COMPRESSER FOR PUMPING FLUID HAVING CHECK VALVES ALIGNED WITH FLUID PORTS

FIELD

[0001] 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

[0002] 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.

[0003] For example, United States patent publication no. US20210270257, published on September 02, 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 112a, 112b. The compression cylinder 100 has a double-acting compression piston for compressing a fluid towards one or the other of the two ends 112a, 112b. The compression piston is driven by two hydraulic cylinders each coupled to the compression cylinder at one of the ends 112a, 112b through a central port. Each end 112a, 112b also has two fluid ports 104a, 104b 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 104a and ports 104b. Each port 104a,104b is connected to a check valve 108a, 108b by an elbow connector 106a, 106b. The elbow connectors 106a,106b are used and have sufficient size so that the check valves 108a, 108b are offset from the hydraulic cylinders at each end 112a, 112b of the compression cylinder 100. The check valves 108a,108b are connected by flanges and pipes to the fluid input source and the output destination. The check valves 108a, 108b are configured and oriented to control the fluid flow at the ports 104a, 104b.

[0004] It is desirable to improve the efficiency or performance of such fluid compressors.

SUMMARY

[0005] 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.

[0006] 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.

[0007] 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.

[0008] 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.

[0009] 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.

[0010] 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.

[0011] 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.

[0012] 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.

[0013] In some embodiments, the check valves are in-line check valves.

[0014] 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.

[0015] 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.

[0016] In some embodiments, the plurality of check valves are in-line check valves.

[0017] 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.

[0018] 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

[0019] In the figures, which illustrate example embodiments:

[0020] FIG.1 is a front perspective view of a comparison compressor;

[0021] FIG. 2A is a schematic cross-sectional view of a simplified compressor, according to an example embodiment;

[0022] FIG. 2B is a schematic view of the compressor of FIG. 2A in operation at a first state;

[0023] FIG. 2C is a schematic view of the compressor of FIG. 2A in operation at a second state;

[0024] FIG. 2D is a schematic view of the compressor of FIG. 2A in operation at a third state;

[0025] FIG. 2E is a schematic view of the compressor of FIG. 2A in operation at a fourth state;

[0026] FIG. 3A 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. 2A;

[0027] FIG. 3B 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. 2A;

[0028] FIG. 4 is a schematic cross-sectional view of a simplified compressor, according to another example embodiment;

[0029] FIG. 5A is a cross-sectional rear perspective view of a compressor according to a further example embodiment;

[0030] FIGS. 5B and 5C are partially transparent, front perspective views of the compressor of FIG. 5A;

[0031] FIG. 5D is a partially transparent, rear perspective view of the compressor of FIG.5A;

[0032] FIGS. 5E and 5F are front perspective and top plan views of the compressor of FIG. 5A;

[0033] FIG. 5G is a partially transparent front view of the compressor of FIG. 5A;

[0034] FIG. 5H is a cross sectional end view of the compressor of FIG. 5A, along the line A-A in FIG. 5G;

[0035] FIG. 5I is an end view of the compressor of FIG. 5A;

[0036] FIG. 5J is a cross-sectional rear perspective view of the compressor of FIG. 5A, with some check valves in an open configuration;

[0037] FIG. 5K is a cross-sectional rear perspective view of the compressor of FIG. 5A, with some check valves in an open configuration;

[0038] FIG. 6A is a partially transparent, cross-sectional rear perspective view of a compressor according to a further embodiment;

[0039] FIGS. 6B and 6C are front perspective views of the compressor of FIG. 6A;

[0040] FIGS. 6D and 6E are top plan and front views of the compressor of FIG. 6A;

[0041] FIG. 6F is a cross sectional end view of the compressor of FIG.6A, along the line A-A in FIG. 6E;

[0042] FIG. 6G is an end view of the compressor of FIG. 6A;

[0043] FIG. 7A is a partially transparent, cross-sectional top perspective view of a compressor according to a further embodiment;

[0044] FIGS. 7B and 7C are front perspective views of the compressor of FIG. 7A;

[0045] FIGS. 7D and 7E are top plan and front views of the compressor of FIG. 7A;

[0046] FIG. 7F is a cross sectional end view of the compressor of FIG. 7A, along the line B-B in FIG. 7E;

[0047] FIG. 7G is an end view of the compressor of FIG. 7A; and

[0048] FIG. 8 is a schematic view of an oil and gas producing well system.

DETAILED DESCRIPTION

[0049] 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 108a or 108b, particularly in the ports 104a or 104b and the elbow connectors 106a or 106b. This large dead volume leads to decreased pumping efficiency and performance. This problem would be exaggerated when the sizes of the elbow connectors 106a, 106b and the check valves 108a, 108b 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.

[0050] 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.

[0051] 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.

[0052] 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.

[0053] 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.

[0054] 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.

[0055] 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.

[0056] 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.

[0057] 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.

[0058] An example compressor 200 is schematically illustrated in FIG. 2A. 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 228a, 228b at either end. The inner surface of tubular wall 226 and the inner surfaces of end plates 228a, 228b define compression chamber 204, which has first end 205a and second end 205b. Piston 206 may be reciprocally moveable within compression chamber 204 in an axial direction towards first end 205a or second end 205b as indicated by the arrows in FIG. 2A. Piston 206 divides compression chamber 204 into two adjacent first and second compression chamber sections 208a, 208b. At first end 205a of compression chamber 204 there may be two ports 210a, 212a configured to allow fluid to flow into and out of compression chamber section 208a. As shown in FIG. 2A, ports 210a, 212a may be cylindrical linear channels extending from the outer vertical side to the inner vertical side of plate 228a. At second end 205b there may be two ports 210b, 212b configured to allow fluid to flow into and out of compression chamber section 208b. As shown in FIG. 2A, ports 210b, 212b may be cylindrical linear channels extending from the outer vertical side to the inner vertical side of plate 228b. To each of ports 210a, 210b, 212a, 212b, respective check valves 216a, 216b, 218a, 218b may be connected. Check valves 216a, 216b, 218a, 218b, 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.

[0059] Check valves 216a, 216b, 218a, 218b 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 216a, 216b, 218a, 218b may be a threaded in-line check valve such as a 3" SCV Check Valve made by DFT Inc.

[0060] Check valves 216a, 216b, 218a, 218b may be connected to their respective ports 210a, 210b, 212a, 212b by any suitable method. For example, check valves 216a, 216b, 218a, 218b may have threaded fittings at either end configured to engage with corresponding threaded fittings at the outer end of ports 210a, 210b, 212a, 212b. In other embodiments, check valves 216a, 216b, 218a, 218b may be configured to be partially inserted into their respective ports 210a, 210b, 212a, 212b and secured by a suitable method such as welding.

[0061] The orientation of check valves 216a, 216b, 218a, 218b relative to ports 210a, 210b, 212a, 212b will determine if each port functions as an inlet port or an outlet port. As depicted in FIG. 2A, check valves 216a, 216b may be oriented such that ports 210a, 210b operate as inlet ports to supply fluid to compression chamber 204. This is achieved by connecting the outlet side of check valve 216a to the outer end of port 210a such that, when check valve 216a is in an open configuration, fluid is only permitted to flow into chamber section 208a through port 210a. Fluid is prevented from flowing out of chamber section 208a through check valve 216a at all times by the orientation of check valve 216a.

[0062] Similarly, the outlet side of check valve 216b may be connected to the outer end of port 210b such that, when check valve 216b is in an open configuration, fluid is only permitted to flow into chamber section 208b through port 210b. Fluid is prevented from flowing out of chamber section 208b through check valve 216b at all times by the orientation of check valve 216b.

[0063] Check valves 218a, 218b may be oriented such that ports 212a, 212b operate as outlet ports to remove fluid from compression chamber 204. The inlet side of check valve 218a may be connected to the outer end of port 212a such that, when check valve 218a is in an open configuration, fluid is only permitted to flow from chamber section 208a through port 212a. Fluid is prevented from flowing into chamber section 208a through check valve 218a at all times by the orientation of check valve 218a.

[0064] Similarly, the inlet end of check valve 218b may be connected to the outer end of port 212b such that, when check valve 218b is in an open configuration, fluid is only permitted to flow from chamber section 208b through port 212b. Fluid is prevented from flowing into chamber section 208b through check valve 218b at all times.

[0065] A pair of inlet conduits 220a, 220b may be connected to respective check valves 216a, 216b to supply fluid from a fluid source and a pair of outlet conduits 222a, 222b may be connected to respective check valves 218a, 218b, to receive compressed fluid from check valves 218a, 218b. In the embodiment shown in FIG.

2A, check valves 216a, 216b, 218a, 218b may be positioned inline with their respective ports 210a, 210b, 212a, 212b in the axial direction, which are in turn positioned inline with the axial direction of movement of piston 206.

[0066] With reference to FIGS. 2B to 2E, piston 206 may reciprocally move between first end of stroke position 224a at first end 205a of compression chamber 204 (shown in FIG. 2B) and second end of stroke position 224b at second end 205b of compression chamber 204 (shown in FIG. 2D). FIGS. 3A and 3B depict the change in volume of compression chamber sections 208a, 208b with the position of piston 206. With reference to FIG. 3A, when piston 206 is at position 224a, the volume of first compression chamber 208a 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 224b. As piston 206 returns to first end of stroke position 224a, the volume of first compression chamber will decease back to the minimum volume.

[0067] Similarly, as shown in FIG. 3B, the volume of second compression chamber 208b will increase from a minimum volume at the second end of stroke position 224b to a maximum volume at the first end of stroke position 224a.

[0068] As check valves 216a, 216b, 218a, 218b are positioned inline with their respective ports 210a, 210b, 212a, 212b, they may be positioned closer to their respective port. This will beneficially reduce the path volume between check valves 216a, 218a and piston 206 when piston 206 is first end of stroke position 224a and between check valves 216b, 218b and piston 206 when piston 206 is second end of stroke position 224b. As such, the dead volumes in the compressors shown in FIGS 3A and 3B are less than that of the comparative compressor shown in FIG. 1.

[0069] 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 208a, 208b. Flow of fluid in and out of each compression chamber section 208a, 208b 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. 2B to 2D, with direction of fluid flow at each stage indicated. Piston 206 may start at first end of stroke position 224a shown in FIG. 2B and move, via the intermediate position shown in FIG. 2C to second stroke position 224b shown in FIG. 2D. Piston 206 may then reverse direction from second end of stroke position 224b and return to first end of stroke position shown in FIG. 2B, via the intermediate position shown in FIG. 2E. The change in volume and representative examples for the variation in pressure of first and second compression chambers 208a, 208b are shown in FIGS. 3A and 3B respectively.

[0070] Turning first to FIG. 2B, piston 206 is shown at first end of stroke position 224a. Check valves 216a, 216b, 218a, 218b are all closed such that fluid cannot flow into or out of first or second compression chamber sections 208a, 208b. Fluid will already be located in first and second compression chamber sections 208a, 208b having previously been drawn in during previous strokes.

[0071] As piston 206 moves in direction indicated by the arrow in FIG. 2B, the pressure in first compression chamber section 208a will drop as the volume increases (as shown between (i) and (ii) of FIG. 3A), causing a pressure differential to develop between the outer and inner sides of inlet check valve 216a. Once the differential pressure reaches the threshold pressure of valve 216a, valve 216a will open and fluid will flow from conduit 220a into first compression chamber section 208a, via inlet port 210a as shown in FIG. 2C. Once valve 216a is open, the pressure within first compression chamber section 208a will remain generally constant until piston 206 reaches the second end of stroke position 224b, (as shown between (ii) and (iii) of FIG. 3A). Once piston 206 reaches second end of stroke position 224b (FIG. 2D), valve 216a will close when the pressure differential between the outer and inner sides of valve 216a drops and reaches the reseal pressure of valve 216a.

[0072] At the same time, movement of piston 206 decreases the volume of second compression chamber 208b and increases the pressure within chamber section 208b as the fluid within chamber section 208b is compressed (as shown between (vi) to (vii) of FIG. 3B). This will cause a pressure differential to develop between the inner and outer side of outlet check valve 218b. Once the pressure differential reaches the threshold pressure of valve 218b, valve 218b will open and will flow out of second compression chamber section 208b and into conduit 222b, via outlet port 212b. Once valve 218b is open, the pressure within second compression chamber section 208b will remain generally constant (as shown between (vii) to (viii) of FIG. 3B) until piston 206 reaches second end of stroke position 224b. Once piston 206 reaches second end of stroke position 224b (FIG. 2D), valve 218b will close due to the pressure differential between the outer and inner sides of valve 218b dropping and reaching the reseal pressure of valve 218b.

[0073] Next, compressor 300 is configured for the return drive stroke. At second end of stroke position 224b shown in FIG. 2D, all check valves will be closed and with reference to (iii) of FIG. 3A, first compression chamber 208a 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. 3B, second compression chamber 208b 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 208a).

[0074] As piston 206 moves in the direction indicated by the arrow in FIG. 2D, the pressure in second compression chamber section 208b will drop as the volume increases (as shown between (viii) and (ix) of FIG. 3B), causing a pressure differential to develop between the outer and inner sides of inlet check valve 216b. Once the differential pressure reaches the threshold pressure of valve 216b, valve 216b will open and fluid will flow from conduit 220b into first compression chamber section 208b, via inlet port 210b (FIG. 2E). Once valve 216b is open, the pressure within second compression chamber will remain generally constant until piston 206 reaches the first end of stroke position 224a, (as shown between (ix) and (x) of FIG.

3B). Once piston 206 reaches first end of stroke position 224a (FIG. 2B), valve 216b will close when the pressure differential between the outer and inner sides of valve 216b drops and reaches the reseal pressure of valve 216b.

[0075] At the same time, movement of piston 206 decreases the volume of first compression chamber 208a and increases the pressure in chamber section 208a as the fluid within is compressed (as shown between (iii) to (iv) of FIG. 3A). This will cause a pressure differential to develop between the inner and outer side of outlet check valve 218a. Once the pressure differential reaches the threshold pressure of valve 218a, valve 218a will open and will flow out of first compression chamber section 208a and into conduit 222a, via outlet port 212a. Once valve 218a is open, the pressure within first compression chamber section 208a will remain generally constant (as shown between (iv) to (v) of FIG. 3A) until piston 206 reaches first end of stroke position 224a. Once piston 206 reaches first end of stroke position 224a (FIG. 2B), valve 218a will close due to the pressure differential between the outer and inner sides of valve 218a dropping, reaching the reseal pressure of valve 218a.

[0076] 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 224a, 224b.

[0077] 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 228a’, 228b’. At first end 205a there may be two ports 210a’, 212a’ configured to allow fluid to flow into and out of first compression chamber section 208a. Ports 210a’, 212a’ may be cylindrical channels within plate 228a’ extending from an outer side to an inner side of second end plate 228a’. Port 210a’ may extend from the upper horizontal face to the inner vertical face of first end plate 228a’. Port 212a’ may extend from the lower horizontal face to the inner vertical face of first end plate 228a’.

[0078] Similarly, at second end 205b there may be two ports 210b’, 212b’ configured to allow fluid to flow into and out of second compression chamber section 208b. Ports 210b’, 212b’ may be cylindrical channels within plate 228b’ extending from an outer side to an inner side of second end plate 228b’. Port 210b’ may extend from the upper horizontal face to the inner vertical face of first end plate 228b’. Port 212b’ may extend from the lower vertical face to the inner vertical face of second end plate 228b’.

[0079] Similar to compressor 200, to each of ports 210a’, 210b’, 212a’, 212b’ respective check valves 216a, 216b, 218a, 218b may be connected. As the outer ends of ports 210a’, 212a’ are on the respective upper and lower faces of first end plate 228a’ and the outer ends of ports 210b’, 212b’ are on the respective upper and lower faces of second end plate 228b’, check valves 216a, 216b, 218a, 218b are positioned perpendicular to the axial direction of movement of piston 206.

[0080] As shown in FIG. 4, ports 210a’, 210b’, 212a’, 212b’ extend vertically though the respective end plate, before turning at 90 degrees inwards. In other embodiments, ports 210a’, 210b’, 212a’, 212b’ may follow any other suitable path, such as a curved path.

[0081] FIGS. 5A to 5I 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 305a and second end 305b (FIG. 5A). First cylinder 302 may include cylinder barrel/tubular wall 326 positioned between first and second cylinder head plates 328a, 328b at respective first and second ends 305a, 305b 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 305a or second end 305b. Piston 306 may divide compression chamber 302 into two adjacent compression chamber sections 308a (FIG. 5C), 308b (FIG. 5B). First compression chamber section 308a may be defined by the interior surface of tubular wall 326, a surface of piston 306 and the inner face 336a of first head plate 328a (FIG. 5C). Second compression chamber section 308b may be formed on the opposite side of piston 306 to first compression chamber section 308a and may be defined by the interior surface of tubular wall 326, a surface of piston 306 and the inner face 336b of second head plate 328b (FIG. 5B).

[0082] Piston 306 may be reciprocally moveable within first cylinder 302 between a first end of stroke position 324a (FIGS. 5A and 5B) and second end of stroke position 324b (FIG. 5C). 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 336a of first head plate 328a. Likewise, for a physical second end of stroke position, the surface of piston 306 will contact the inner face 336b of second head plate 328b. 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 328a, 328b. For example, in an embodiment, a pre-defined end of stroke position may be 0.5” away from first or second head plates 328a, 328b.

[0083] Compressor 300 may also include first and second, one way acting, hydraulic cylinders 330a, 330b (FIG. 5B) positioned at opposite ends of compressor 300. Hydraulic cylinders 330a, 330b 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.

[0084] First cylinder 302 and hydraulic cylinders 330a, 330b may have generally circular cross-sections although alternately shaped cross sections are possible in some embodiments.

[0085] With reference to FIG. 5C, first head plate 328a may have a generally square or rectangular shape with a pair of upper first inlet ports 310a, a pair of lower first outlet ports 312a and centrally located piston rod opening 332a. First inlet ports 310a and first outlet ports 312a may be circular openings that extend through first head plate 328a from outer face 334a to inner face 336a of first head plate 328a. Similarly, with reference to FIGS. 5B and 5H, second head plate 328b may have a generally square or rectangular shape with a pair of upper second inlet ports 310b, a pair of lower second outlet ports 312b and centrally located piston rod opening 332b. Second inlet ports 310b and second outlet ports 312b may be circular openings that extend through first head plate 328b from outer face 334b to inner face 336b of first head plate 328b.

[0086] First inlet ports 310a are configured to receive fluid at outer first end 338a and communicate fluid to inner second end 340a inside first chamber section 308a (FIG. 5A). Similarly, second inlet ports 310b are configured to receive fluid at outer first end 338b and communicate fluid to an inner, second end 340b inside second chamber section 308b (FIG. 5A).

[0087] First outlet ports 312a are configured to receive fluid from first chamber section 308a at inner first end 342a and communicate fluid to outer second end 344a. Similarly, second outlet ports 312b are configured to receive fluid from second chamber section 308b at inner first end 342b and communicate fluid to outer second end 344b.

[0088] Connected to each of first ends 338a, 338b of inlet ports 310a, 310b may be respective inlet check valves 316a, 316b configured to ensure that fluid may flow into compression chamber 304 from inlet ports 310a, 310b (i.e., fluid only travels from first ends 338a, 338b to second ends 340a, 340b). In some embodiments, inlet check valves 316a, 316b may be connected directly to first ends 338a, 338b of inlet ports 310a, 310b. In the embodiment shown in FIG. 5A, short conduits 346a, sized to be partially received within first ends 338a of inlet ports 310a, may be disposed between inlet check valve 316a and first inlet ports 310a to facilitate connection of check valves 316a. Similarly, short conduits 346b, sized to be partially received within first ends 338b of inlet ports 310b, may be disposed between inlet check valve 316b and second inlet port 310b to facilitate connection of check valve 316b.

[0089] Similarly, connected to each of the second ends 344a, 344b of outlet ports 312a, 312b may be respective outlet check valves 318a, 318b configured to ensure that fluid may only flow from compression chamber 304 into outlet ports 312a, 312b, (i.e., fluid only travels in the direction from first ends 342a, 342b to second ends 344a, 344b). In some embodiments, outlet check valves 318a, 318b may be connected directly to second ends 344a, 344b of outlet ports 312a, 312b. In the embodiment shown in FIG. 5A, short conduits 348a, sized to be partially received within second ends 344a of outlet ports 312a, may be disposed between outlet check valve 318a and first outlet port 312a to facilitate connection of check valve 318a. Similarly, short conduits 348b, sized to be partially received within second ends 344b of outlet ports 312b, may be disposed between outlet check valve 318b and second outlet port 312b to facilitate connection of check valve 318b.

[0090] Connections between ports 310a, 310b, 312a, 312b, conduits 346a, 346b, 348a, 348 and check valves 316a, 316b, 318a, 318b may be facilitated by any suitable method, such as welding or by providing complementary threaded ends between adjoining components.

[0091] 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 316a, 316b, 318a, 318b 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. 2A, check valves 316a, 316b, 318a, 318b are all in a closed configuration and fluid may not enter or leave compression chamber 304.

[0092] With reference to FIG. 5J, inlet check valve 316a and outlet check valve 318b are shown in the open configuration. This configuration is similar to as shown in FIG. 2C for compressor 200 and may occur when piston 306 is moving from first end of stroke position 324a to second end of stroke position 324b and the pressure differential across check valves 316a, 318b has reached the threshold pressure of the valves. With inlet check valves 316a in an open configuration, fluid can flow as indicated through secondary conduits 360a, inlet check valve connectors 364a, inlet check valves 316a, conduits 346a and into first compression chamber section 308a through first inlet ports 310a. With outlet check valves 318b in an open configuration, fluid can flow as indicated from second compression chamber section 308b, through second outlet ports 312b, conduits 348b, outlet check valves 318b, and into outlet check valve connectors 378b.

[0093] With reference to FIG. 5K, inlet check valve 316b and outlet check valve 318a are shown in the open configuration. This configuration is similar to as shown in FIG. 2E for compressor 200 and may occur when piston 306 is moving from second end of stroke position 324b to first end of stroke position 324a and the pressure differential across check valves 316b, 318a has reached the threshold pressure of the valves. With inlet check valves 316b in an open configuration, fluid can flow as indicated through secondary conduits 360b, inlet check valve connectors 364b, inlet check valves 316b, conduits 346b and into second compression chamber section 308b through first inlet ports 310b. With outlet check valves 318a in an open configuration, fluid can flow as indicated from first compression chamber section 308a, through first outlet ports 312a, conduits 348a, outlet check valves 318a, and into outlet check valve connectors 378a.

[0094] By providing multiple, smaller inlet and outlet ports on each of first and second head plates 328a, 328b (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.

[0095] With reference to FIGS. 5B-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.

[0096] On the fluid intake side of compressor 300, suction intake manifold 350 may have two manifold outlets 351a and 351b and a single manifold inlet 351c. A flange associated with outlet 351a is connected to first flange 354a of inlet connector 356a. Inlet connector 356a may include primary conduit 358a, which may have the same interior channel diameter as manifold 350, and a pair of smaller, spaced apart secondary conduits 360a extending orthogonally from primary conduit 358a (FIG. 5B). Flanges 361a associated with secondary conduits 360a are each connected to flanges 365a associated with inlet check valve connectors 364a which are in turn configured to connect to input check valves 316a. As such, inlet connector 356a and inlet check valve connectors 364a may provide fluid communication from outlet 351a of suction intake manifold 350 to inlet check valves 316a.

[0097] Similarly, a flange associated with outlet 351b is connected to first flange 354b of inlet connector 356b. Inlet connector 356b may include a primary conduit 358b, which may have the same interior channel diameter as manifold 350, and a pair of smaller, spaced apart secondary conduits 360b extending orthogonally from primary conduit 358b (FIGS. 5B, 5D). Flanges 361b associated with secondary conduits 360b are connected to flanges 365b associated with check valve connectors 364b, configured to connect to input check valves 316b. As such, inlet connector 356b and inlet check valve connectors 364b may provide fluid communication from outlet 351b of suction intake manifold 350 to inlet check valves 316b.

[0098] With reference to FIG. 5C, on the fluid pressure discharge side of compressor 300, pressure discharge manifold 352 may have two manifold inlets 353a and 353b and a single manifold outlet 353c. A flange associated with inlet 353a is connected to first flange 368a of outlet connector 370a. Outlet connector 370a may include primary conduit 372a, which may have the same interior channel diameter as manifold 352 and a pair of smaller, spaced apart secondary conduits 374a extending orthogonally from primary conduit 372a. Flanges 375a associated with secondary conduits 374a are connected to flanges 379a associated with outlet check valve connectors 378a, which are configured to connect to outlet check valves 318a. As such, outlet connector 370a and outlet check valve connectors 378a may provide fluid communication from outlet check valves 318a to manifold inlet 353a of pressure discharge manifold 352.

[0099] Similarly, a flange associated with inlet 353b is connected to a first flange 368b of outlet connector 370b. Outlet connector 370a may include a primary conduit 372b, which may have the same interior channel diameter as manifold 352 and a pair of smaller, spaced apart secondary conduits 374b extending orthogonally from primary conduit 372b. Flanges 375b associated with secondary conduits 374b are connected to flanges 379b associated with outlet check valve connectors 378b, which are configured to connect to outlet check valves 318b. As such, outlet connector 370b and outlet check valve connectors 378b may provide fluid communication from outlet check valves 318b to manifold inlet 353b of pressure discharge manifold 352.

[00100] Inlet connector 356a may also include second flange 382a at the opposite end of conduit 358a to first flange 354a and inlet connector 356b may also include second flange 382b at the opposite end of conduit 358b to first flange 354b (FIG. 5B). Blanking plates 384a, 384b may be secured to second flanges 382a, 382b respectively.

[00101] Outlet connector 370a may also include second flange 386a at the opposite end of conduit 372a to first flange 368a and outlet connector 370b may also include a second flange 386b at the opposite end of conduit 372b to first flange 368b (FIG. 5C). Blanking plates 388a, 388b may be secured to second flanges 386a, 388b respectively.

[00102] Second flanges 382a, 382b, 386a, 386b, may be operable to facilitate connections between multiple compressors, a representative example of which will be discussed later.

[00103] 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 358a, 358b, 372a, 372b may all have approximately the same interior channel diameter, such as in the range of 4-6 inches or even greater. Secondary conduits 360a, 360b, 374a, 374b, check valve connectors 364a, 364b, 378a, 378b and conduits 346a, 346b, 348a, 346b 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.

[00104] As shown in FIGS. 5A to 5I, compressor 300 is configured with inlet ports 310a, 310b at the top and outlet ports 312a, 312b at the bottom of cylinder heads 328a, 328b. 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.

[00105] 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.

[00106] In other embodiments, the upper two ports on each of cylinder heads 328a, 328b 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.

[00107] 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 330a, 330b.

[00108] 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 330a, 330b in order to determine when piston 306 is approaching or has reached either of the end of stroke positions 324a, 324b. 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 US 10,544,783, and US 20210270257, the entire contents of each of which are incorporated herein by reference.

[00109] Turning to FIGS. 6A to 6G, 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 428a, 428b at respective first and second ends 305a, 305b of compression chamber 304. First head plate 428a may have a generally square or rectangular shape with a pair of upper first inlet ports 410a, a pair of lower first outlet ports 412a and a centrally located piston rod opening 432a (not shown). As shown in FIG. 6A, first inlet ports 410a may extend within first head plate 428a in a downwards direction from first ends 438a in top face 435a before turning at 90 degrees inwards to second ends 440a in inner face 436a of first head plate 428a. First outlet ports 412a may extend in an outwards direction from first ends 442a in inner face 436a of first head plate 428a before turning at 90 degrees downwards to second ends 444a in bottom face 437a of first head plate 428a.

[00110] Similarly, second head plate 428b may have a generally square or rectangular shape with a pair of upper second inlet ports 410b, a pair of lower second outlet ports 412b and a centrally located piston rod opening 432b (FIG. 6F). Second inlet ports 410b may extend within second head plate 428b in a downwards direction from first ends 438b in top face 435b before turning at 90 degrees inwards to second ends 440b in inner face 436a of second head plate 428a. Second outlet ports 412a may extend in an outwards direction from first ends 442b in inner face 436a of second head plate 428b before turning at 90 degrees downwards to second ends 444b in bottom face 437b of second head plate 428b.

[00111] Connected to each of the first ends 438a, 438b of inlet ports 410a, 410b may be respective inlet check valves 316a, 316b configured to ensure that fluid may flow into compression chamber 304 from inlet ports 410a, 410b (i.e., fluid only travels in the direction from first ends 438a, 438b to second ends 440a, 440b of inlet ports 410a, 410b). In some embodiments, inlet check valves 316a, 316b may be connected directly to first ends 438a, 438b of inlet ports 410a, 410b. In the embodiment shown in FIG. 6A, short conduits 346a, sized to be partially received within first ends 438a of inlet ports 410a, may be disposed between inlet check valves 316a and first inlet ports 410a. Similarly, short conduits 346b, sized to be partially received within first ends 438b of inlet ports 410b, may be disposed between inlet check valves 316b and second inlet ports 410b.

[00112] Similarly, connected to each of the second ends 444a, 444b of outlet ports 412a, 412b may be respective outlet check valves 318a, 318b configured to ensure that fluid may flow into outlet ports 412a, 412b, from compression chamber 304 (i.e., fluid only travels in the direction from first ends 442a, 442b to second ends 444a, 444b of outlet ports 412a, 412b). In some embodiments, outlet check valves 318a, 318b may be connected directly to second ends 444a, 444b of outlet ports 412a, 412b. In the embodiment shown in FIG. 6A, short conduits 348a, sized to be partially received within second ends 444a of outlet ports 412a, may be disposed between outlet check valves 318a and first outlet ports 412a. Similarly, short conduits 348b, sized to be partially received within second ends 444b of outlet ports 412b, may be disposed between outlet check valves 318b and second outlet ports 412b.

[00113] Configuring compressor 400 such that the inlet and outlet ports are on the upper and lower faces of cylinder heads 428a, 428b provides additional space on the outer faces 434a, 434b of cylinder heads 428a, 428b. This may provide space for accommodating larger diameter hydraulic cylinders on compressor 400 as desired.

[00114] In other embodiments of compressor 400, the upper ports on each of cylinder heads 428a, 428b may be outlet ports whilst the lower ports may be inlet ports.

[00115] Referring to FIGS. 6B to 6E, 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 316a, 316b, 318a, 318b 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 451a and 451b and a single manifold inlet 451c. A flange associated with outlet 451a is connected to a first flange 354a of inlet connector 356a, which is in turn connected to first inlet check valves 316a through inlet check valve connectors 364a. A flange associated with outlet 451b is connected to a first flange of inlet connector 356b which is in turn connected to second inlet check valves 316b through check valve connectors 364b.

[00116] On the fluid pressure discharge side of compressor 400, pressure discharge manifold 452 may have two manifold inlets 453a and 453b and a single manifold outlet 453c. A flange associated with inlet 453a is connected to first flange 368a of outlet connector 370a which is in turn connected to first outlet check valves 318a through outlet check valve connectors 378a. A flange associated with inlet 453b is connected to a first flange 368b of outlet connector 370b which is in turn connected to second outlet check valves 318a through outlet check valve connectors 378b.

[00117] Providing first and second inlet and first and second outlet ports through each of first and second head plates 428a, 428b 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 428a, 428b. For example, the pair of first inlet ports 410a 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 410a would be required to have a larger diameter, for example about 4 inches. This would undesirably significantly increase the thickness of head plate 428a 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.

[00118] Turning to FIGS. 7A to 7G, another embodiment of a compressor 500 is shown, which is another example embodiment of compressor 200 shown in FIG. 2A.

[00119] In comparison to compressor 300 described above, first head plate 528a, whilst generally similar to first head plate 328a, may be configured with a pair of first inlet ports 510a vertically spaced from each other on a first side of first head plate 528a. Similar to first inlet ports 310a, first inlet ports 510a may extend through first head plate 528a and are configured to receive fluid at an outer, first end 538a and communicate fluid to an inner, second end 540a inside first chamber section

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

[00120] Second head plate 528b may be generally similar to first head plate 328b and may be configured with a pair of second inlet ports 510b vertically spaced from each other on a first side of second head plate 528b. Similar to second inlet ports 310b, second inlet ports 510b may extend through second head plate 528b and are configured to receive fluid at an outer, first end 538b and communicate fluid to an inner, second end 540b inside second chamber section 308b (FIG. 7A). Second head plate 528b may also be configured with a pair of first outlet ports 512b, vertically spaced from each other on the opposite side of second head plate 528b to first inlet ports 510a. Similar to second outlet ports 312b, second outlet ports 512b may extend through second head plate 528b and are configured to receive fluid at an inner, first end 542b inside second chamber section 308b and communicate fluid to an outer, second end 544b.

[00121] First and second inlet ports 510a, 510b may be connected to suction intake manifold 350 in a similar manner to as described above for compressor 300 through inlet connectors 356a, 356b, inlet check valve connectors 364a, 364b and inlet check valves 316a, 316b for supplying fluid to compression chamber 304, with inlet connectors 356a, 356b and intake manifold 350 oriented to accommodate the different inlet port configuration of compressor 500.

[00122] First and second outlet ports 512a, 512b may be connected to pressure discharge manifold 352 in a similar manner to as described above for compressor 300 through outlet check valves 318a, 318b, outlet check valve connectors 378a, 378b and outlet connectors 370a, 370b for receiving fluid from compression chamber

304, with outlet connectors 370a, 370b and pressure discharge manifold 352 oriented to accommodate the different outlet port configuration of compressor 500.

[00123] 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.

[00124] 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 United States Patent Application Serial No. 16/147,188, filed September 28, 2018 (now United States Patent Serial No. 10,544,783, issued January 28, 2020), the entire contents of which is hereby incorporated herein by reference.

[00125] Well shaft 1108 may have along its length, one or more generally hollow cylindrical tubular, concentrically positioned, well casings 1120a, 1120b, 1120c, including an inner-most production casing 1120a that may extend for substantially the entire length of the well shaft 1108. Intermediate casing 1120b may extend concentrically outside of production casing 1120a for a substantial length of the well shaft 1108, but not to the same depth as production casing 1120a. Surface casing 1120c may extend concentrically around both production casing 1120a and intermediate casing 1120b, but may only extend from proximate the surface of the ground level, down a relatively short distance of the well shaft 1108.

[00126] 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 351c 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 353c and flow via piping 1130 to interconnect to pipeline 1132.

[00127] 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.

[00128] 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 P1 may have its pressure boosted to a second pressure P2 (that is greater than P1) 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 P3 (that is greater than P2).

[00129] 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 308a, 308b 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 386a, 386b (with blanking plates 388a, 388b removed) on the first compressor may be interconnected to manifold inlet 351c or second flanges 382a, 382b of the second compressor.

[00130] 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.

[00131] 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.

[00132] The compressors may also be employed in other oilfield and other non-oilfield environments to transfer gas and multi-phase fluids efficiently and quietly.

[00133] 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.

[00134] 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.

[00135] 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 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,

wherein each one of the first and second ports defines a fluid flow path extending along an axial direction of the 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 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,

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 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.

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

4. The compressor of claim 1, wherein the first ports comprise at least two outlet ports, and the second ports comprise at least two outlet ports.

5. The compressor of claim 1, further comprising a plurality of first conduits each connecting one of the check valves to its associated port.

6. The compressor of claim 5, wherein each one of the first conduits defines a straight fluid path between the check valve and the port connected by the respective first conduit.

7. The compressor of claim 5, wherein 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, the compressor further comprising:

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;

a third conduit connected to the second check valves for receiving compressed fluid from the compression chamber through the outlet ports.

8. The compressor of claim 7, wherein 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.

9. The compressor of claim 1, wherein 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.

10. The compressor of claim 1, wherein 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.

11. The compressor of claim 1, wherein the check valves are in-line check valves.

12. A compressor comprising:

a first cylinder for compressing a fluid, comprising

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,

wherein, 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,

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.

13. The compressor of claim 12, wherein 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.

14. The compressor of claim 12, wherein the plurality of check valves are in-line check valves.

15. The compressor of claim 12, further comprising a plurality of first conduits each connecting one of the check valves to its associated port.

16. The compressor of claim 15, wherein each one of the first conduits defines a straight fluid path between the check valve and the port connected by the respective first conduit.

17. A system for compressing a fluid, comprising first and second compressors each as defined in claim 1, wherein 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.

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.