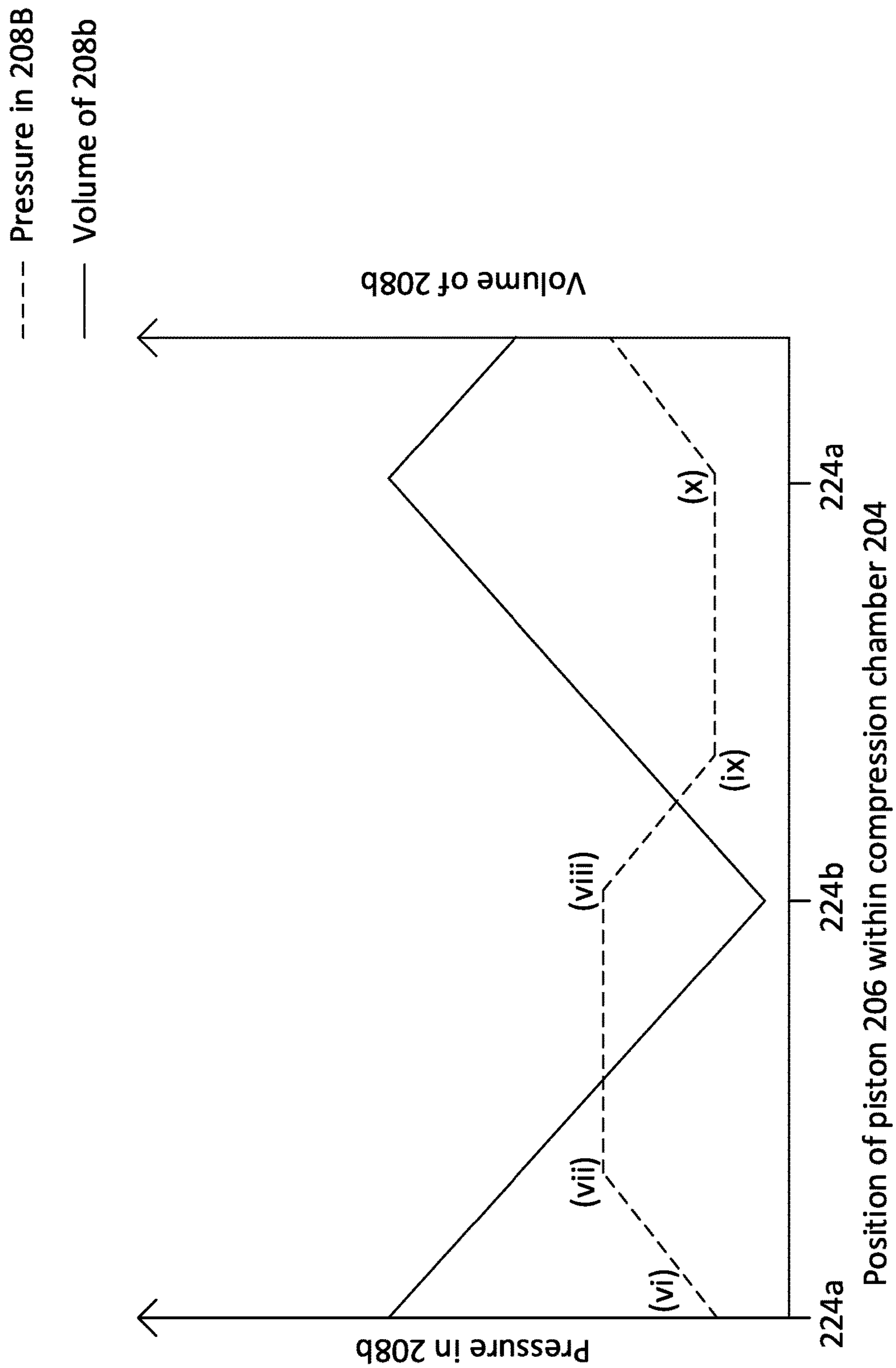

Pressure in 208B
Volume of 208b
Volume of 208b
Pressure in 208b
(vi)
(vii)
(viii)
(ix)
(x)
224a
224b
224a
Position of piston 206 within compression chamber 204

FIG. 3B

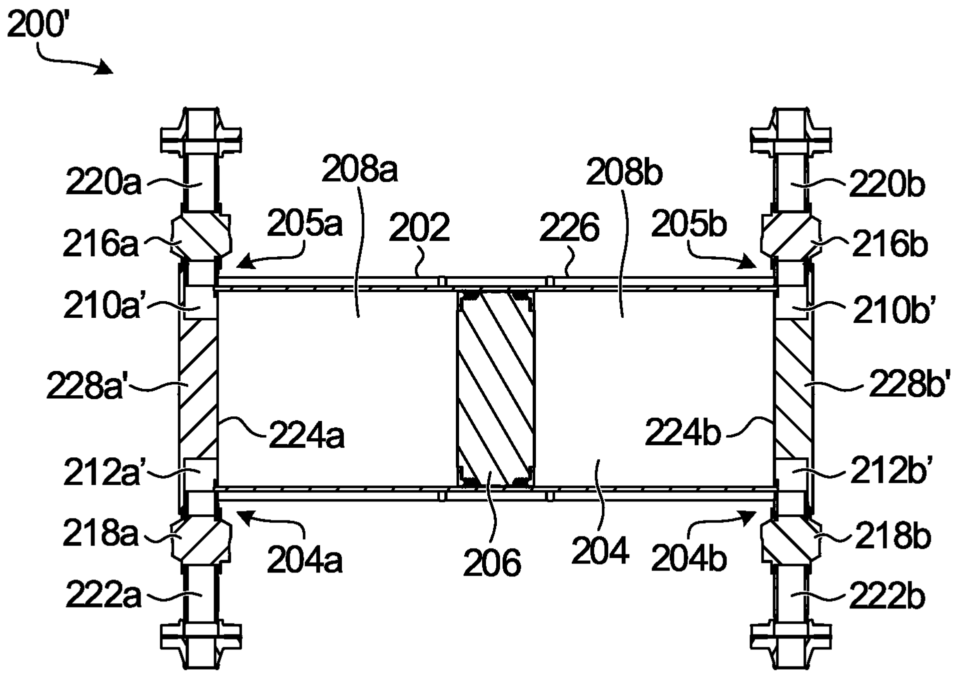
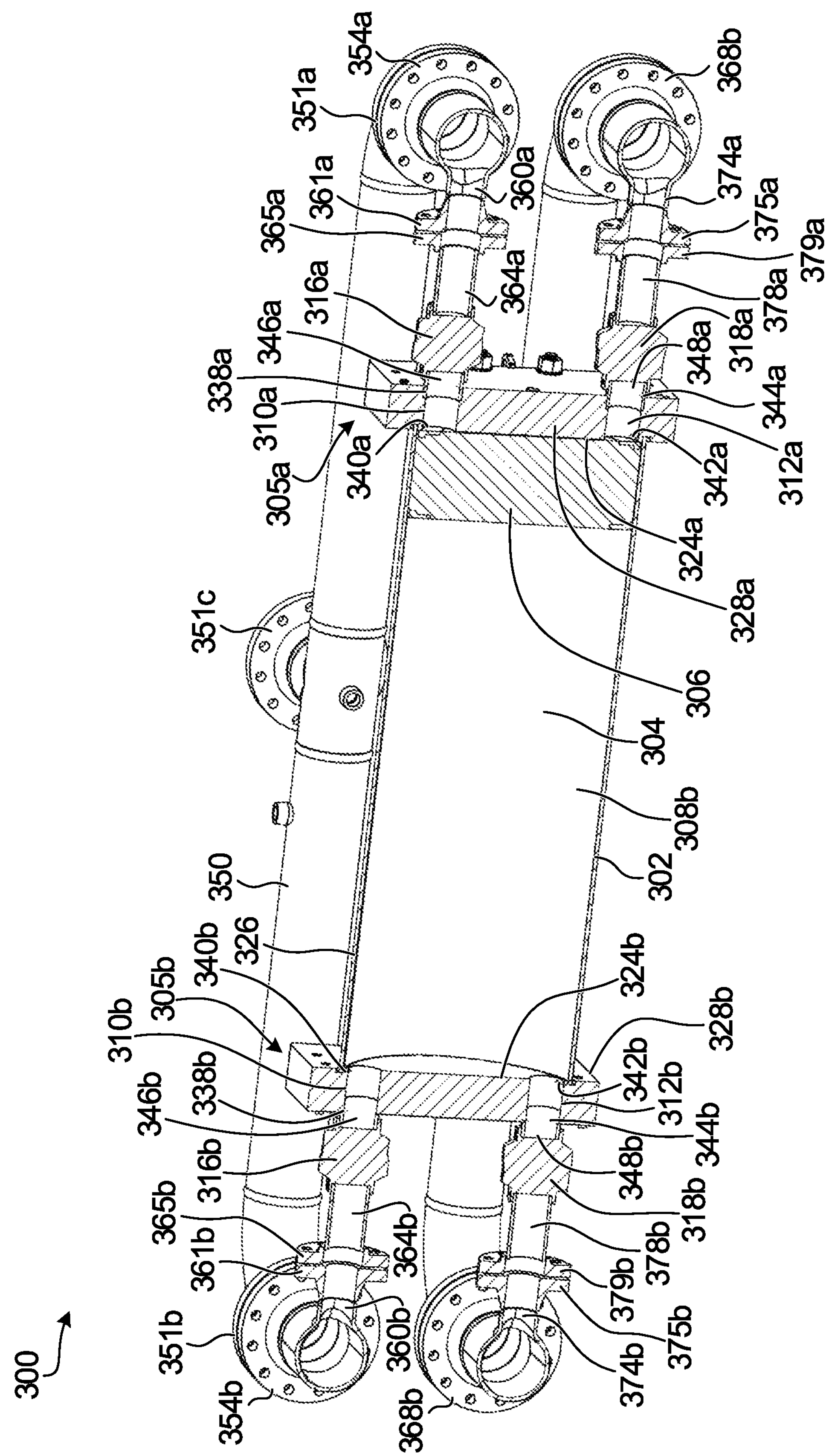

200'
220a
208a
208b
220b
216a
205a
202
226
205b
216b
210a'
210b'
228a'
228b'
224a
224b
212a'
212b'
218a
218b
204a
206
204
204b
222a
222b

FIG. 4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348a
338a
344a
310a
342a
312a
305a
340a
324a
328a
351c
306
304
308b
302
350
326
340b
305b
310b
324b
328b
342b
312b
338b
346b
344b
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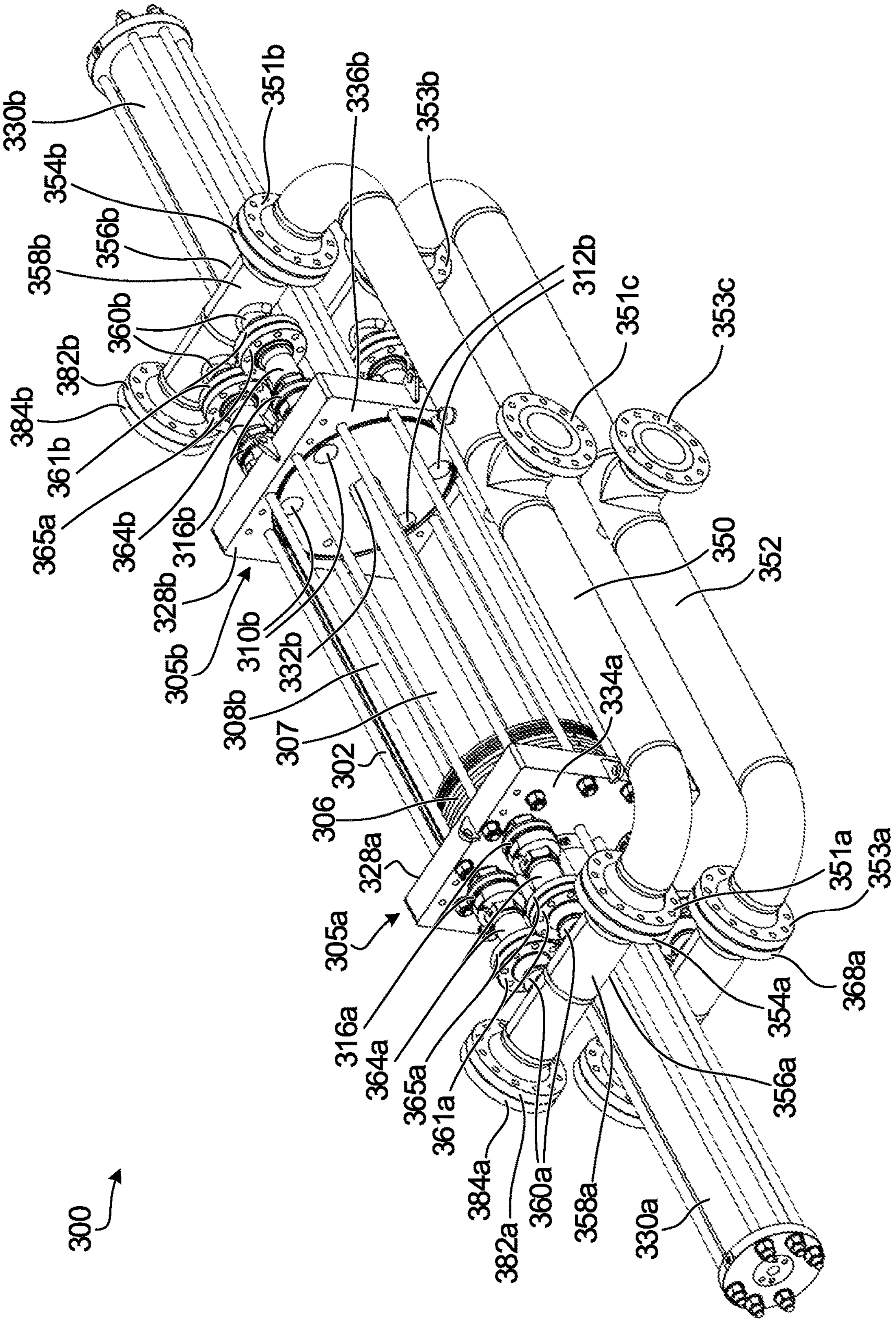
354b
368b

FIG. 5A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328b
305b
310b
332b
308b
307
302
306
328a
305a
312b
351c
353c
350
352
334a
316a
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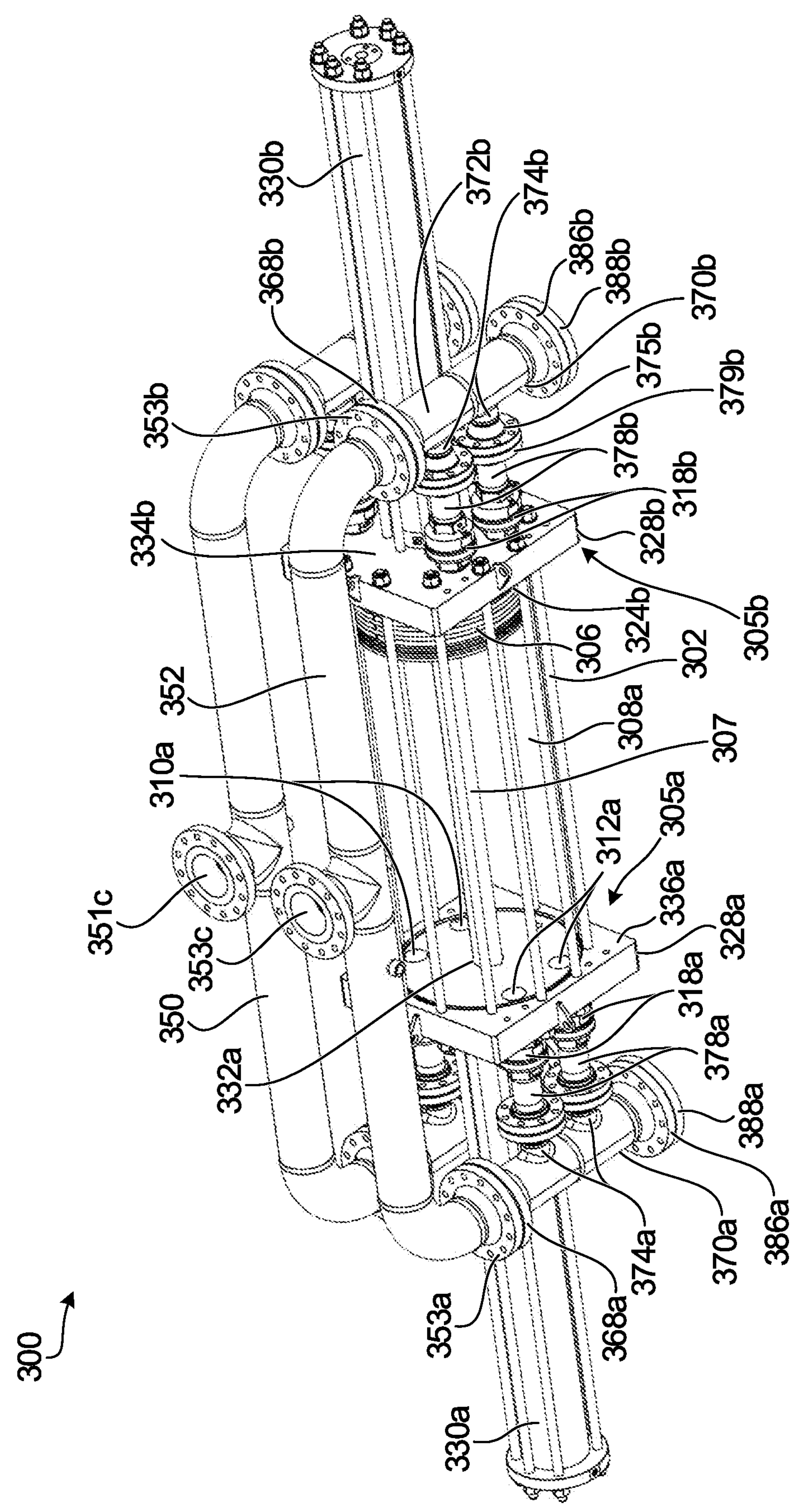
368a
351a
353a

FIG. 5B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305a
336a
351c
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FIG. 5C

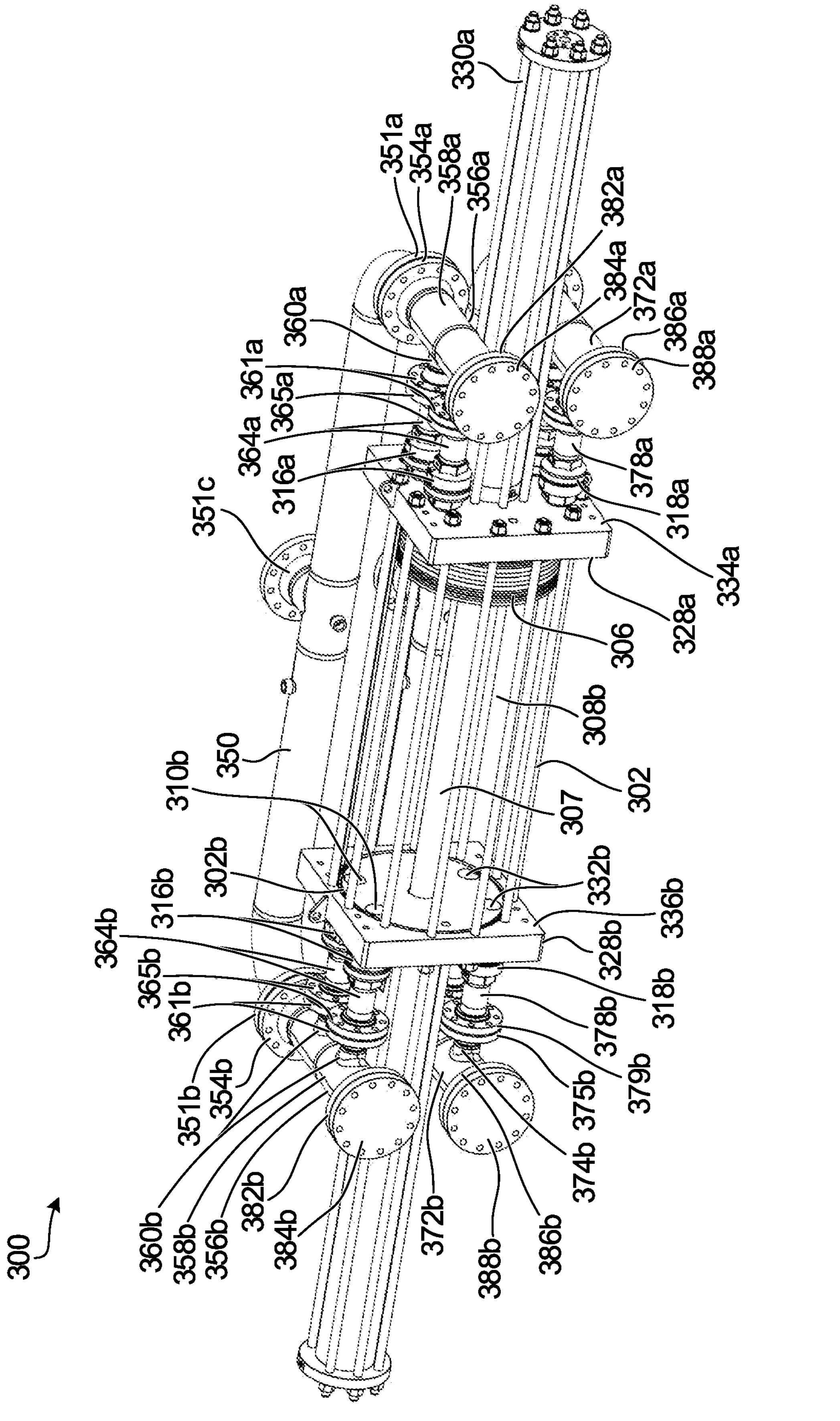
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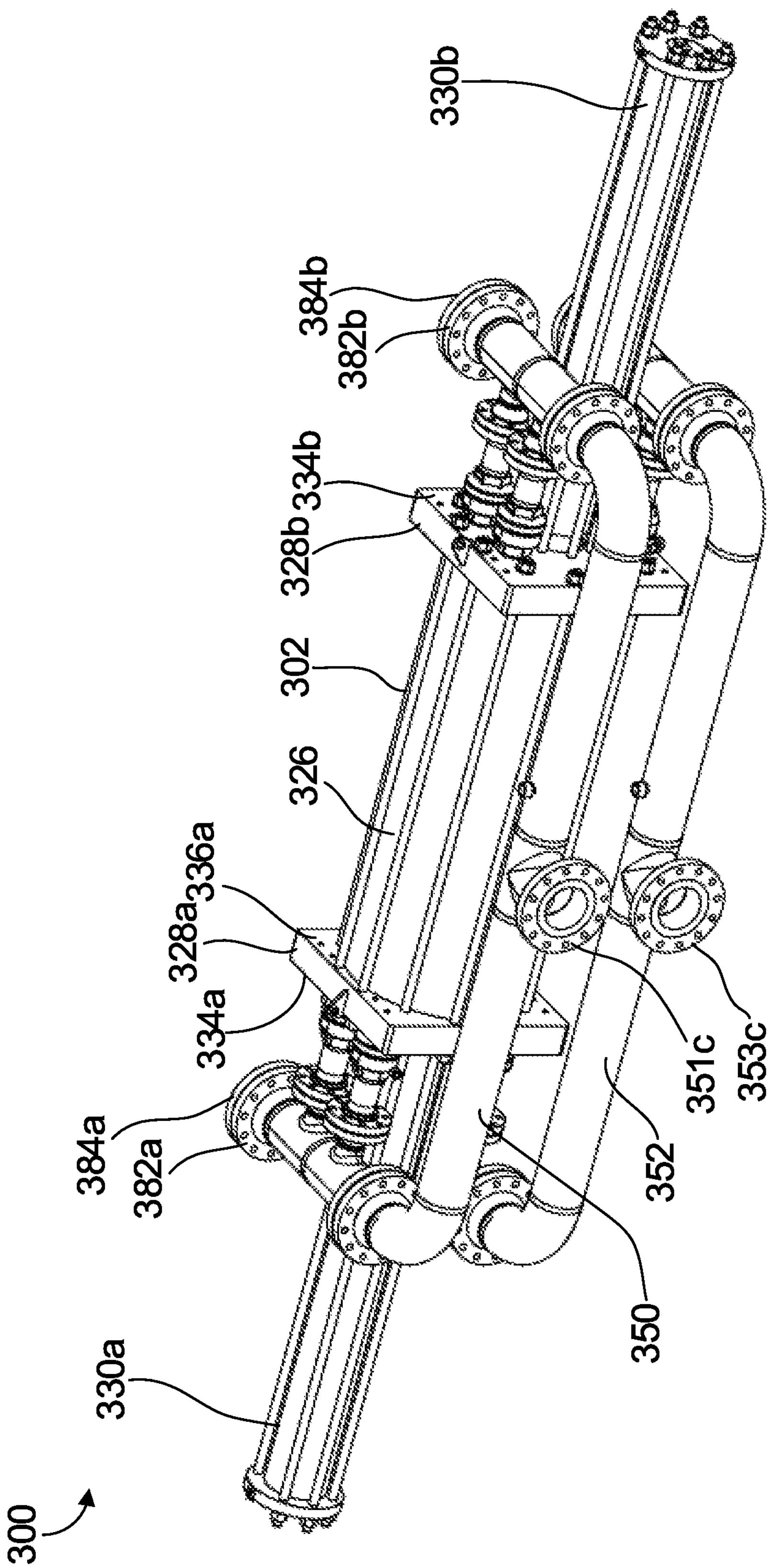
FIG. 5D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330a
300

FIG. 5E

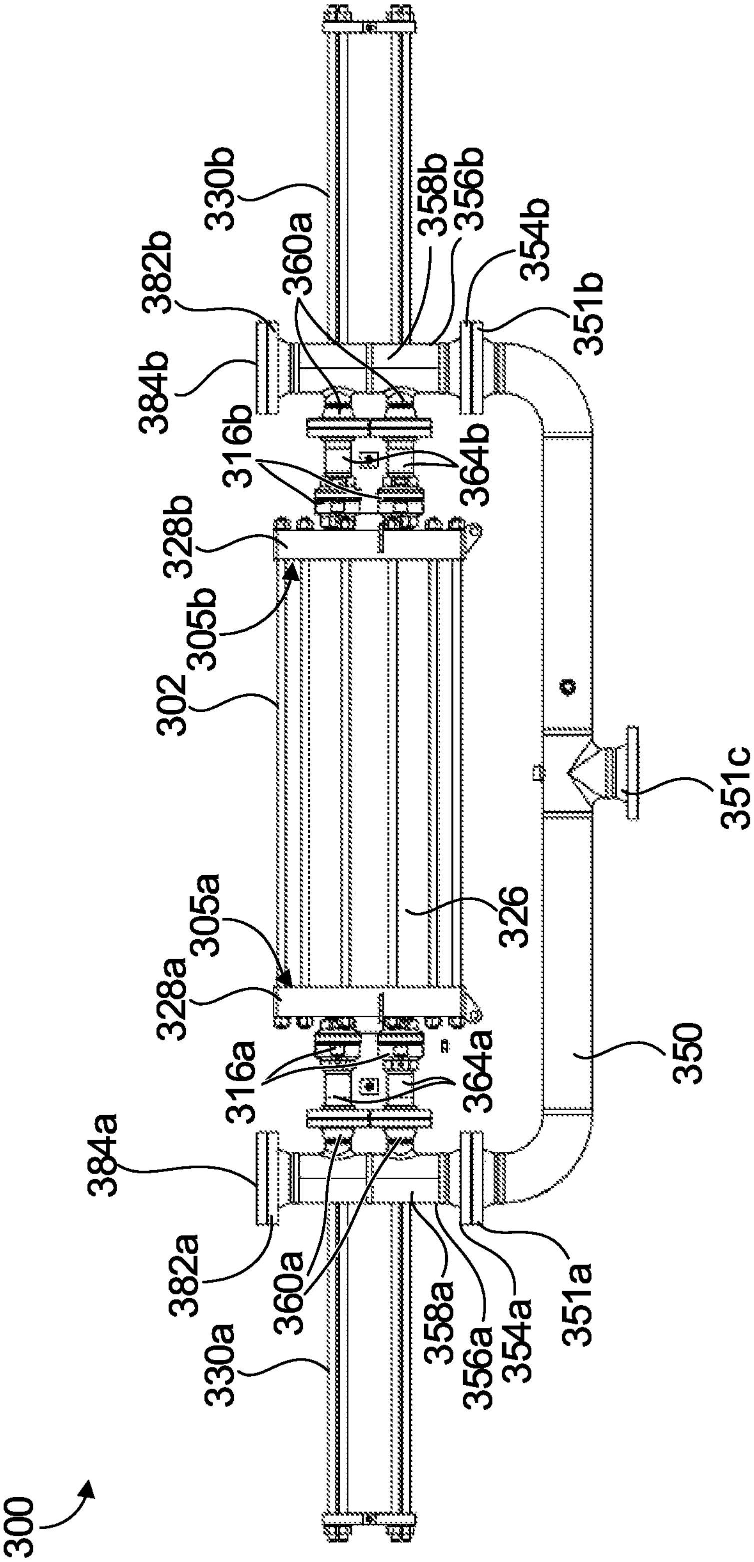
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FIG. 5F

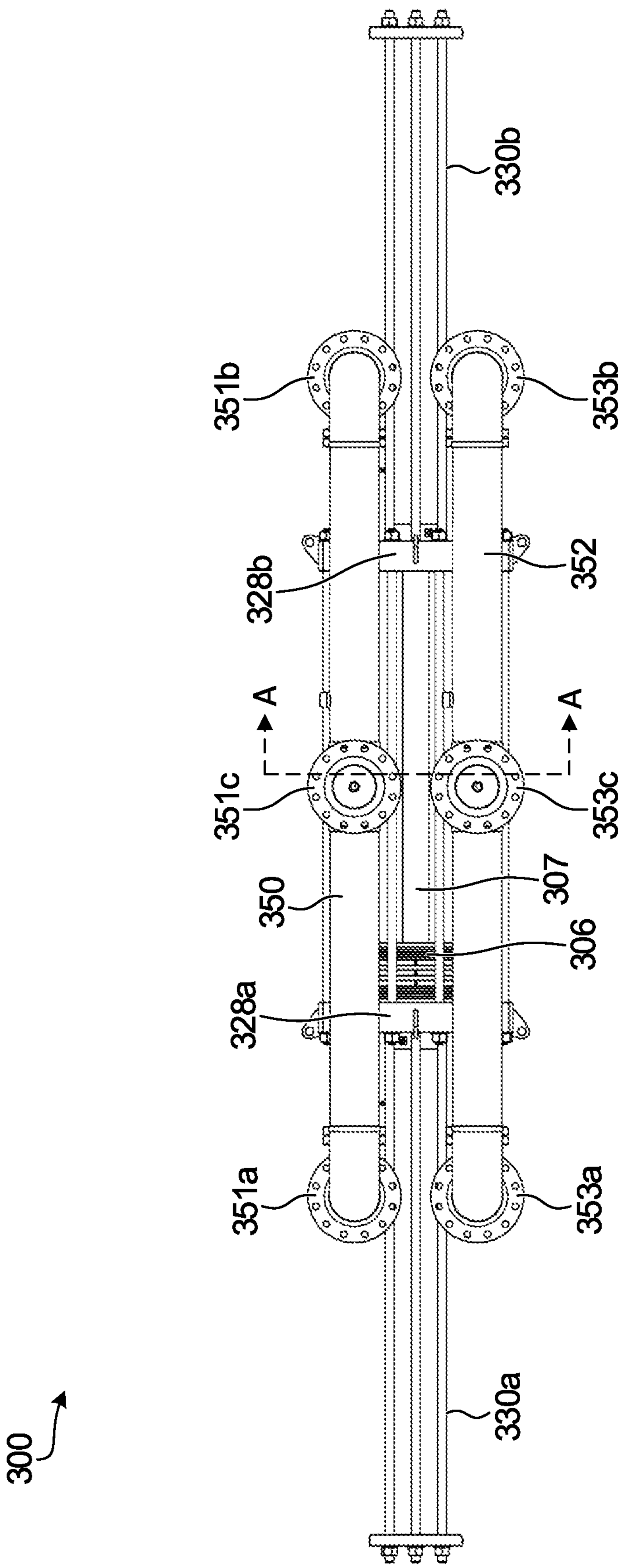
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FIG. 5G

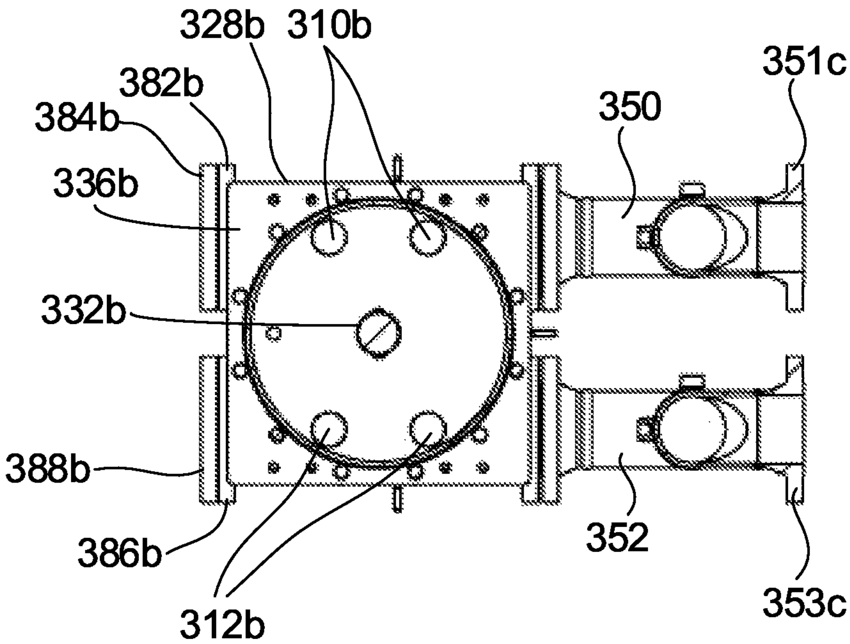
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FIG. 5H

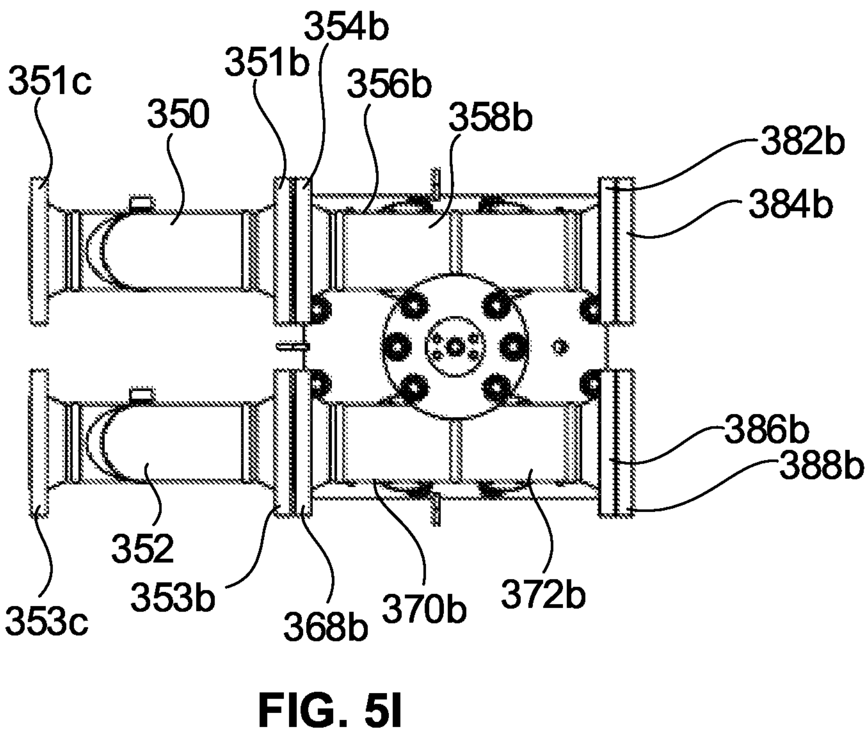
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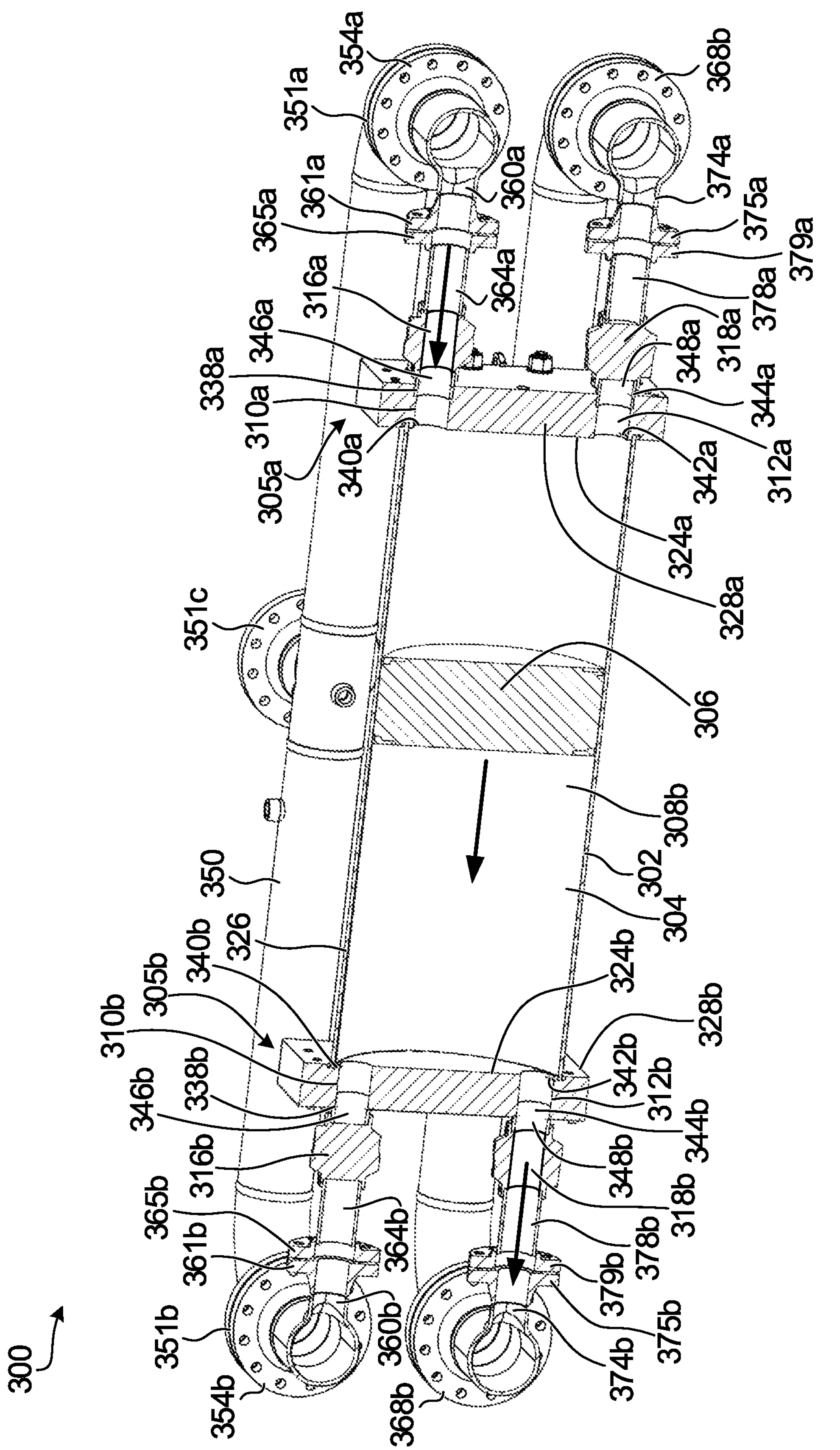
FIG. 5I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328a
351c
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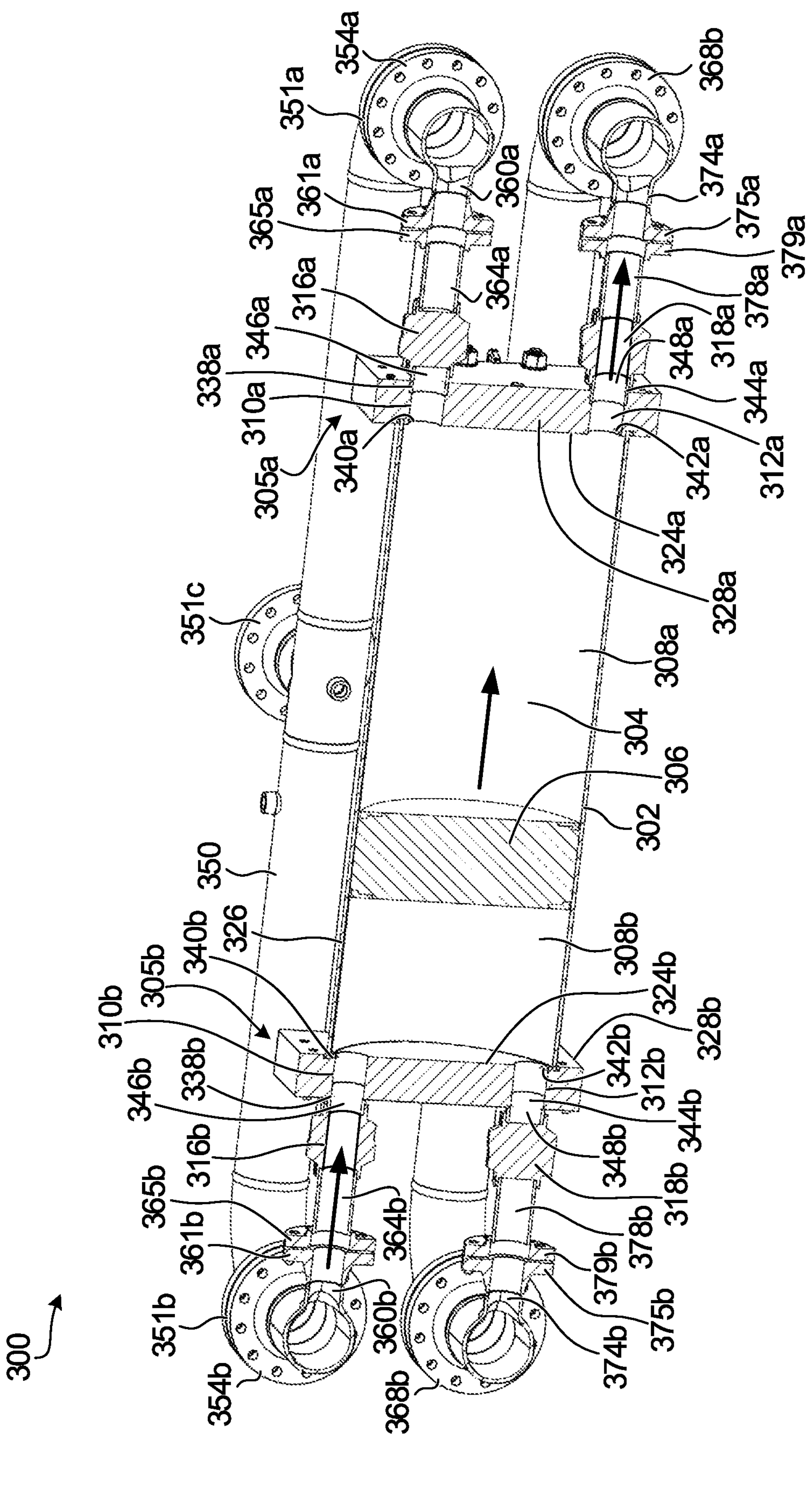
FIG. 5J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351c
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FIG. 5K

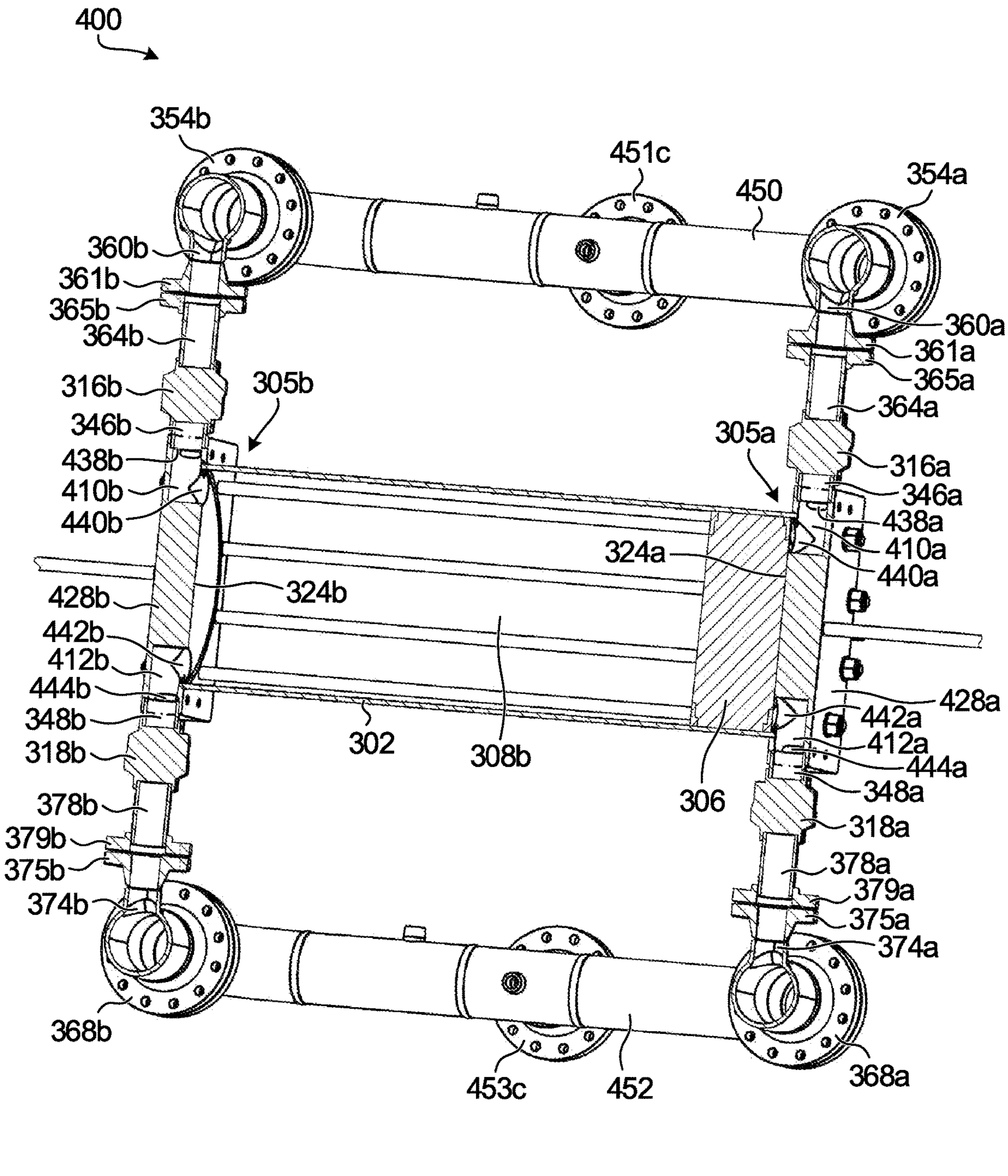

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FIG. 6A

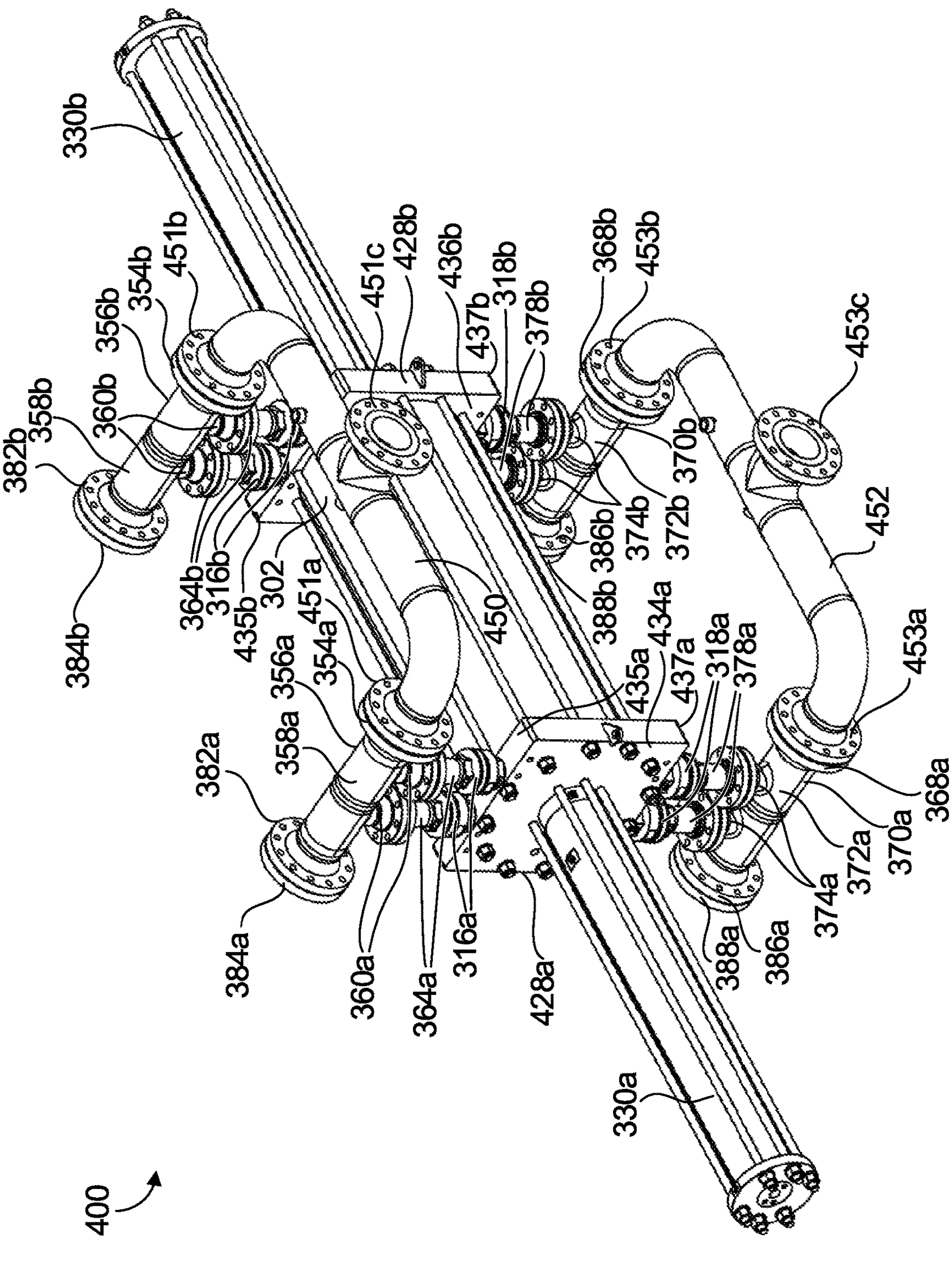
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FIG. 6B

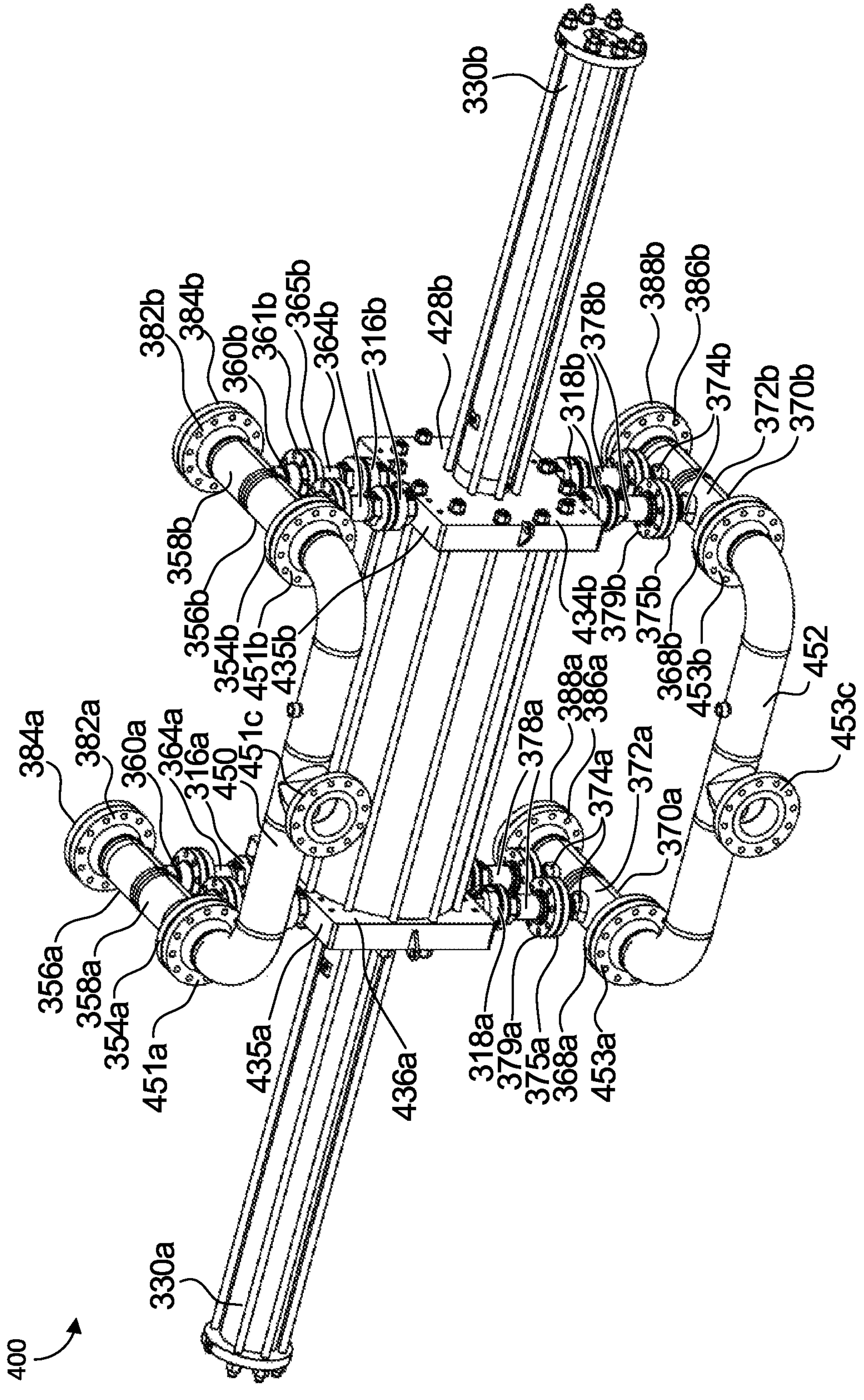
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FIG. 6C

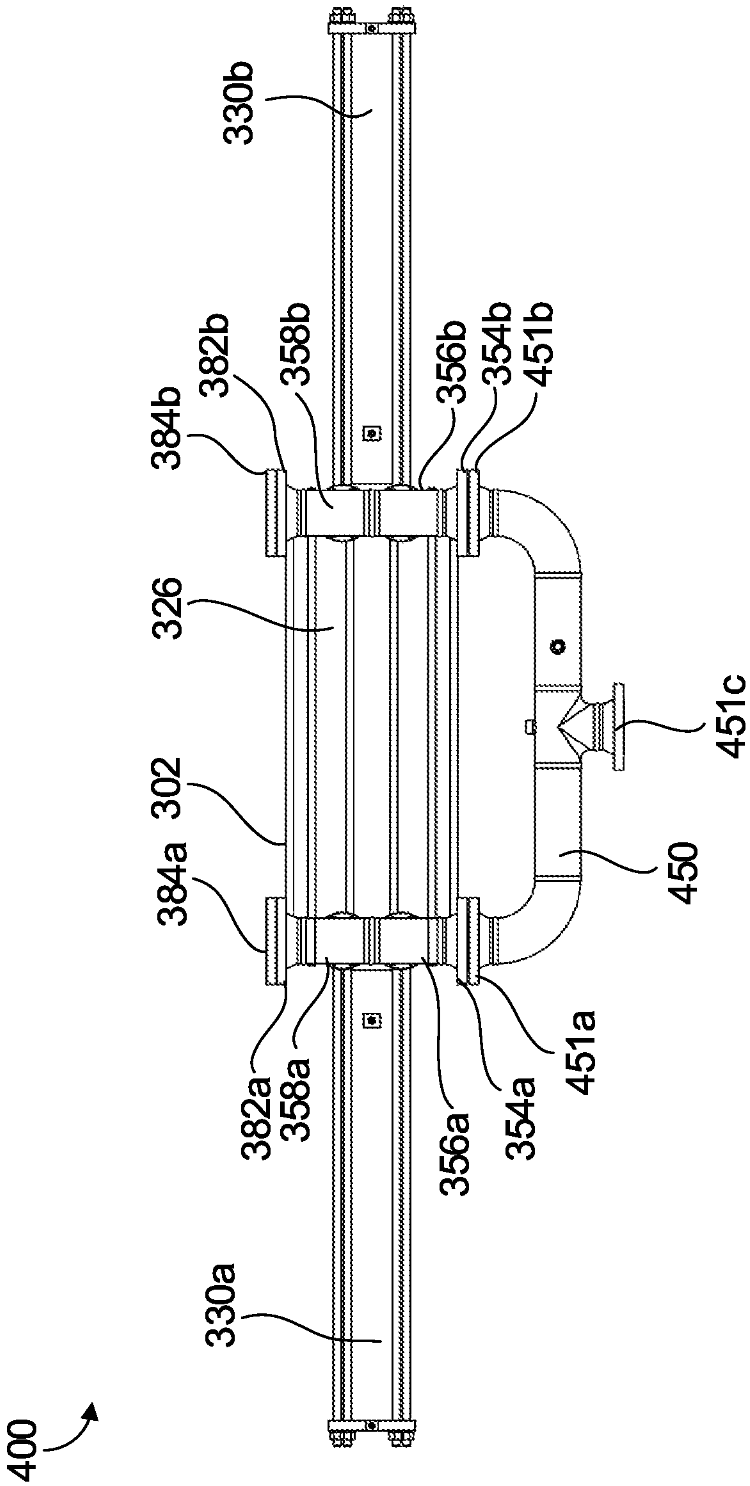
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FIG. 6D

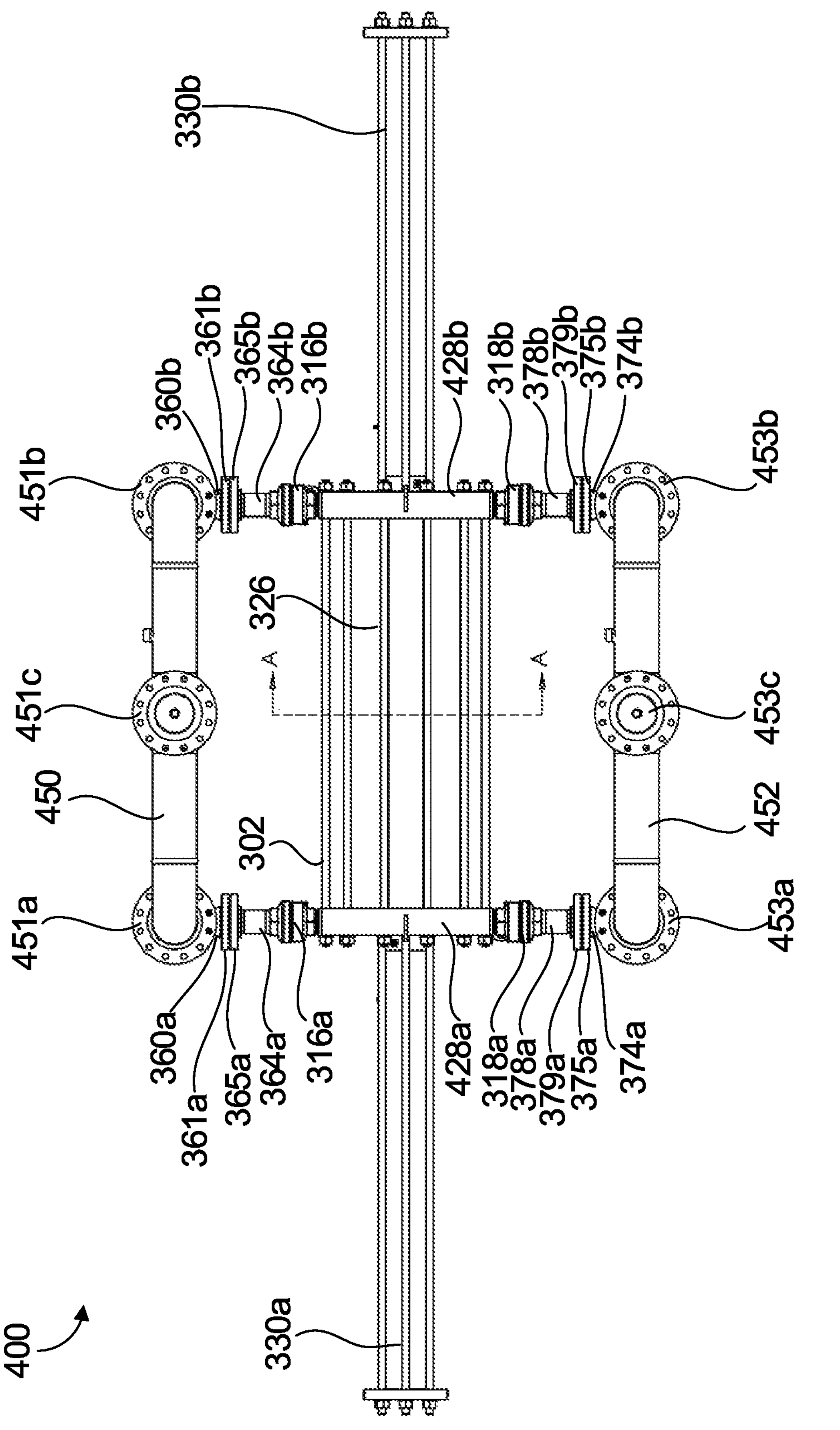
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FIG. 6E

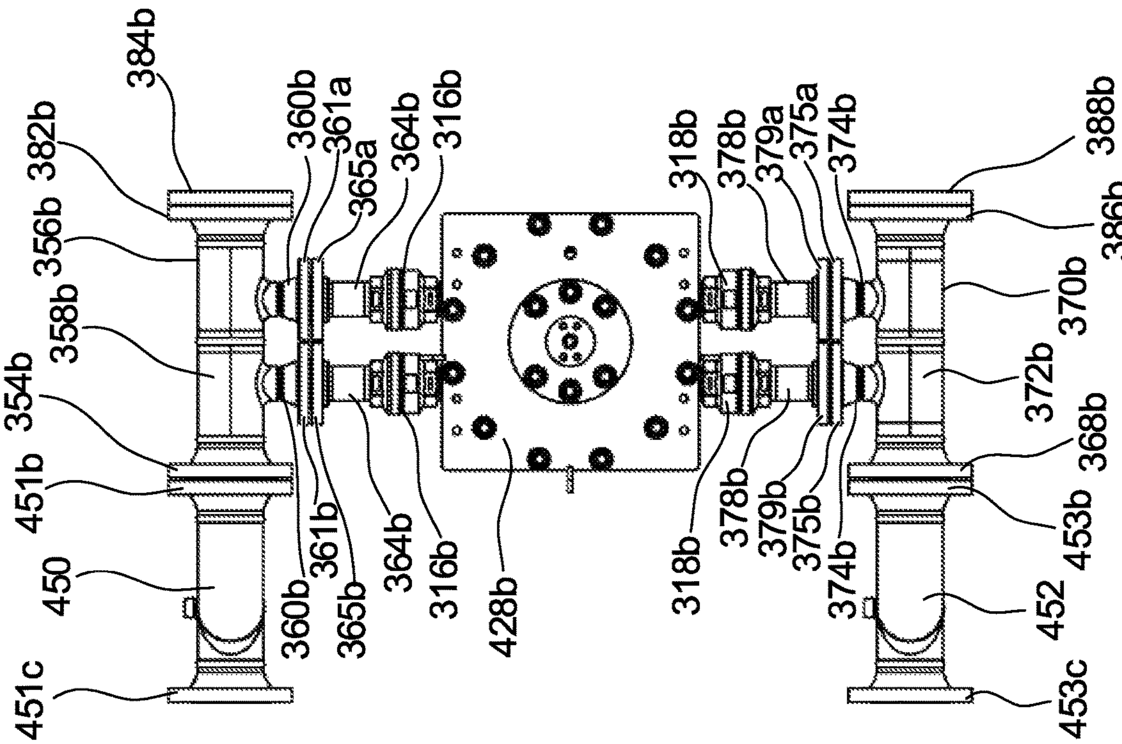
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FIG. 6G

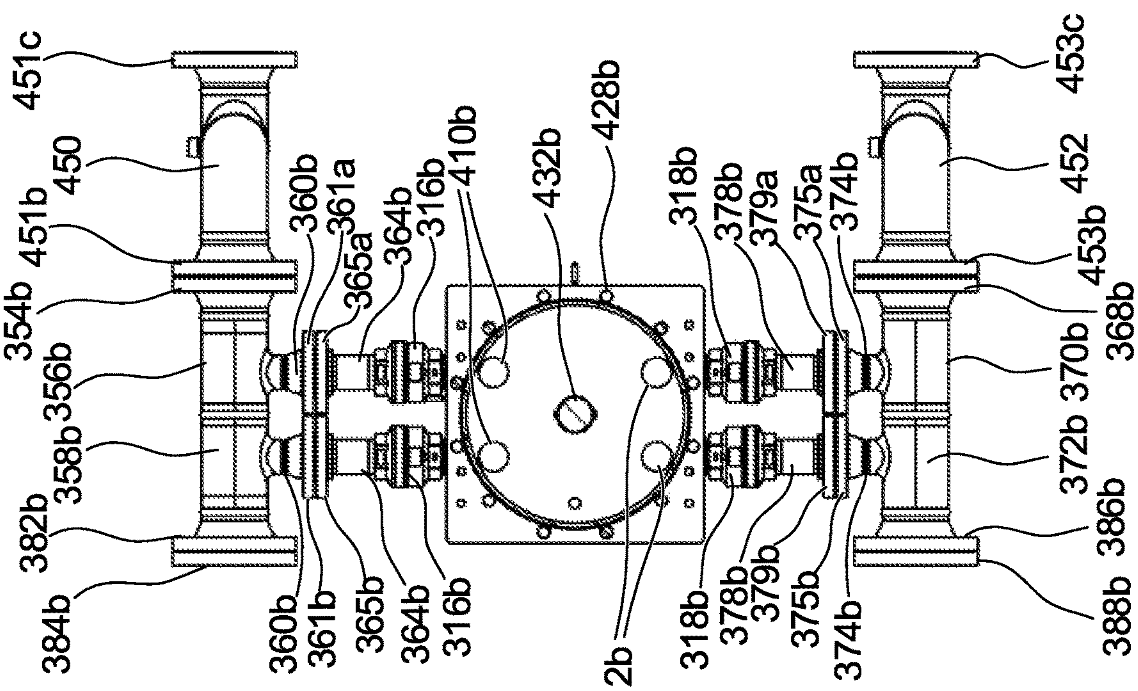
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FIG. 6F

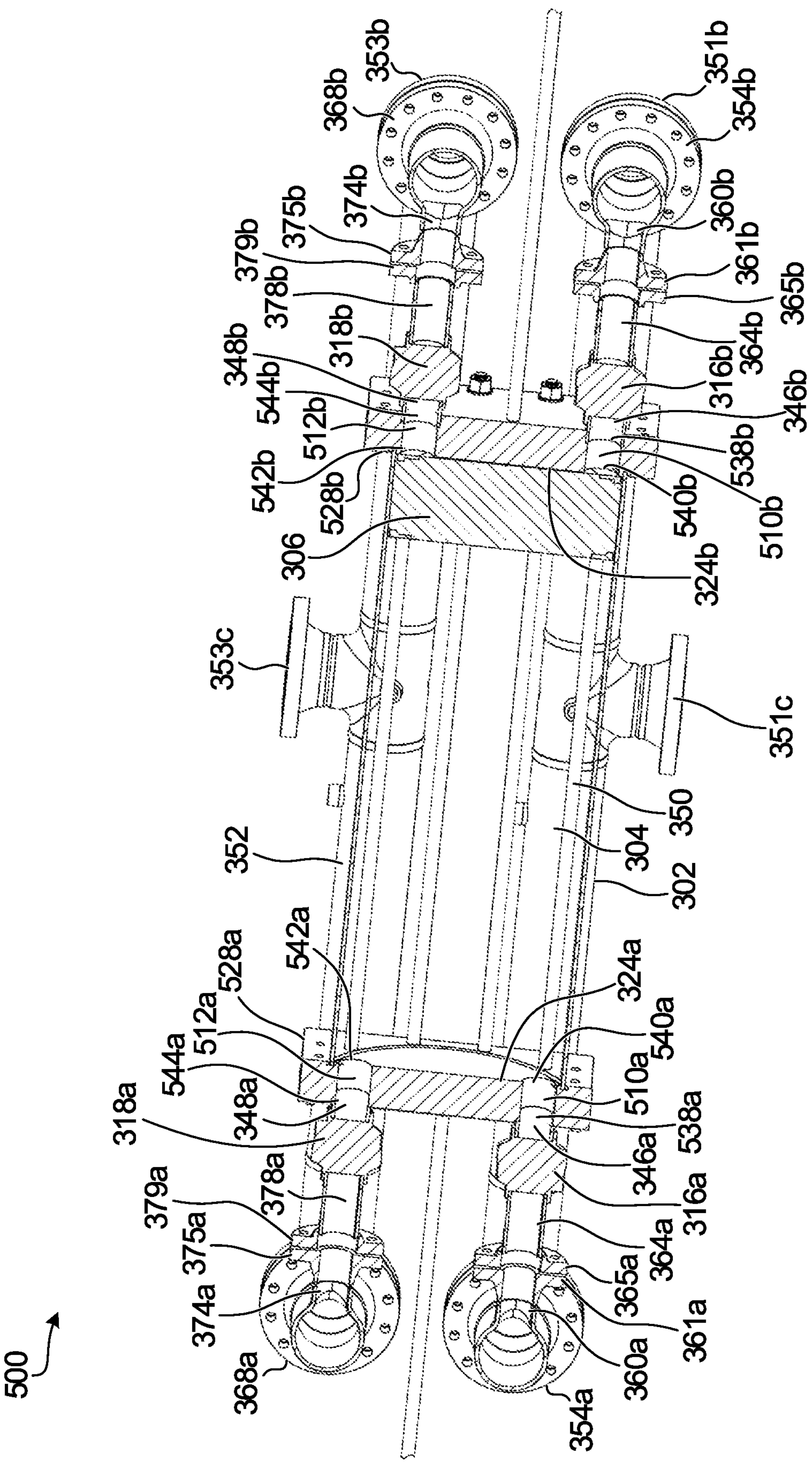
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FIG. 7A

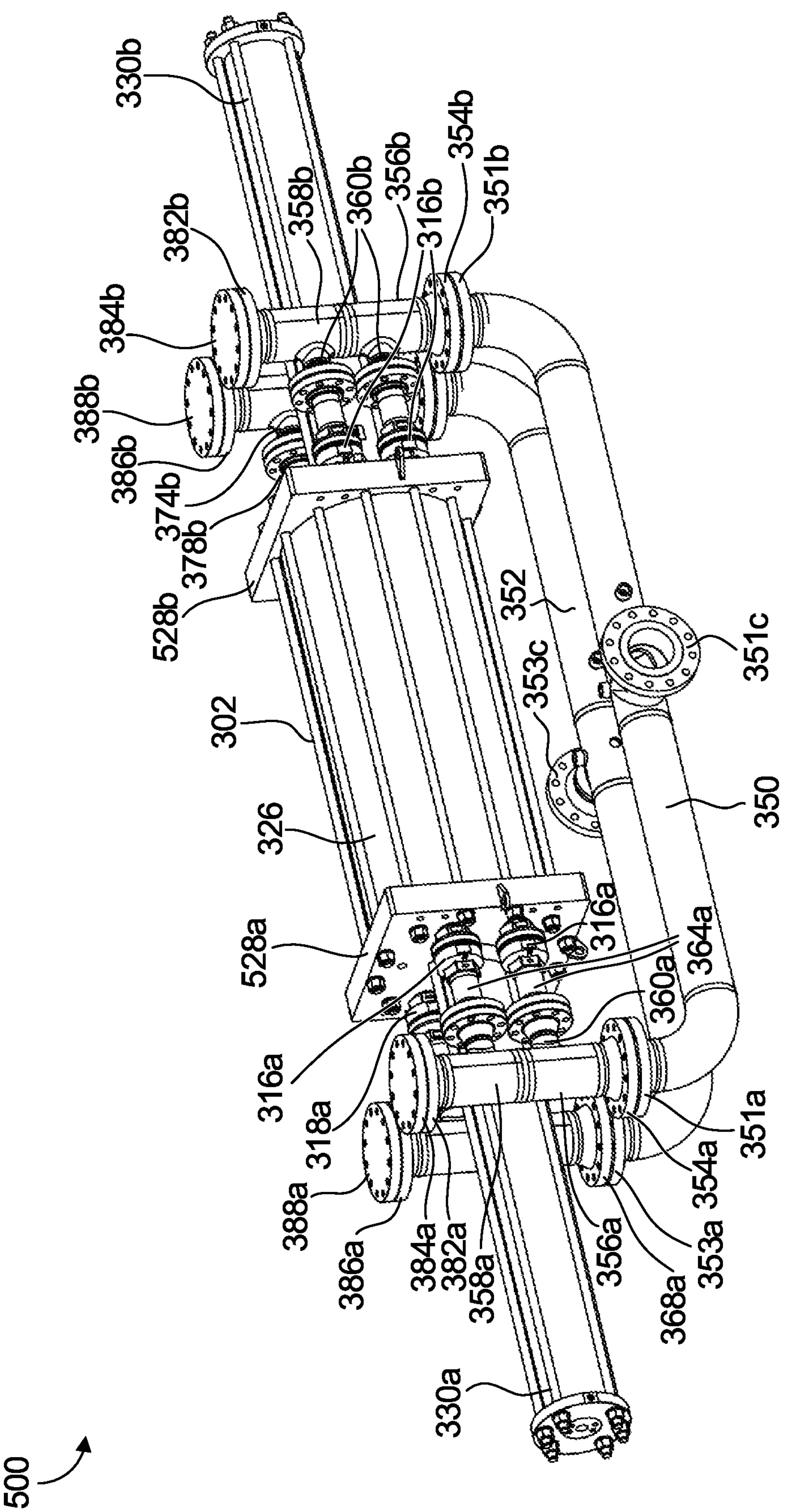
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FIG. 7B

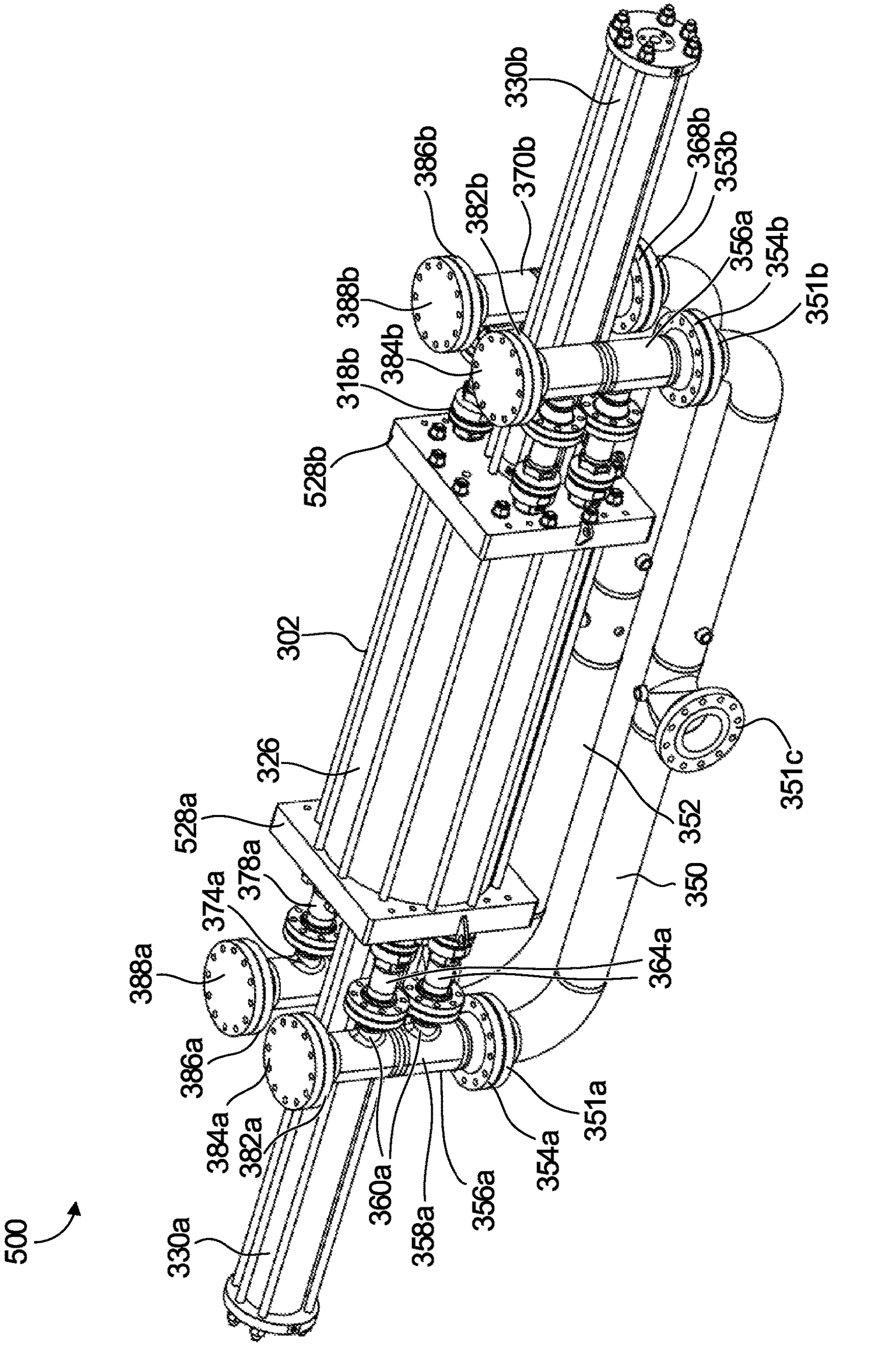
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FIG. 7C

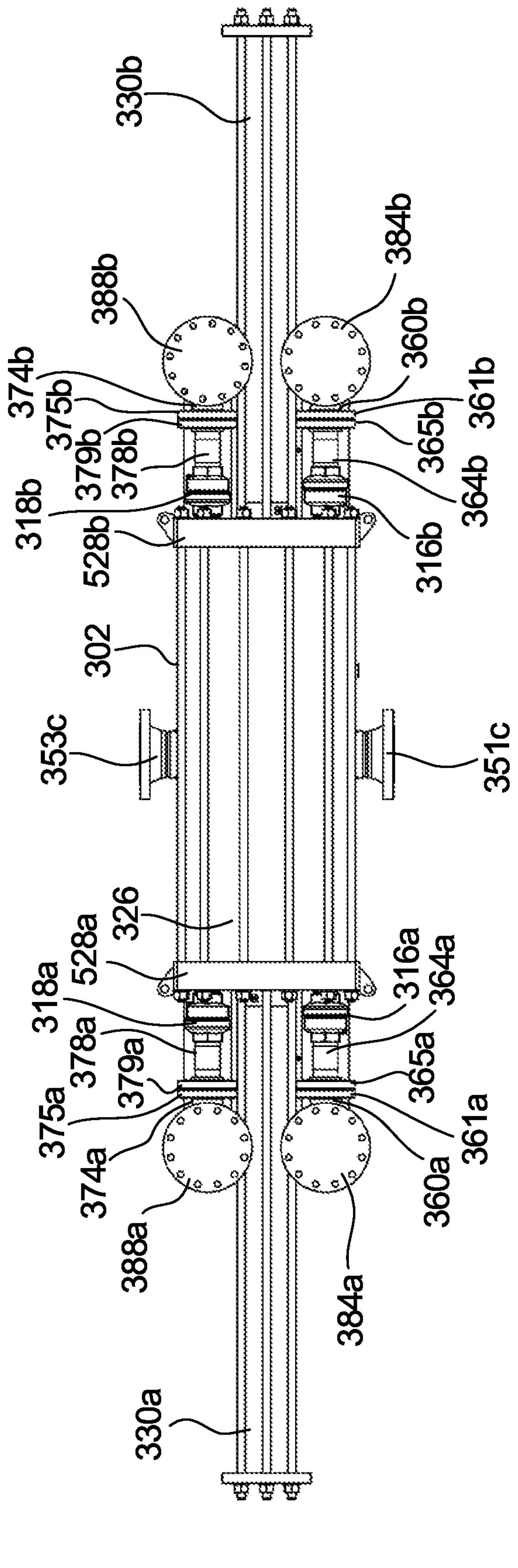
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FIG. 7D

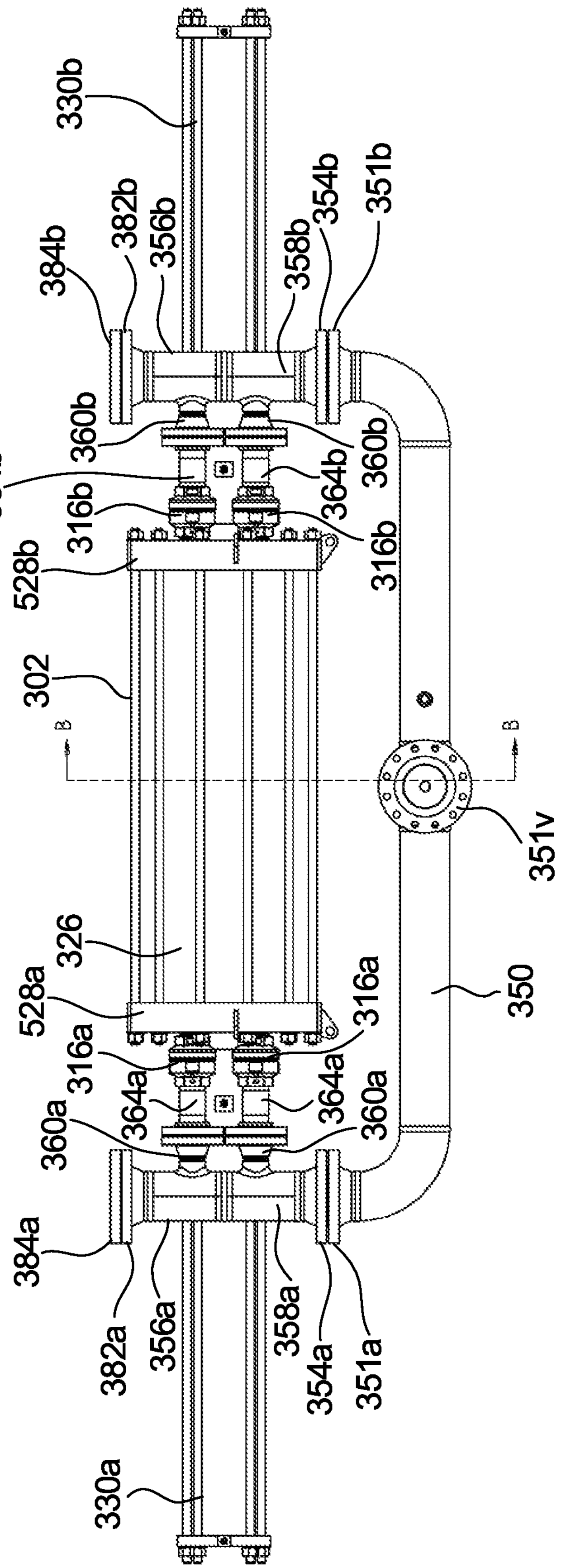
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FIG. 7E

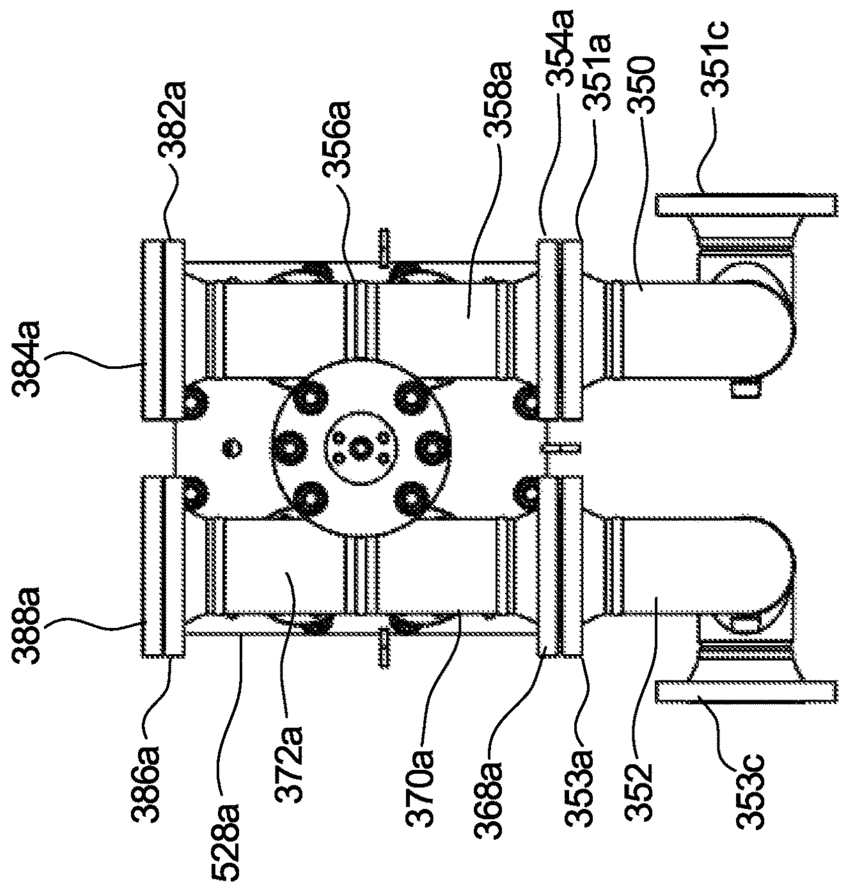
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FIG. 7G

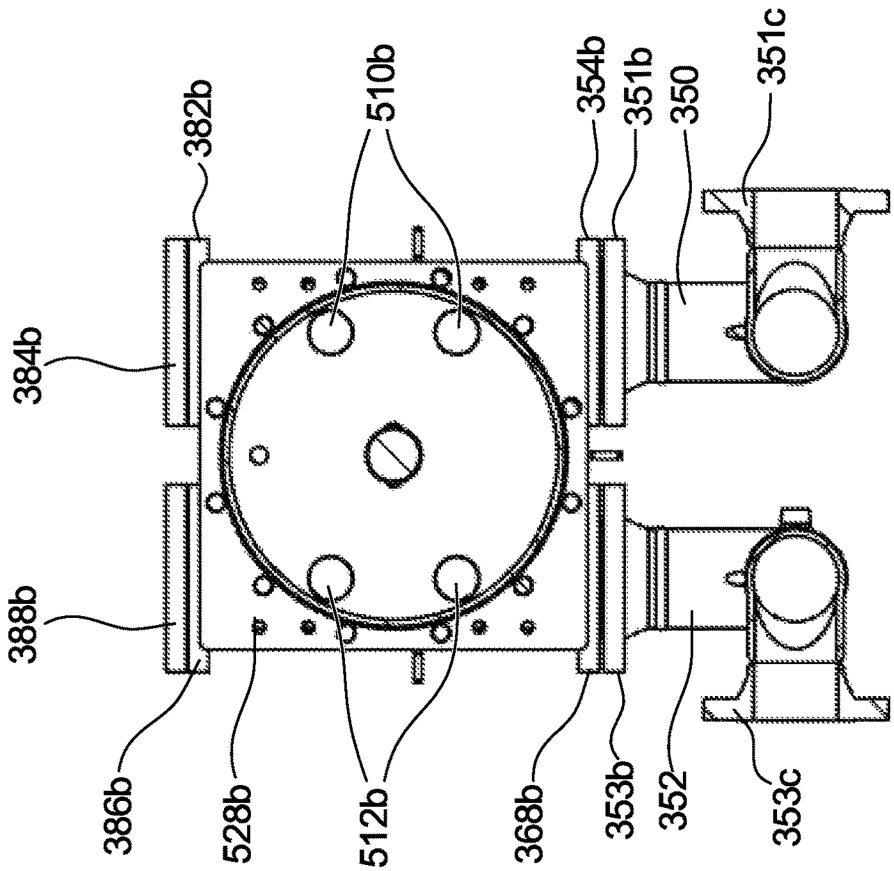
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FIG. 7F

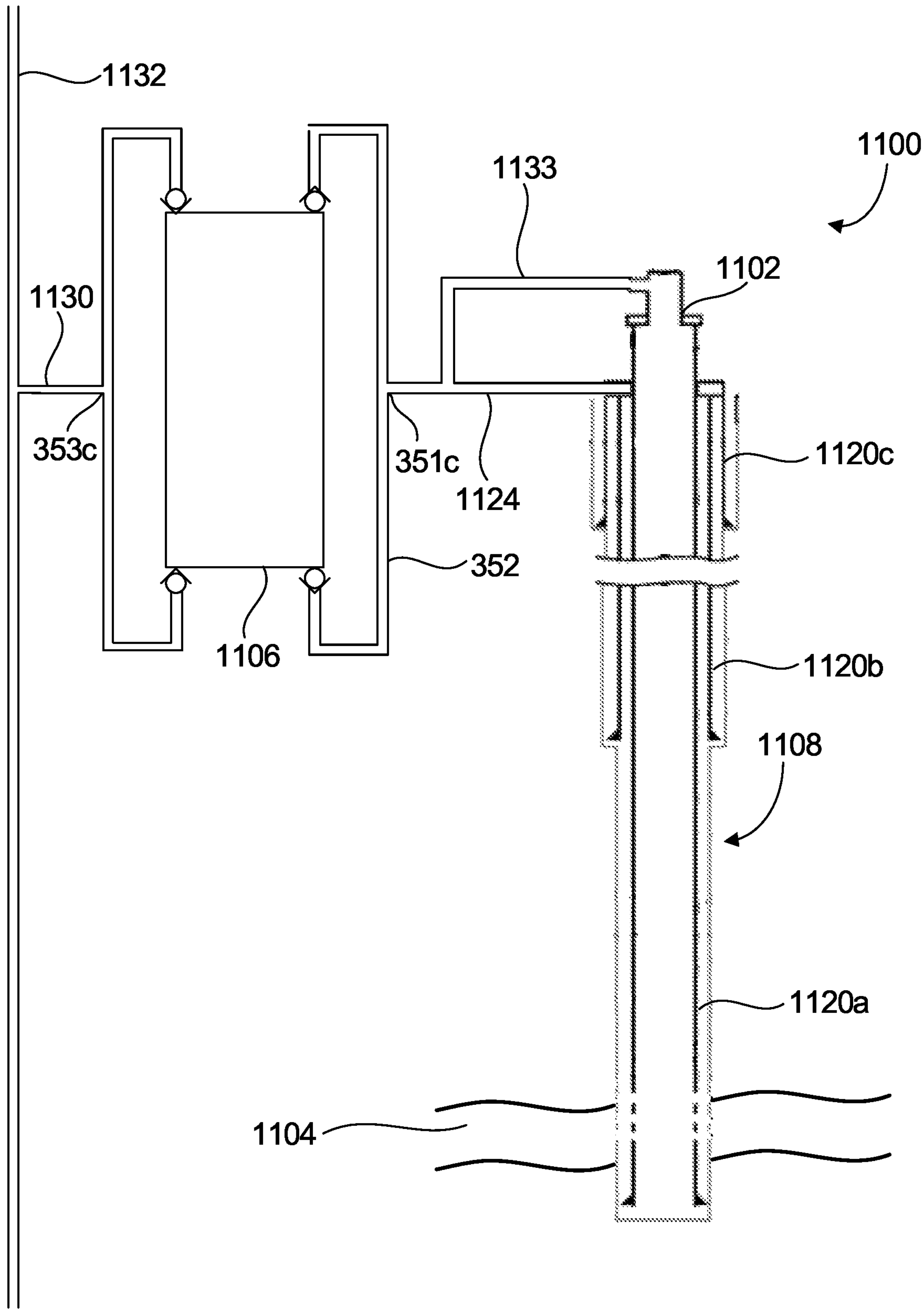
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FIG. 8

COMPRESSOR FOR PUMPING FLUID HAVING CHECK VALVES ALIGNED WITH FLUID PORTS

FIELD

The present disclosure relates generally to fluid compression or pumping devices and systems, and specifically to fluid compressors having fluid ports and check valves connected to the ports.

BACKGROUND

Fluid compressors are useful for pumping fluids. A fluid compressor typically has a fluid chamber and a pair of fluid ports serving as an inlet or outlet of the fluid chamber. Check valves may be connected to the fluid ports for controlling fluid flow through the inlet or outlet ports.

For example, United States patent publication no. US20210270257, published on Sep. 2, 2021, disclosed fluid compressors for pumping multiphase fluids. A representative view of a compressor **100** disclosed therein is shown in FIG. **1**. Compressor **100** includes a compression cylinder **102** having opposite ends **112***a*, **112***b*. The compression cylinder **100** has a double-acting compression piston for compressing a fluid towards one or the other of the two ends **112***a*, **112***b*. The compression piston is driven by two hydraulic cylinders each coupled to the compression cylinder at one of the ends **112***a*, **112***b* through a central port. Each end **112***a*, **112***b* also has two fluid ports **104***a*, **104***b* spaced from the central port, one of which is an inlet port and the other of which is an outlet port. The fluid to be pumped can flow in and out of compression cylinder **102** through ports **104***a* and ports **104***b*. Each port **104***a*,**104***b* is connected to a check valve **108***a*, **108***b* by an elbow connector **106***a*, **106***b*. The elbow connectors **106***a*,**106***b* are used and have sufficient size so that the check valves **108***a*, **108***b* are offset from the hydraulic cylinders at each end **112***a*, **112***b* of the compression cylinder **100**. The check valves **108***a*,**108***b* are connected by flanges and pipes to the fluid input source and the output destination. The check valves **108***a*, **108***b* are configured and oriented to control the fluid flow at the ports **104***a*, **104***b*.

It is desirable to improve the efficiency or performance of such fluid compressors.

SUMMARY

In an embodiment, the present disclosure relates to a compressor that comprises a first cylinder for compressing a fluid. The first cylinder comprises a chamber configured to receive a fluid and having a first end and a second end, a piston reciprocally movable in the chamber for alternately compressing the fluid towards the first or second end, three or more first ports at the first end of the chamber, the first ports comprising at least one first inlet port and at least one first outlet port, and three or more second ports at the second end of the chamber, the second ports comprising at least one second inlet port and at least one second outlet port. Each one of the first and second ports defines a fluid flow path extending along an axial direction of the port. The compressor also comprises at least one second cylinder each connected and configured to drive movement of the piston in the first cylinder through one of the first and second ends and a plurality of check valves, each associated with one of the first and second ports and connected inline with the associated port along the axial direction of the associated port. The piston is reciprocally movable in the chamber along an axial direction of the chamber, and the axial directions of the first and second ports are parallel to the axial direction of the chamber.

In some embodiments the check valves connected to the inlet ports are oriented to allow the fluid to flow into the compression chamber through the inlet ports and the check valves connected to the outlet ports are oriented to allow fluid to flow out of the compression chamber through the outlet ports.

In some embodiments, the first ports comprise at least two inlet ports, and the second ports comprise at least two inlet ports. In some embodiments, the first ports comprise at least two outlet ports, and the second ports comprise at least two outlet ports.

In at least some of the embodiments presented herein, the compressor further comprises a plurality of first conduits each connecting one of the check valves to its associated port. In some embodiments, each one of the first conduits defines a straight fluid path between the check valve and the port connected by the respective first conduit.

In some embodiments, the check valves connected to the inlet ports are first check valves and the check valves connected to the outlet ports are second check valves and the compressor further comprises a second conduit connected to the first check valves for connecting a fluid source to the inlet ports to supply the fluid from the fluid source to the compression chamber though the inlet ports, and a third conduit connected to the second check valves for receiving compressed fluid from the compression chamber through the outlet ports.

In some embodiments, each of the second and third conduits comprises a first end comprising a first flange, a plurality of second ends each comprising a second flange for connecting the respective second end to one of the check valves and at least one third end comprising a third flange and a removable blanking plate coupled to the third flange.

In some embodiments, the first ports comprise two first inlet ports and two first outlet ports, and the second ports comprise two second inlet ports and two second outlet ports.

In some embodiments, the at least one first inlet port is positioned above the at least one first outlet port, and the at least one second inlet port is positioned above the at least one second outlet port.

In some embodiments, the check valves are in-line check valves.

In another embodiment, the present disclosure relates to a compressor that comprises a first cylinder for compressing a fluid. The first cylinder comprises a chamber configured to receive a fluid and having a first end and a second end, a piston reciprocally movable in the chamber along an axial direction of the chamber for alternately compressing the fluid towards the first or second end, a plurality of first inlet ports and a plurality of first outlet ports at the first end of the chamber and a plurality of second inlet ports and a plurality of second outlet ports at the second end of the chamber. Each one of the inlet and outlet ports defines a fluid flow path extending along an axial direction of the port, the axial directions of the inlet and outlet ports being perpendicular to the axial direction of the chamber. The compressor also comprises at least one second cylinder each connected and configured to drive movement of the piston in the first cylinder through one of the first and second ends and a plurality of check valves, each associated with one of the inlet and outlet ports and connected inline with the associated port along the axial direction of the associated port.

In some embodiments, the first inlet ports are positioned above the first outlet ports at the first end of the chamber and the second inlet ports are positioned above the second outlet ports at the second end of the chamber.

In some embodiments, the plurality of check valves are in-line check valves.

In some embodiments, the compressor further comprises a plurality of first conduits each connecting one of the check valves to its associated port. In some embodiments, each one of the first conduits defines a straight fluid path between the check valve and the port connected by the respective first conduit.

In another embodiment, the present disclosure relates to a system for compressing a fluid, comprising first and second compressors each as defined herein. The first and second compressors are connected such that the compressed fluid from the outlet ports of the first compressor is fed into the inlet ports of the second compressor for further compression.

BRIEF DESCRIPTION OF THE DRAWINGS

In the figures, which illustrate example embodiments:

FIG. **1** is a front perspective view of a comparison compressor;

FIG. **2**A is a schematic cross-sectional view of a simplified compressor, according to an example embodiment;

FIG. **2**B is a schematic view of the compressor of FIG. **2**A in operation at a first state;

FIG. **2**C is a schematic view of the compressor of FIG. **2**A in operation at a second state;

FIG. **2**D is a schematic view of the compressor of FIG. **2**A in operation at a third state;

FIG. **2**E is a schematic view of the compressor of FIG. **2**A in operation at a fourth state;

FIG. **3**A is a line graph illustrating schematically the changes in the fluid volume and pressure between an end of the compression chamber and the piston during a piston stroke in the compressor of FIG. **2**A;

FIG. **3**B is a line graph illustrating schematically the changes in the fluid volume and pressure between another end of the compression chamber and the piston during a piston stroke in the compressor of FIG. **2**A;

FIG. **4** is a schematic cross-sectional view of a simplified compressor, according to another example embodiment;

FIG. **5**A is a cross-sectional rear perspective view of a compressor according to a further example embodiment;

FIGS. **5**B and **5**C are partially transparent, front perspective views of the compressor of FIG. **5**A;

FIG. **5**D is a partially transparent, rear perspective view of the compressor of FIG. **5**A;

FIGS. **5**E and **5**F are front perspective and top plan views of the compressor of FIG. **5**A;

FIG. **5**G is a partially transparent front view of the compressor of FIG. **5**A;

FIG. **5**H is a cross sectional end view of the compressor of FIG. **5**A, along the line A-A in FIG. **5**G;

FIG. **5**I is an end view of the compressor of FIG. **5**A;

FIG. **5**J is a cross-sectional rear perspective view of the compressor of FIG. **5**A, with some check valves in an open configuration;

FIG. **5**K is a cross-sectional rear perspective view of the compressor of FIG. **5**A, with some check valves in an open configuration;

FIG. **6**A is a partially transparent, cross-sectional rear perspective view of a compressor according to a further embodiment;

FIGS. **6**B and **6**C are front perspective views of the compressor of FIG. **6**A;

FIGS. **6**D and **6**E are top plan and front views of the compressor of FIG. **6**A;

FIG. **6**F is a cross sectional end view of the compressor of FIG. **6**A, along the line A-A in FIG. **6**E;

FIG. **6**G is an end view of the compressor of FIG. **6**A;

FIG. **7**A is a partially transparent, cross-sectional top perspective view of a compressor according to a further embodiment;

FIGS. **7**B and **7**C are front perspective views of the compressor of FIG. **7**A;

FIGS. **7**D and **7**E are top plan and front views of the compressor of FIG. **7**A;

FIG. **7**F is a cross sectional end view of the compressor of FIG. **7**A, along the line B-B in FIG. **7**E;

FIG. **7**G is an end view of the compressor of FIG. **7**A; and

FIG. **8** is a schematic view of an oil and gas producing well system.

DETAILED DESCRIPTION

It has been recognized that when the compression piston within the compression chamber of the compressor **100** as shown in FIG. **1** reaches an end of stroke position, a relatively large dead volume (or minimal chamber volume) still undesirably remains within the space between the piston face and the check valves **108***a* or **108***b*, particularly in the ports **104***a* or **104***b* and the elbow connectors **106***a* or **106***b*. This large dead volume leads to decreased pumping efficiency and performance. This problem would be exaggerated when the sizes of the elbow connectors **106***a*, **106***b* and the check valves **108***a*, **108***b* are increased to provide increased throughput or to pump certain liquids such as liquids produced from a well in oil and gas applications. It is thus desirable to provide a fluid compressor with reduced dead volume to increase the compression ratio of the compressor without reducing or limiting the pumping throughput.

The present inventor has discovered a number of solutions to address the above problem. First, connecting a check valve to an inlet/outlet port without an elbow connector therebetween can provide a straight, shortened fluid flow path between the port and the check valve, thus reducing the dead volume. The straight flow path will also improve the flow characteristics in the flow path, thereby increasing pumping efficiency.

As can be appreciated, when the elbow connector between the check valve and the port is eliminated or replaced with a straight connector, the check valve can be positioned closer to the port, reducing the path volume between the end of the piston and the check valve. This will beneficially reduce the dead volume (i.e., the volume of compressed fluid retained within the compressor at the end of each stroke) of the compressor. With a smaller dead volume, the compressor will be able to draw in, compress and expel a larger volume of liquid on each stroke, and provide a higher compression ratio on each stroke.

Due to the limited room at each end of the compression cylinder in the presence of the hydraulic cylinder coupled to the compression cylinder, the sizes of the inlet and outlet ports and the check valves are constrained, which in turn limits the fluid throughput. However, the present inventor realized that three or more fluid communication ports may be provided at each end of the compressor to increase the fluid throughput. For example, at least two of the end ports may be inlet ports, or at least two of the end ports may be outlet ports. In some embodiments, two inlet ports and two outlet ports may be provided at each end of the compressor.

The multiple inlet or outlet ports can be sized and arranged so they are offset from the hydraulic cylinder at the same end.

Accordingly, an example embodiment herein relates to a compressor for receiving a fluid supply, compressing the fluid and then moving the fluid to another location. The fluid may be a gas, a liquid or a multiphase fluid that comprises 100% gas, 100% liquid, or any proportion of gas/liquid therebetween. The compressor may include a compression chamber configured to receive a fluid which is compressed towards a first end or a second end of the compression chamber by a piston that is reciprocally moveable along an axial direction. The first and second ends of the chamber may each include three or more ports for fluid communication. At least one first inlet port at the first end of the compression chamber and at least one second inlet port at the second end of the compression chamber are configured to allow fluid to enter the compression chamber. The compressor may also include at least one first outlet port at the first end of the compression chamber and at least one second outlet port at the second end of the compression chamber, both configured to allow fluid to exit the compression chamber. Movement of the piston may be driven by at least one second cylinder connected to the piston within the first cylinder. The compressor may also include a plurality of check valves, each connected to one of the inlet and outlet ports, inline with the respective port along the axial direction. The position and alignment of the check valves relative to their respective port reduces dead volume and provides a straight flow path for fluid in and out of the compression chamber.

In an embodiment the check valves are oriented to be aligned with the axial direction of movement of the piston within the compression chamber. In a further embodiment, the check valves are perpendicular to the axial direction of movement of the piston within the compression chamber.

In an embodiment, the compressor may have two first inlet ports at the first end of the compression chamber and two second inlet ports at the second end of the compression chamber. The compressor may also include two first outlet ports at the first end of the compression chamber and two second outlet ports at the second end of the compression chamber. These ports may advantageously increase space at each end of the compressor for additional components to be accommodated such as for example, different sizes of hydraulic cylinders to drive movement of the piston.

In an embodiment, a first compressor may be configured to be connected to a second compressor. The first compressor may compress a fluid to a first pressure **P1** and the second compressor may further compress the fluid to a second higher pressure **P2**.

The compressors may be configured to be operable to transfer multiphase mixtures of substances that comprise 100% gas, 100% liquid, or any proportion of gas/liquid therebetween, wherein during operation, the ratio of gas/liquid is changing, either intermittently, periodically, or substantially continuously. The compressors can also handle fluids that may also carry abrasive solid materials such as sand without damaging important components of the compressor system such as the surfaces of various cylinders and pistons.

An example compressor **200** is schematically illustrated in FIG. **2**A. As depicted, compressor **200** may include first cylinder **202** for compressing a fluid. First cylinder **202** may include tubular wall **226** with first and second end plates **228***a*, **228***b* at either end. The inner surface of tubular wall **226** and the inner surfaces of end plates **228***a*, **228***b* define compression chamber **204**, which has first end **205***a* and second end **205***b*. Piston **206** may be reciprocally moveable within compression chamber **204** in an axial direction towards first end **205***a* or second end **205***b* as indicated by the arrows in FIG. **2**A. Piston **206** divides compression chamber **204** into two adjacent first and second compression chamber sections **208***a*, **208***b*. At first end **205***a* of compression chamber **204** there may be two ports **210***a*, **212***a* configured to allow fluid to flow into and out of compression chamber section **208***a*. As shown in FIG. **2**A, ports **210***a*, **212***a* may be cylindrical linear channels extending from the outer vertical side to the inner vertical side of plate **228***a*. At second end **205***b* there may be two ports **210***b*, **212***b* configured to allow fluid to flow into and out of compression chamber section **208***b*. As shown in FIG. **2**A, ports **210***b*, **212***b* may be cylindrical linear channels extending from the outer vertical side to the inner vertical side of plate **228***b*. To each of ports **210***a*, **210***b*, **212***a*, **212***b*, respective check valves **216***a*, **216***b*, **218***a*, **218***b* may be connected. Check valves **216***a*, **216***b*, **218***a*, **218***b*, may be any suitable check valve, also known as a non-return valve, reflux valve, foot valve or one way valve, and are configured to move between an open configuration and a closed configuration. When in a closed configuration fluid flow is not permitted in either direction through the check valve. When in an open configuration, the check valves allow fluid to flow through in one direction only from an inlet side to an outlet side of the check valve. The check valve may switch from a closed configuration to an open configuration when the pressure is greater on the inlet side of the port than the outlet side, creating a pressure differential across the check valve. Once the pressure differential reaches a pre-determined value, known as the threshold pressure (also known as the cracking pressure), the check valves are configured to open, permitting fluid flow from the inlet side to the outlet side only. The check valves may be operable to be adjustable such that the threshold pressure that causes the check valve to open may be set at a desired value. The check valves are configured to switch from the open configuration back to the closed configuration, preventing fluid flow therethrough once the pressure differential drops to a lower pressure, known as the reseal pressure.

Check valves **216***a*, **216***b*, **218***a*, **218***b* may be any suitable type as is known in the art. For example, the check valves may be ball check valves, diaphragm check valves, swing check valves, lift check valves, in-line check valves or reed valves. In a specific embodiment, check valves **216***a*, **216***b*, **218***a*, **218***b* may be a threaded in-line check valve such as a 3" SCV Check Valve made by DFT Inc.

Check valves **216***a*, **216***b*, **218***a*, **218***b* may be connected to their respective ports **210***a*, **210***b*, **212***a*, **212***b* by any suitable method. For example, check valves **216***a*, **216***b*, **218***a*, **218***b* may have threaded fittings at either end configured to engage with corresponding threaded fittings at the outer end of ports **210***a*, **210***b*, **212***a*, **212***b*. In other embodiments, check valves **216***a*, **216***b*, **218***a*, **218***b* may be configured to be partially inserted into their respective ports **210***a*, **210***b*, **212***a*, **212***b* and secured by a suitable method such as welding.

The orientation of check valves **216***a*, **216***b*, **218***a*, **218***b* relative to ports **210***a*, **210***b*, **212***a*, **212***b* will determine if each port functions as an inlet port or an outlet port. As depicted in FIG. **2**A, check valves **216***a*, **216***b* may be oriented such that ports **210***a*, **210***b* operate as inlet ports to supply fluid to compression chamber **204**. This is achieved by connecting the outlet side of check valve **216***a* to the outer end of port **210***a* such that, when check valve **216***a* is in an open configuration, fluid is only permitted to flow into chamber section **208**_a_ through port **210**_a_. Fluid is prevented from flowing out of chamber section **208**_a_ through check valve **216**_a_ at all times by the orientation of check valve **216**_a_.

Similarly, the outlet side of check valve **216**_b_ may be connected to the outer end of port **210**_b_ such that, when check valve **216**_b_ is in an open configuration, fluid is only permitted to flow into chamber section **208**_b_ through port **210**_b_. Fluid is prevented from flowing out of chamber section **208**_b_ through check valve **216**_b_ at all times by the orientation of check valve **216**_b_.

Check valves **218**_a_, **218**_b_ may be oriented such that ports **212**_a_, **212**_b_ operate as outlet ports to remove fluid from compression chamber **204**. The inlet side of check valve **218**_a_ may be connected to the outer end of port **212**_a_ such that, when check valve **218**_a_ is in an open configuration, fluid is only permitted to flow from chamber section **208**_a_ through port **212**_a_. Fluid is prevented from flowing into chamber section **208**_a_ through check valve **218**_a_ at all times by the orientation of check valve **218**_a_.

Similarly, the inlet end of check valve **218**_b_ may be connected to the outer end of port **212**_b_ such that, when check valve **218**_b_ is in an open configuration, fluid is only permitted to flow from chamber section **208**_b_ through port **212**_b_. Fluid is prevented from flowing into chamber section **208**_b_ through check valve **218**_b_ at all times.

A pair of inlet conduits **220**_a_, **220**_b_ may be connected to respective check valves **216**_a_, **216**_b_ to supply fluid from a fluid source and a pair of outlet conduits **222**_a_, **222**_b_ may be connected to respective check valves **218**_a_, **218**_b_, to receive compressed fluid from check valves **218**_a_, **218**_b_. In the embodiment shown in FIG. **2**A, check valves **216**_a_, **216**_b_, **218**_a_, **218**_b_ may be positioned inline with their respective ports **210**_a_, **210**_b_, **212**_a_, **212**_b_ in the axial direction, which are in turn positioned inline with the axial direction of movement of piston **206**.

With reference to FIGS. **2**B to **2**E, piston **206** may reciprocally move between first end of stroke position **224**_a_ at first end **205**_a_ of compression chamber **204** (shown in FIG. **2**B) and second end of stroke position **224**_b_ at second end **205**_b_ of compression chamber **204** (shown in FIG. **2**D). FIGS. **3**A and **3**B depict the change in volume of compression chamber sections **208**_a_, **208**_b_ with the position of piston **206**. With reference to FIG. **3**A, when piston **206** is at position **224**_a_, the volume of first compression chamber **208**_a_ is at a minimum volume (also referred to as the dead volume) and increases to a maximum volume once piston **206** reaches second end of stroke position **224**_b_. As piston **206** returns to first end of stroke position **224**_a_, the volume of first compression chamber will decease back to the minimum volume.

Similarly, as shown in FIG. **3**B, the volume of second compression chamber **208**_b_ will increase from a minimum volume at the second end of stroke position **224**_b_ to a maximum volume at the first end of stroke position **224**_a_.

As check valves **216**_a_, **216**_b_, **218**_a_, **218**_b_ are positioned inline with their respective ports **210**_a_, **210**_b_, **212**_a_, **212**_b_, they may be positioned closer to their respective port. This will beneficially reduce the path volume between check valves **216**_a_, **218**_a_ and piston **206** when piston **206** is first end of stroke position **224**_a_ and between check valves **216**_b_, **218**_b_ and piston **206** when piston **206** is second end of stroke position **224**_b_. As such, the dead volumes in the compressors shown in FIGS. **3**A and **3**B are less than that of the comparative compressor shown in FIG. **1**.

As will be explained below, as piston **206** reciprocates within compression chamber **204**, fluid may alternately enter, and exit each of the compression chamber sections **208**_a_, **208**_b_. Flow of fluid in and out of each compression chamber section **208**_a_, **208**_b_ is controlled by the state of each of the check valves attached to the ports. One complete cycle of compressor **200** is illustrated in FIGS. **2**B to **2**D, with direction of fluid flow at each stage indicated. Piston **206** may start at first end of stroke position **224**_a_ shown in FIG. **2**B and move, via the intermediate position shown in FIG. **2**C to second stroke position **224**_b_ shown in FIG. **2**D. Piston **206** may then reverse direction from second end of stroke position **224**_b_ and return to first end of stroke position shown in FIG. **2**B, via the intermediate position shown in FIG. **2**E. The change in volume and representative examples for the variation in pressure of first and second compression chambers **208**_a_, **208**_b_ are shown in FIGS. **3**A and **3**B respectively.

Turning first to FIG. **2**B, piston **206** is shown at first end of stroke position **224**_a_. Check valves **216**_a_, **216**_b_, **218**_a_, **218**_b_ are all closed such that fluid cannot flow into or out of first or second compression chamber sections **208**_a_, **208**_b_. Fluid will already be located in first and second compression chamber sections **208**_a_, **208**_b_ having previously been drawn in during previous strokes.

As piston **206** moves in direction indicated by the arrow in FIG. **2**B, the pressure in first compression chamber section **208**_a_ will drop as the volume increases (as shown between (i) and (ii) of FIG. **3**A), causing a pressure differential to develop between the outer and inner sides of inlet check valve **216**_a_. Once the differential pressure reaches the threshold pressure of valve **216**_a_, valve **216**_a_ will open and fluid will flow from conduit **220**_a_ into first compression chamber section **208**_a_, via inlet port **210**_a_ as shown in FIG. **2**C. Once valve **216**_a_ is open, the pressure within first compression chamber section **208**_a_ will remain generally constant until piston **206** reaches the second end of stroke position **224**_b_, (as shown between (ii) and (iii) of FIG. **3**A). Once piston **206** reaches second end of stroke position **224**_b_ (FIG. **2**D), valve **216**_a_ will close when the pressure differential between the outer and inner sides of valve **216**_a_ drops and reaches the reseal pressure of valve **216**_a_.

At the same time, movement of piston **206** decreases the volume of second compression chamber **208**_b_ and increases the pressure within chamber section **208**_b_ as the fluid within chamber section **208**_b_ is compressed (as shown between (vi) to (vii) of FIG. **3**B). This will cause a pressure differential to develop between the inner and outer side of outlet check valve **218**_b_. Once the pressure differential reaches the threshold pressure of valve **218**_b_, valve **218**_b_ will open and will flow out of second compression chamber section **208**_b_ and into conduit **222**_b_, via outlet port **212**_b_. Once valve **218**_b_ is open, the pressure within second compression chamber section **208**_b_ will remain generally constant (as shown between (vii) to (viii) of FIG. **3**B) until piston **206** reaches second end of stroke position **224**_b_. Once piston **206** reaches second end of stroke position **224**_b_ (FIG. **2**D), valve **218**_b_ will close due to the pressure differential between the outer and inner sides of valve **218**_b_ dropping and reaching the reseal pressure of valve **218**_b_.

Next, compressor **300** is configured for the return drive stroke. At second end of stroke position **224**_b_ shown in FIG. **2**D, all check valves will be closed and with reference to (iii) of FIG. **3**A, first compression chamber **208**_a_ will be at a maximum volume and contain fluid drawn in during the previous stroke. At the same time, with reference to (viii) of FIG. **3**B, second compression chamber **208**_b_ will have its minimum volume and contain a volume of pressurised fluid (i.e. fluid at a higher pressure than the fluid in first compression chamber **208***a*).

As piston **206** moves in the direction indicated by the arrow in FIG. **2**D, the pressure in second compression chamber section **208***b* will drop as the volume increases (as shown between (viii) and (ix) of FIG. **3**B), causing a pressure differential to develop between the outer and inner sides of inlet check valve **216***b*. Once the differential pressure reaches the threshold pressure of valve **216***b*, valve **216***b* will open and fluid will flow from conduit **220***b* into first compression chamber section **208***b*, via inlet port **210***b* (FIG. **2**E). Once valve **216***b* is open, the pressure within second compression chamber will remain generally constant until piston **206** reaches the first end of stroke position **224***a*, (as shown between (ix) and (x) of FIG. **3**B). Once piston **206** reaches first end of stroke position **224***a* (FIG. **2**B), valve **216***b* will close when the pressure differential between the outer and inner sides of valve **216***b* drops and reaches the reseal pressure of valve **216***b*.

At the same time, movement of piston **206** decreases the volume of first compression chamber **208***a* and increases the pressure in chamber section **208***a* as the fluid within is compressed (as shown between (iii) to (iv) of FIG. **3**A). This will cause a pressure differential to develop between the inner and outer side of outlet check valve **218***a*. Once the pressure differential reaches the threshold pressure of valve **218***a*, valve **218***a* will open and will flow out of first compression chamber section **208***a* and into conduit **222***a*, via outlet port **212***a*. Once valve **218***a* is open, the pressure within first compression chamber section **208***a* will remain generally constant (as shown between (iv) to (v) of FIG. **3**A) until piston **206** reaches first end of stroke position **224***a*. Once piston **206** reaches first end of stroke position **224***a* (FIG. **2**B), valve **218***a* will close due to the pressure differential between the outer and inner sides of valve **218***a* dropping, reaching the reseal pressure of valve **218***a*.

The foregoing movement and compression of fluid within compression chamber **204** will continue as piston **206** continues to move between the first and second end of stroke positions **224***a*, **224***b*.

Turning to FIG. **4**, an example compressor **200'** according to another embodiment is shown schematically. Compressor **200'** may be generally similar to compressor **200** as described above but in this embodiment, at either end of tubular wall **226** are first and second end plates **228***a*', **228***b*'. At first end **205***a* there may be two ports **210***a*', **212***a*' configured to allow fluid to flow into and out of first compression chamber section **208***a*. Ports **210***a*', **212***a*' may be cylindrical channels within plate **228***a*' extending from an outer side to an inner side of second end plate **228***a*'. Port **210***a*' may extend from the upper horizontal face to the inner vertical face of first end plate **228***a*'. Port **212***a*' may extend from the lower horizontal face to the inner vertical face of first end plate **228***a'*.

Similarly, at second end **205***b* there may be two ports **210***b*', **212***b*' configured to allow fluid to flow into and out of second compression chamber section **208***b*. Ports **210***b*', **212***b*' may be cylindrical channels within plate **228***b*' extending from an outer side to an inner side of second end plate **228***b*'. Port **210***b*' may extend from the upper horizontal face to the inner vertical face of first end plate **228***b*'. Port **212***b*' may extend from the lower vertical face to the inner vertical face of second end plate **228***b'*.

Similar to compressor **200**, to each of ports **210***a*', **210***b*', **212***a*', **212***b*' respective check valves **216***a*, **216***b*, **218***a*, **218***b* may be connected. As the outer ends of ports **210***a*', **212***a*' are on the respective upper and lower faces of first end plate **228***a*' and the outer ends of ports **210***b*', **212***b*' are on the respective upper and lower faces of second end plate **228***b*', check valves **216***a*, **216***b*, **218***a*, **218***b* are positioned perpendicular to the axial direction of movement of piston **206**.

As shown in FIG. **4**, ports **210***a*', **210***b*', **212***a*', **212***b*' extend vertically though the respective end plate, before turning at 90 degrees inwards. In other embodiments, ports **210***a*', **210***b*', **212***a*', **212***b*' may follow any other suitable path, such as a curved path.

FIGS. **5**A to **5**I illustrate a compressor **300**, which is an example embodiment of compressor **200**. Compressor **300** may include first cylinder **302** for compressing a fluid within compression chamber **304** having first end **305***a* and second end **305***b* (FIG. **5**A). First cylinder **302** may include cylinder barrel/tubular wall **326** positioned between first and second cylinder head plates **328***a*, **328***b* at respective first and second ends **305***a*, **305***b* of compression chamber **304**. First cylinder **302** may also include piston **306**, reciprocally moveable within compression chamber **304** in an axial direction towards first end **305***a* or second end **305***b*. Piston **306** may divide compression chamber **302** into two adjacent compression chamber sections **308***a* (FIG. **5**C), **308***b* (FIG. **5**B). First compression chamber section **308***a* may be defined by the interior surface of tubular wall **326**, a surface of piston **306** and the inner face **336***a* of first head plate **328***a* (FIG. **5**C). Second compression chamber section **308***b* may be formed on the opposite side of piston **306** to first compression chamber section **308***a* and may be defined by the interior surface of tubular wall **326**, a surface of piston **306** and the inner face **336***b* of second head plate **328***b* (FIG. **5**B).

Piston **306** may be reciprocally moveable within first cylinder **302** between a first end of stroke position **324***a* (FIGS. **5**A and **5**B) and second end of stroke position **324***b* (FIG. **5**C). The end of stroke positions may be a physical end of stroke positions whereby for a physical first end of stroke position, the surface of piston **306** will contact the inner face **336***a* of first head plate **328***a*. Likewise, for a physical second end of stroke position, the surface of piston **306** will contact the inner face **336***b* of second head plate **328***b*. More desirably, for example to reduce noise and wear on components of compressor **300** during operation, the end of stroke positions are pre-defined end of stroke positions selected such that when piston **306** is almost at the physical end of stroke position, but not yet in contact with first or second head plates **328***a*, **328***b*. For example, in an embodiment, a pre-defined end of stroke position may be 0.5" away from first or second head plates **328***a*, **328***b*.

Compressor **300** may also include first and second, one way acting, hydraulic cylinders **330***a*, **330***b* (FIG. **5**B) positioned at opposite ends of compressor **300**. Hydraulic cylinders **330***a*, **330***b* may each include a hydraulic piston therewithin, each connected to opposite ends of piston rod **307** and each configured to provide a driving force that acts in an opposite direction to each other, both acting inwardly towards each other and towards first cylinder **302**, thus driving reciprocal movement of piston **306**.

First cylinder **302** and hydraulic cylinders **330***a*, **330***b* may have generally circular cross-sections although alternately shaped cross sections are possible in some embodiments.

With reference to FIG. **5**C, first head plate **328***a* may have a generally square or rectangular shape with a pair of upper first inlet ports **310***a*, a pair of lower first outlet ports **312***a* and centrally located piston rod opening **332***a*. First inlet ports **310***a* and first outlet ports **312***a* may be circular openings that extend through first head plate **328***a* from outer face **334***a* to inner face **336***a* of first head plate **328***a*. Similarly, with reference to FIGS. **5**B and **5**H, second head plate **328***b* may have a generally square or rectangular shape with a pair of upper second inlet ports **310***b*, a pair of lower second outlet ports **312***b* and centrally located piston rod opening **332***b*. Second inlet ports **310***b* and second outlet ports **312***b* may be circular openings that extend through first head plate **328***b* from outer face **334***b* to inner face **336***b* of first head plate **328***b*.

First inlet ports **310***a* are configured to receive fluid at outer first end **338***a* and communicate fluid to inner second end **340***a* inside first chamber section **308***a* (FIG. **5**A). Similarly, second inlet ports **310***b* are configured to receive fluid at outer first end **338***b* and communicate fluid to an inner, second end **340***b* inside second chamber section **308***b* (FIG. **5**A).

First outlet ports **312***a* are configured to receive fluid from first chamber section **308***a* at inner first end **342***a* and communicate fluid to outer second end **344***a*. Similarly, second outlet ports **312***b* are configured to receive fluid from second chamber section **308***b* at inner first end **342***b* and communicate fluid to outer second end **344***b*.

Connected to each of first ends **338***a*, **338***b* of inlet ports **310***a*, **310***b* may be respective inlet check valves **316***a*, **316***b* configured to ensure that fluid may flow into compression chamber **304** from inlet ports **310***a*, **310***b* (i.e., fluid only travels from first ends **338***a*, **338***b* to second ends **340***a*, **340***b*). In some embodiments, inlet check valves **316***a*, **316***b* may be connected directly to first ends **338***a*, **338***b* of inlet ports **310***a*, **310***b*. In the embodiment shown in FIG. **5**A, short conduits **346***a*, sized to be partially received within first ends **338***a* of inlet ports **310***a*, may be disposed between inlet check valve **316***a* and first inlet ports **310***a* to facilitate connection of check valves **316***a*. Similarly, short conduits **346***b*, sized to be partially received within first ends **338***b* of inlet ports **310***b*, may be disposed between inlet check valve **316***b* and second inlet port **310***b* to facilitate connection of check valve **316***b*.

Similarly, connected to each of the second ends **344***a*, **344***b* of outlet ports **312***a*, **312***b* may be respective outlet check valves **318***a*, **318***b* configured to ensure that fluid may only flow from compression chamber **304** into outlet ports **312***a*, **312***b*, (i.e., fluid only travels in the direction from first ends **342***a*, **342***b* to second ends **344***a*, **344***b*). In some embodiments, outlet check valves **318***a*, **318***b* may be connected directly to second ends **344***a*, **344***b* of outlet ports **312***a*, **312***b*. In the embodiment shown in FIG. **5**A, short conduits **348***a*, sized to be partially received within second ends **344***a* of outlet ports **312***a*, may be disposed between outlet check valve **318***a* and first outlet port **312***a* to facilitate connection of check valve **318***a*. Similarly, short conduits **348***b*, sized to be partially received within second ends **344***b* of outlet ports **312***b*, may be disposed between outlet check valve **318***b* and second outlet port **312***b* to facilitate connection of check valve **318***b*.

Connections between ports **310***a*, **310***b*, **312***a*, **312***b*, conduits **346***a*, **346***b*, **348***a*, **348** and check valves **316***a*, **316***b*, **318***a*, **318***b* may be facilitated by any suitable method, such as welding or by providing complementary threaded ends between adjoining components.

In operation, compressor **300** may operate in a similar manner to as previously described for compressor **200**. Similar to as described above for compressor **200**, check valves **316***a*, **316***b*, **318***a*, **318***b* are operable to move between open and closed configurations depending on the pressure differential across each check valve. When in a closed configuration, fluid is not permitted to flow in either direction through the check valve. When in an open configuration, fluid is permitted to flow in one direction only through the check valve. As shown in FIG. **2**A, check valves **316***a*, **316***b*, **318***a*, **318***b* are all in a closed configuration and fluid may not enter or leave compression chamber **304**.

With reference to FIG. **5**J, inlet check valve **316***a* and outlet check valve **318***b* are shown in the open configuration. This configuration is similar to as shown in FIG. **2**C for compressor **200** and may occur when piston **306** is moving from first end of stroke position **324***a* to second end of stroke position **324***b* and the pressure differential across check valves **316***a*, **318***b* has reached the threshold pressure of the valves. With inlet check valves **316***a* in an open configuration, fluid can flow as indicated through secondary conduits **360***a*, inlet check valve connectors **364***a*, inlet check valves **316***a*, conduits **346***a* and into first compression chamber section **308***a* through first inlet ports **310***a*. With outlet check valves **318***b* in an open configuration, fluid can flow as indicated from second compression chamber section **308***b*, through second outlet ports **312***b*, conduits **348***b*, outlet check valves **318***b*, and into outlet check valve connectors **378***b*.

With reference to FIG. **5**K, inlet check valve **316***b* and outlet check valve **318***a* are shown in the open configuration. This configuration is similar to as shown in FIG. **2**E for compressor **200** and may occur when piston **306** is moving from second end of stroke position **324***b* to first end of stroke position **324***a* and the pressure differential across check valves **316***b*, **318***a* has reached the threshold pressure of the valves. With inlet check valves **316***b* in an open configuration, fluid can flow as indicated through secondary conduits **360***b*, inlet check valve connectors **364***b*, inlet check valves **316***b*, conduits **346***b* and into second compression chamber section **308***b* through first inlet ports **310***b*. With outlet check valves **318***a* in an open configuration, fluid can flow as indicated from first compression chamber section **308***a*, through first outlet ports **312***a*, conduits **348***a*, outlet check valves **318***a*, and into outlet check valve connectors **378***a*.

By providing multiple, smaller inlet and outlet ports on each of first and second head plates **328***a*, **328***b* (and corresponding smaller check valves and connectors) as opposed to single larger ports on each head plate, larger hydraulic cylinders may be used with compressor **300**, which may be desirable in some applications such as when compressing a fluid with a high proportion of liquid.

With reference to FIGS. **5**B-D in particular, the fluid communication system is shown, which provides fluid to compressor **300** to be compressed within compression chamber **304**, may include suction intake manifold **350** and pressure discharge manifold **352**.

On the fluid intake side of compressor **300**, suction intake manifold **350** may have two manifold outlets **351***a* and **351***b* and a single manifold inlet **351***c*. A flange associated with outlet **351***a* is connected to first flange **354***a* of inlet connector **356***a*. Inlet connector **356***a* may include primary conduit **358***a*, which may have the same interior channel diameter as manifold **350**, and a pair of smaller, spaced apart secondary conduits **360***a* extending orthogonally from primary conduit **358***a* (FIG. **5**B). Flanges **361***a* associated with secondary conduits **360***a* are each connected to flanges **365***a* associated with inlet check valve connectors **364***a* which are in turn configured to connect to input check valves **316***a*. As such, inlet connector **356***a* and inlet check valve connectors **364***a* may provide fluid communication from outlet **351***a* of suction intake manifold **350** to inlet check valves **316***a*.

Similarly, a flange associated with outlet **351***b* is connected to first flange **354***b* of inlet connector **356***b*. Inlet connector **356***b* may include a primary conduit **358***b*, which may have the same interior channel diameter as manifold **350**, and a pair of smaller, spaced apart secondary conduits **360***b* extending orthogonally from primary conduit **358***b* (FIGS. **5**B, **5**D). Flanges **361***b* associated with secondary conduits **360***b* are connected to flanges **365***b* associated with check valve connectors **364***b*, configured to connect to input check valves **316***b*. As such, inlet connector **356***b* and inlet check valve connectors **364***b* may provide fluid communication from outlet **351***b* of suction intake manifold **350** to inlet check valves **316***b*.

With reference to FIG. **5**C, on the fluid pressure discharge side of compressor **300**, pressure discharge manifold **352** may have two manifold inlets **353***a* and **353***b* and a single manifold outlet **353***c*. A flange associated with inlet **353***a* is connected to first flange **368***a* of outlet connector **370***a*. Outlet connector **370***a* may include primary conduit **372***a*, which may have the same interior channel diameter as manifold **352** and a pair of smaller, spaced apart secondary conduits **374***a* extending orthogonally from primary conduit **372***a*. Flanges **375***a* associated with secondary conduits **374***a* are connected to flanges **379***a* associated with outlet check valve connectors **378***a*, which are configured to connect to outlet check valves **318***a*. As such, outlet connector **370***a* and outlet check valve connectors **378***a* may provide fluid communication from outlet check valves **318***a* to manifold inlet **353***a* of pressure discharge manifold **352**.

Similarly, a flange associated with inlet **353***b* is connected to a first flange **368***b* of outlet connector **370***b*. Outlet connector **370***a* may include a primary conduit **372***b*, which may have the same interior channel diameter as manifold **352** and a pair of smaller, spaced apart secondary conduits **374***b* extending orthogonally from primary conduit **372***b*. Flanges **375***b* associated with secondary conduits **374***b* are connected to flanges **379***b* associated with outlet check valve connectors **378***b*, which are configured to connect to outlet check valves **318***b*. As such, outlet connector **370***b* and outlet check valve connectors **378***b* may provide fluid communication from outlet check valves **318***b* to manifold inlet **353***b* of pressure discharge manifold **352**.

Inlet connector **356***a* may also include second flange **382***a* at the opposite end of conduit **358***a* to first flange **354***a* and inlet connector **356***b* may also include second flange **382***b* at the opposite end of conduit **358***b* to first flange **354***b* (FIG. **5**B). Blanking plates **384***a*, **384***b* may be secured to second flanges **382***a*, **382***b* respectively.

Outlet connector **370***a* may also include second flange **386***a* at the opposite end of conduit **372***a* to first flange **368***a* and outlet connector **370***b* may also include a second flange **386***b* at the opposite end of conduit **372***b* to first flange **368***b* (FIG. **5**C). Blanking plates **388***a*, **388***b* may be secured to second flanges **386***a*, **388***b* respectively.

Second flanges **382***a*, **382***b*, **386***a*, **386***b*, may be operable to facilitate connections between multiple compressors, a representative example of which will be discussed later.

The manifolds, conduits and connectors described above may be sized dependent upon the required output/discharge pressures and output flow rates to be produced by compressor **300** and may be sized in order to achieve a desired maximum required flow velocity through compressor **300**. In an embodiment the maximum flow velocity is 23 feet per second. For example, in some embodiments, suction intake manifold **350**, pressure discharge manifold **352** and primary conduits **358***a*, **358***b*, **372***a*, **372***b* may all have approximately the same interior channel diameter, such as in the range of 4-6 inches or even greater. Secondary conduits **360***a*, **360***b*, **374***a*, **374***b*, check valve connectors **364***a*, **364***b*, **378***a*, **378***b* and conduits **346***a*, **346***b*, **348***a*, **346***b* may all have approximately the same interior channel diameter, such as in the range of 2-4 inches or even greater. Connections between the manifolds, check valves and conduits described above may be secured by any suitable method, such as by welding or by using threaded connections.

As shown in FIGS. **5**A to **5**I, compressor **300** is configured with inlet ports **310***a*, **310***b* at the top and outlet ports **312***a*, **312***b* at the bottom of cylinder heads **328***a*, **328***b*. This configuration may be beneficial, for example when compressor **300** is handling a fluid that contains a significant proportion of solids and/or debris which will migrate to the bottom of compression chamber **304** due to gravity and will be pumped out of chamber **304** during reciprocal movement of piston **306**. This may increase the reliability of compressor **300** as the accumulation of solids and/or debris within compression chamber **304** is reduced.

However, the configuration of inlet and outlet ports may be selected according to the particular application of compressor **300** and may depend on a number of factors such as the desired inlet (suction) pressure, outlet pressure, gas and liquid volume fraction of the fluid and the proportion of solids and other debris in the fluid.

In other embodiments, the upper two ports on each of cylinder heads **328***a*, **328***b* may be outlet ports whilst the lower two ports may be inlet ports. This configuration may be beneficial, for example, when handling a fluid with a higher gas volume fraction and when a lower inlet pressure is desired.

Compressor **300** may be in hydraulic fluid communication with a hydraulic fluid supply system which may provide an open loop or closed loop hydraulic fluid supply circuit. The hydraulic fluid supply system may be configured to supply a driving fluid to drive the hydraulic pistons in hydraulic cylinders **330***a*, **330***b*.

Compressor **300** may also include a controller to control the operation of compressor **300**, such as by changing the operational mode of the hydraulic fluid supply system. The control system may include a number of sensors such as proximity sensors in order to detect the position of components such as piston **306** within first cylinder **302** or pistons within hydraulic cylinders **330***a*, **330***b* in order to determine when piston **306** is approaching or has reached either of the end of stroke positions **324***a*, **324***b*. The controller may use information from the sensors to control the hydraulic fluid system in order to control and adjust the reversal of piston **306** in either direction. Examples of hydraulic cylinders, hydraulic fluid supply system and a control system suitable for use with compressor **300** are disclosed in U.S. Pat. No. 10,544,783, and US 20210270257, the entire contents of each of which are incorporated herein by reference.

Turning to FIGS. **6**A to **6**G, another embodiment of a compressor **400** is shown, which is an example embodiment of the compressor **200'** shown in FIG. **4**. First cylinder **302** of compressor **400** may include cylinder barrel/tubular wall **326** positioned between first and second cylinder head plates **428***a*, **428***b* at respective first and second ends **305***a*, **305***b* of compression chamber **304**. First head plate **428***a* may have a generally square or rectangular shape with a pair of upper first inlet ports **410***a*, a pair of lower first outlet ports **412***a* and a centrally located piston rod opening **432***a* (not shown). As shown in FIG. **6**A, first inlet ports **410***a* may extend within first head plate **428***a* in a downwards direction from first ends **438***a* in top face **435***a* before turning at 90 degrees inwards to second ends **440***a* in inner face **436***a* of first head plate **428***a*. First outlet ports **412***a* may extend in an outwards direction from first ends **442***a* in inner face **436***a* of first head plate **428***a* before turning at 90 degrees downwards to second ends **444***a* in bottom face **437***a* of first head plate **428***a*.

Similarly, second head plate **428***b* may have a generally square or rectangular shape with a pair of upper second inlet ports **410***b*, a pair of lower second outlet ports **412***b* and a centrally located piston rod opening **432***b* (FIG. **6**F). Second inlet ports **410***b* may extend within second head plate **428***b* in a downwards direction from first ends **438***b* in top face **435***b* before turning at 90 degrees inwards to second ends **440***b* in inner face **436***a* of second head plate **428***a*. Second outlet ports **412***a* may extend in an outwards direction from first ends **442***b* in inner face **436***a* of second head plate **428***b* before turning at 90 degrees downwards to second ends **444***b* in bottom face **437***b* of second head plate **428***b*.

Connected to each of the first ends **438***a*, **438***b* of inlet ports **410***a*, **410***b* may be respective inlet check valves **316***a*, **316***b* configured to ensure that fluid may flow into compression chamber **304** from inlet ports **410***a*, **410***b* (i.e., fluid only travels in the direction from first ends **438***a*, **438***b* to second ends **440***a*, **440***b* of inlet ports **410***a*, **410***b*). In some embodiments, inlet check valves **316***a*, **316***b* may be connected directly to first ends **438***a*, **438***b* of inlet ports **410***a*, **410***b*. In the embodiment shown in FIG. **6**A, short conduits **346***a*, sized to be partially received within first ends **438***a* of inlet ports **410***a*, may be disposed between inlet check valves **316***a* and first inlet ports **410***a*. Similarly, short conduits **346***b*, sized to be partially received within first ends **438***b* of inlet ports **410***b*, may be disposed between inlet check valves **316***b* and second inlet ports **410***b*.

Similarly, connected to each of the second ends **444***a*, **444***b* of outlet ports **412***a*, **412***b* may be respective outlet check valves **318***a*, **318***b* configured to ensure that fluid may flow into outlet ports **412***a*, **412***b*, from compression chamber **304** (i.e., fluid only travels in the direction from first ends **442***a*, **442***b* to second ends **444***a*, **444***b* of outlet ports **412***a*, **412***b*). In some embodiments, outlet check valves **318***a*, **318***b* may be connected directly to second ends **444***a*, **444***b* of outlet ports **412***a*, **412***b*. In the embodiment shown in FIG. **6**A, short conduits **348***a*, sized to be partially received within second ends **444***a* of outlet ports **412***a*, may be disposed between outlet check valves **318***a* and first outlet ports **412***a*. Similarly, short conduits **348***b*, sized to be partially received within second ends **444***b* of outlet ports **412***b*, may be disposed between outlet check valves **318***b* and second outlet ports **412***b*.

Configuring compressor **400** such that the inlet and outlet ports are on the upper and lower faces of cylinder heads **428***a*, **428***b* provides additional space on the outer faces **434***a*, **434***b* of cylinder heads **428***a*, **428***b*. This may provide space for accommodating larger diameter hydraulic cylinders on compressor **400** as desired.

In other embodiments of compressor **400**, the upper ports on each of cylinder heads **428***a*, **428***b* may be outlet ports whilst the lower ports may be inlet ports.

Referring to FIGS. **6**B to **6**E, the fluid communication system that provides fluid to compressor **400** may be generally similar to the fluid communication system of compressor **300**, but is sized to connect to the differently positioned check valves **316***a*, **316***b*, **318***a*, **318***b* on compressor **400**. The fluid communication system may include suction intake manifold **450** and pressure discharge manifold **452**. Suction intake manifold **450** may have two manifold outlets **451***a* and **451***b* and a single manifold inlet **451***c*. A flange associated with outlet **451***a* is connected to a first flange **354***a* of inlet connector **356***a*, which is in turn connected to first inlet check valves **316***a* through inlet check valve connectors **364***a*. A flange associated with outlet **451***b* is connected to a first flange of inlet connector **356***b* which is in turn connected to second inlet check valves **316***b* through check valve connectors **364***b*.

On the fluid pressure discharge side of compressor **400**, pressure discharge manifold **452** may have two manifold inlets **453***a* and **453***b* and a single manifold outlet **453***c*. A flange associated with inlet **453***a* is connected to first flange **368***a* of outlet connector **370***a* which is in turn connected to first outlet check valves **318***a* through outlet check valve connectors **378***a*. A flange associated with inlet **453***b* is connected to a first flange **368***b* of outlet connector **370***b* which is in turn connected to second outlet check valves **318***a* through outlet check valve connectors **378***b*.

Providing first and second inlet and first and second outlet ports through each of first and second head plates **428***a*, **428***b* as opposed to a larger single inlet and single outlet port in each head plate may be desirable in order to reduce the thickness of head plates **428***a*, **428***b*. For example, the pair of first inlet ports **410***a* may each have a diameter of around 2 inches. In order to achieve a similar flow velocity of fluid, a single inlet port to replace ports **410***a* would be required to have a larger diameter, for example about 4 inches. This would undesirably significantly increase the thickness of head plate **428***a* in order to accommodate the larger port within, increasing the size, weight and cost (through the extra material required for the thicker cylinder head) of the compressor.

Turning to FIGS. **7**A to **7**G, another embodiment of a compressor **500** is shown, which is another example embodiment of compressor **200** shown in FIG. **2**A.

In comparison to compressor **300** described above, first head plate **528***a*, whilst generally similar to first head plate **328***a*, may be configured with a pair of first inlet ports **510***a* vertically spaced from each other on a first side of first head plate **528***a*. Similar to first inlet ports **310***a*, first inlet ports **510***a* may extend through first head plate **528***a* and are configured to receive fluid at an outer, first end **538***a* and communicate fluid to an inner, second end **540***a* inside first chamber section **308***a* (FIG. **7**A). First head plate **528***a* may also be configured with a pair of first outlet ports **512***a*, vertically spaced from each other on the opposite side of first head plate **528***a* to first inlet ports **510***a*. Similar to first outlet ports **312***b*, first outlet ports **512***b* may extend through first head plate **528***a* and are configured to receive fluid at an inner, first end **542***a* inside first chamber section **308***a* and communicate fluid to an outer, second end **544***a*.

Second head plate **528***b* may be generally similar to first head plate **328***b* and may be configured with a pair of second inlet ports **510***b* vertically spaced from each other on a first side of second head plate **528***b*. Similar to second inlet ports **310***b*, second inlet ports **510***b* may extend through second head plate **528***b* and are configured to receive fluid at an outer, first end **538***b* and communicate fluid to an inner, second end **540***b* inside second chamber section **308***b* (FIG. **7**A). Second head plate **528***b* may also be configured with a pair of first outlet ports **512***b*, vertically spaced from each other on the opposite side of second head plate **528***b* to first inlet ports **510***a*. Similar to second outlet ports **312***b*, second outlet ports **512***b* may extend through second head plate **528***b* and are configured to receive fluid at an inner, first end **542***b* inside second chamber section **308***b* and communicate fluid to an outer, second end **544***b*.

First and second inlet ports **510***a*, **510***b* may be connected to suction intake manifold **350** in a similar manner to as described above for compressor **300** through inlet connectors **356***a*, **356***b*, inlet check valve connectors **364***a*, **364***b* and inlet check valves **316***a*, **316***b* for supplying fluid to compression chamber **304**, with inlet connectors **356***a*, **356***b* and intake manifold **350** oriented to accommodate the different inlet port configuration of compressor **500**.

First and second outlet ports **512***a*, **512***b* may be connected to pressure discharge manifold **352** in a similar manner to as described above for compressor **300** through outlet check valves **318***a*, **318***b*, outlet check valve connectors **378***a*, **378***b* and outlet connectors **370***a*, **370***b* for receiving fluid from compression chamber **304**, with outlet connectors **370***a*, **370***b* and pressure discharge manifold **352** oriented to accommodate the different outlet port configuration of compressor **500**.

With reference to FIG. **8** an example oil and gas producing well system **1100** is illustrated, which utilises a compressor **1106**, which may be any compressors described above. Oil and gas producing well system **1100** is illustrated schematically and may be installed at, and in, a well shaft (also referred to as a well bore) **1108** and may be used for extracting liquid and/or gases (e.g., oil and/or natural gas) from an oil and gas bearing reservoir **1104**.

Extraction of liquids including oil as well as other liquids such as water from reservoir **1104** may be achieved by methods such as the use of a down-well pump, which operates to bring a volume of oil toward the surface to a well head **1102**. An example of a suitable down-well pump is disclosed in U.S. patent application Ser. No. 16/147,188, filed Sep. 28, 2018 (now U.S. patent Ser. No. 10,544,783, issued Jan. 28, 2020), the entire contents of which is hereby incorporated herein by reference.

Well shaft **1108** may have along its length, one or more generally hollow cylindrical tubular, concentrically positioned, well casings **1120***a*, **1120***b*, **1120***c*, including an inner-most production casing **1120***a* that may extend for substantially the entire length of the well shaft **1108**. Intermediate casing **1120***b* may extend concentrically outside of production casing **1120***a* for a substantial length of the well shaft **1108**, but not to the same depth as production casing **1120***a*. Surface casing **1120***c* may extend concentrically around both production casing **1120***a* and intermediate casing **1120***b*, but may only extend from proximate the surface of the ground level, down a relatively short distance of the well shaft **1108**.

Natural gas may exit well shaft **1108** into piping **1124** whilst liquid may exit well shaft **1108** through a well head **1102** to an oil flow line **1133**. Oil flow line **1133** may carry the liquid to piping **1124**, which in turn carries the combined gas and oil to inlet manifold **351***c* of compressor **1106**. Compressor **1106** may operate substantially as described above to compress gas and liquid supplied by piping **1124**. Compressed fluid that has been compressed by compressor **1106** may exit though outlet manifold **353***c* and flow via piping **1130** to interconnect to pipeline **1132**.

In another embodiment, a plurality of compressors may be connected in series in order to provide a pressure boost to a fluid. An advantage to this approach is that less energy is required to compress fluid, such as gas, in multiple stages.

In an example embodiment, a first compressor may be connected to a second compressor such that fluid flows through the first compressor to the second compressor. Fluid at a first pressure P**1** may have its pressure boosted to a second pressure P**2** (that is greater than P**1**) by the first compressor. Fluid may then flow to the second compressor, where the pressure of the fluid will be boosted to a third pressure P**3** (that is greater than P**2**).

The first and second compressors may be interconnected in a number of suitable configurations in order for fluid that has been compressed in compression chamber sections **308***a*, **308***b* of the first compressor to flow to the second compressor. For example, when the first and second compressors are both similar to compressor **300**, second flanges **386***a*, **386***b* (with blanking plates **388***a*, **388***b* removed) on the first compressor may be interconnected to manifold inlet **351***c* or second flanges **382***a*, **382***b* of the second compressor.

In one embodiment, the first and second compressors may have different specifications. For example, the second compressor may be configured to handle fluid at a higher pressure and have hydraulic cylinders and a piston with a larger diameter than the first compressor.

For example, in an embodiment, the first compressor may have an inlet pressure of 50 psi and an outlet pressure of 250 psi and the second compressor may have an inlet pressure of 250 psi and an outlet pressure of 500 psi.

The compressors may also be employed in other oilfield and other non-oilfield environments to transfer gas and multi-phase fluids efficiently and quietly.

Whilst the illustrated embodiments depict compressors with two inlet ports and two outlet ports on each cylinder head, other variations are contemplated with different numbers of inlet and/or outlet ports on each cylinder head.

When introducing elements of the present invention or the embodiments thereof, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements.

Of course, the above described embodiments are intended to be illustrative only and in no way limiting. The described embodiments of carrying out the invention are susceptible to many modifications of form, arrangement of parts, details, and order of operation. The invention, therefore, is intended to encompass all such modifications within its scope.

What is claimed is:

1. A compressor comprising:

a first cylinder for compressing a fluid, comprising

a chamber configured to receive the fluid and having a first end and a second end,

a piston reciprocally movable in the chamber for alternately compressing the fluid towards the first end or the second end,

first ports at the first end of the chamber, the first ports comprising a centrally located first opening, at least one first inlet port at an upper portion of the first end, and at least two first outlet ports at a lower portion of the first end, and

second ports at the second end of the chamber, the second ports comprising a centrally located second opening, at least one second inlet port at an upper portion of the second end, and at least two second outlet ports at a lower portion of the second end,

wherein each one of the first and second inlet and outlet ports defines a fluid flow path extending along an axial direction of the respective port;

at least one second cylinder each connected and configured to drive movement of the piston in the first cylinder through one of the first and second openings;

a plurality of inlet check valves including a first inlet check valve associated with the at least one first inlet port and connected inline with the at least one first inlet port along the axial direction of the at least one first inlet port, and a second inlet check valve associated with the at least one second inlet port and connected inline with the at least one second inlet port along the axial direction of the at least one second inlet port;

a first plurality of outlet check valves each associated with a respective one of the at least two first outlet ports and each connected inline to the respective one of the at least two first outlet ports via a respective first connection conduit along the axial direction of the associated one of the at least two first outlet ports, and second plurality of outlet check valves each associated with a respective one of the at least two second outlet ports and each connected inline to the respective one of the at least two second outlet ports via a respective second connection conduit along the axial direction of the associated one of the at least two second outlet ports;

an inlet conduit connected to each one of the plurality of inlet check valves for connecting a fluid source to the at least one first inlet port and the at least one second inlet port to supply the fluid from the fluid source to the chamber through the at least one first inlet port and the at least one second inlet port; and

an outlet conduit connected to each one of the first outlet check valves and the second outlet check valves for receiving the fluid from the chamber through the at least two first outlet ports and the at least two second outlet ports,

wherein the piston is reciprocally movable in the chamber along an axial direction of the chamber, and the axial directions of the first and second ports are parallel to the axial direction of the chamber.

2. The compressor of claim **1**, wherein the first ports comprise at least two first inlet ports, and the second ports comprise at least two second inlet ports.

3. The compressor of claim **1**, wherein each of the inlet and outlet conduits comprises a first end comprising a first flange; and a plurality of second ends each comprising a second flange, each of the second flanges of the inlet conduit for connecting the respective second end to at least one of the plurality of inlet check valves and each of the second flanges of the outlet conduit for connecting the respective second end to at least one of the first plurality of outlet check valves or at least one of the second plurality of outlet check valves; and at least one third end comprising a third flange and a removable blanking plate coupled to the third flange.

4. The compressor of claim **1**, wherein each said first connection conduit and/or each said second connection conduit is partially inserted into the respective associated outlet port.

5. The compressor of claim **1**, wherein the fluid is a multiphase fluid comprising a solid material.

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