

COMPRESSION SYSTEM AND METHOD HAVING CO-AXIAL FLOW DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This Application is a Non-Provisional Application and claims priority to US Provisional Patent Application No. 61/801,688, entitled "Compression System and Method Having Co-Axial Flow Device", filed March 15, 2013, which is herein incorporated by reference.

BACKGROUND

[0002] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present invention, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present invention. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0003] As will be appreciated, fluids, such as natural gas and air, have a wide array of uses in industrial and commercial applications. For instance, natural gas may be used to provide power to a range of vehicles, to heat homes during winter, and to operate various consumer appliances, such as ovens or clothes dryers. Further, natural gas may be used to generate electricity for distribution over a power grid, and may be used in the manufacture of an array of products and materials, including glass, steel, and plastics, for example.

[0004] In order to meet the demand for natural gas, companies may spend a significant amount of time and resources searching for, extracting, and transporting natural gas. It will be appreciated that natural gas may be produced from oil fields, in which case the gas may be referred to as casinghead gas, or

from natural gas fields. As may also be appreciated, transportation of such natural gas, such as through a pipeline from the production site to a consumer, is often facilitated by compression of the gas via a compressor.

[0005] One common type of compressor for such applications is the reciprocating compressor. Such reciprocating compressors are positive-displacement devices that generally utilize a crankshaft that is coupled to pistons, via connecting rods and crossheads, to reciprocally drive the pistons and compress a fluid within attached compression cylinders. As may be appreciated by one skilled in the art, natural gas (or some other fluid) is generally introduced into compression chambers of the cylinders through one or more inlet or suction valve assemblies and, following compression, the fluid generally exits the cylinders via one or more outlet or discharge valve assemblies. Unfortunately, existing arrangements may inefficiently route fluids to and from a compressor causing compression losses.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Various features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying figures in which like characters represent like parts throughout the figures, wherein:

[0007] FIG. 1 is a perspective view of an embodiment of a compressor system including an exemplary co-axial flow device (e.g., toroidal volute);

[0008] FIG. 2 is an axial cross-sectional view of an embodiment of the exemplary compressor of FIG. 1, illustrating internal components of the compressor;

[0009] FIG. 3 is a partial cutaway perspective view of an embodiment of a co-axial flow device (e.g., toroidal volute);

[0010] FIG. 4 is a cross-sectional view of an embodiment of a co-axial flow device (e.g., toroidal volute) in fluid communication with a compressor via a concentric valve;

[0011] FIG. 5 is a cross-sectional view of an embodiment of a co-axial flow device (e.g., toroidal volute) in fluid communication with a compressor through a series of discharge and suction valves;

[0012] FIG. 6 is a cross-sectional view of a piston in a first position with respect to an embodiment of a co-axial flow device (e.g., toroidal volute);

[0013] FIG. 7 is a cross-sectional view of the piston in a second position with respect to an embodiment of a co-axial flow device (e.g., toroidal volute); and

[0014] FIG. 8 is an elevational view of an exemplary poppet in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0015] One or more specific embodiments of the present invention will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0016] When introducing elements of various embodiments of the present invention, 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. Moreover, the use of “top,” “bottom,” “above,” “below,” and variations of these terms is made for convenience, but does not require any particular orientation of the components.

[0017] The disclosed embodiments include a co-axial flow device (e.g., toroidal volute) that increases efficiency, and facilitates valve exchange or substitution in a compression system. The co-axial flow device (e.g., toroidal volute) improves the efficiency in the compression system by effectively routing fluid and by reducing unused cylinder space. When a fluid abruptly changes direction or encounters sharply angled surfaces, the fluid loses momentum/energy. The loss in momentum/energy may therefore cause a system to work more to compensate for the losses and to continue moving the fluid. The additional work increases a system’s energy consumption/input, thereby reducing the system’s overall efficiency. As will be discussed in more detail below, the co-axial flow device (e.g., toroidal volute) reduces resistance to fluid flow by reducing obstacles (i.e., the number of sharp turns and angles that resist fluid flow into and out of the compression system). Moreover, the co-axial flow device (e.g., toroidal volute) routes fluid into and out of one end of a compression cylinder, enabling a piston to extend the length of the cylinder. This reduces unused cylinder space, thereby compressing more fluid per piston stroke. Furthermore, the co-axial flow device (e.g., toroidal volute) enables easy substitution or exchange of valves, to include different kinds of valves. For example, the co-axial flow device (e.g., toroidal volute) enables the system to switch between using a single valve (e.g., concentric valve) and multiple valves (e.g., suction valves, discharge valves, a plate with poppet valves, etc.).

[0018] Turning now to the figures, an exemplary compressor system 10 is provided in FIG. 1. In the presently illustrated embodiment, the compressor system 10 includes a pair of compression cylinders 12 coupled to a frame 14. As discussed in greater detail below, a variety of internal components may be disposed within the cylinders 12 and the frame 14 to enable compression of fluids within the cylinders 12. In one embodiment, the compressor system 10

may be utilized to compress natural gas. However, in other embodiments, the compressor system 10 may be configured and/or utilized to compress other fluids, such as air, inert gases, process gases, and the like. A mechanical power source or driver 16, such as an engine or an electric motor, may be coupled to the compressor system 10 to provide mechanical power to the various internal components and to enable compression of the fluid within the cylinders 12. To facilitate access to such internal components, as may be desired for diagnostic or maintenance purposes, openings in the frame 14 may be provided and selectively accessed via removable covers disposed over the openings.

[0019] The exemplary cylinders 12 may receive and expel gases through a co-axial flow device (e.g., toroidal volute) 18 configured to increase the efficiency of the compressor system 10 by reducing compression losses. In operation, the co-axial flow device (e.g., toroidal volute) 18 enables gas to enter the cylinder 12, where the gas is compressed and then discharged back out of the co-axial flow device 18. However, the co-axial flow device 18 geometry reduces the number of turns and sharp angles that the fluid flows through. With fewer sharp angles and bends, the co-axial flow device 18 enables the fluid to retain more of its velocity, thus reducing compression losses in the compression system 10 as the fluid is more able to maintain momentum. In addition, the co-axial flow device 18 enables pistons within the compression system 10 to extend farther into the cylinders 12, reducing dead space (i.e., space that the cylinders 12 do not travel through). A reduction in dead space enables the pistons to do more work per stroke (i.e., compress more gas per stroke), thus improving the efficiency of the compression system 10.

[0020] Although the exemplary compressor system 10 is illustrated as a two-throw reciprocating compressor, other compressor configurations may also employ and benefit from the presently disclosed techniques. For instance, in other embodiments, the compressor system 10 may include a different number of cylinder throws, such as a four-throw compressor, a six-throw compressor, a couple-free reciprocating compressor, a screw compressor, or the like. Further,

other variations are also envisaged, including variations in the length of stroke, the operating speed, and the size, to name but a few.

[0021] A cross-sectional view of the exemplary compressor system 10 is provided in FIG. 2, which illustrates a number of exemplary internal components of the compressor of FIG. 1. In the presently illustrated embodiment, the frame 14 of the exemplary compressor system 10 includes a hollow central body or housing 22 that generally defines an interior volume 24 in which various internal components may be received, such as a crankshaft 26. In one embodiment, the central body 22 may have a generally curved or cylindrical shape. It should be noted, however, that the central body 22 may have other shapes or configurations in full accordance with the present techniques.

[0022] In operation, the driver 16 rotates the crankshaft 26 supported within the interior volume 24 of the frame 14. In one embodiment, the crankshaft 26 is coupled to crossheads 30 via connecting rods 28 and pins 32. The crossheads 30 are disposed within crosshead guides 34, which generally extend from the central body 22 and facilitate connection of the cylinders 12 to the compressor system 10. In one embodiment, the compressor system 10 includes two crosshead guides 34 that extend generally perpendicularly from opposite sides of the central body or housing 22, although other configurations are also envisaged. As may be appreciated, the rotational motion of the crankshaft 26 is translated via the connecting rods 28 to reciprocal linear motion of the crossheads 30 within the crosshead guides 34.

[0023] As noted above, gas passes through the co-axial flow device 18 and into the cylinders 12 for compression. The crossheads 32 are coupled to pistons 36 disposed within internal compression chambers of the cylinders 12, and the reciprocating motion of the crossheads allows compression of gas within the compression chambers via the pistons 36. Particularly, as a piston 36 is driven forward (i.e., outwardly from central body 22) into a cylinder 12, the piston 36 forces fluid within the cylinder into a smaller volume, thereby increasing the pressure of the gas. The pressurized gas may then exit the cylinder 12 through a

valve and into the co-axial flow device 18. The co-axial flow device 18 enables the compressed gas to exit the compression system 10 with minimal compression losses. The piston 36 may then stroke backward, and additional gas may enter the cylinder 12 through the co-axial flow device 18 and an inlet valve, for compression in the same manner as described above.

[0024] FIG. 3 is a perspective view of an embodiment of a co-axial flow device (e.g., toroidal volute) 60. As explained above, the co-axial flow device 60 increases the efficiency of the compressor system 10 through its geometry and arrangement (i.e., enables the fluid to enter and exit with limited resistance). More specifically, the co-axial flow device 60 reduces the number of sharp turns and angles that resist fluid flow into and out of the compression system 10. Instead of sharp turns, the flow paths in the co-axial flow device 60 gradual turn or curve in the direction of flow, e.g., from an axial direction to a radial direction, or vice versa. In contrast, increased resistance to fluid flow reduces efficiency and increases the effort to move the fluid (i.e., it would increase the work on compression system 10 to move fluid into and out of the system 10).

[0025] The co-axial flow device 60 includes a body 62, a first cavity or flow passage 64 (e.g., a curved annular passage, such as a donut-shaped or toroidal shaped passage), a cylindrical member 66, and a second cavity or flow passage 68. As illustrated, the cylindrical member 66 extends into the first cavity 64 and creates the second cavity or flow passage 68. As illustrated, the passage 68 is a central axial passage, the member 66 is an annular wall disposed around the passage 68, and the passage 64 is an annular passage disposed about the member 66. As discussed below, the member 66 may be described as a curved annular wall, which generally defines a curved perimeter extending circumferentially about the central axis of the device 60 to define both a curved annular outer perimeter of the passage 68 and a curved annular inner perimeter of the passage 64.

[0026] A fluid is able to enter and exit the co-axial flow device 60 through a series of openings. In the present embodiment, the co-axial flow device 60

includes a first opening 70, a second opening 72, a third opening 74, and a fourth opening 76. These openings 70, 72, 74, and 76 function as inlets and outlets for fluid moving through the co-axial flow device 60 and the compression system 10. The openings 70, 72, 74, and 76 may be inlets or outlets depending on how the fluid flows through the compression system 10. As illustrated, the opening 70 is a radial opening, while openings 72, 74, and 76 are axial openings. Furthermore, the openings 74 and 76 are central axial openings, and opening 72 is an annular axial opening concentric with the central axial opening 74. In operation, a fluid at a first pressure may enter the compressions system 10 and the co-axial flow device 60 through the first opening 70 in a radial direction, as indicated by arrow 69. As the fluid passes through the first opening 70, the fluid enters the first cavity or flow passage 64 and flows around the cylindrical member 66 in a circumferential direction 71 and/or axial direction 73. The first cavity or flow passage 64 turns (e.g., gradually curves or bends) and directs the fluid toward valve(s) 80 resting in the opening 72. The fluid passes through the valve(s) 80 and opening 72, such that the fluid is compressed by the compressor 10. After the fluid is compressed to a second pressure, the fluid flows back through the valve(s) 80 and the third opening 74 and into the cylindrical member 66, i.e., into passage 68. The fluid then passes through the cylindrical member 66 (i.e., passage 68) in the axial direction 75, before exiting the co-axial flow device 60 through the fourth opening or outlet 76.

[0027] In another embodiment, the fluid may flow into and out of the compression system 10 in the opposite manner as that described above. For example, fluid at a first pressure may enter the co-axial flow device 60 and the compression system 10 through the opening 76. The fluid may then travel through the second cavity or flow passage 68 of the cylindrical member 66, where the fluid exits the passage 68 through opening 74. As the fluid exits the opening 74, the fluid enters the valve(s) 80 resting in the opening 72. After compression, the valve(s) 80 routes the fluid, now at a second pressure, into the first cavity or flow passage 64. The first cavity or flow passage 64 then turns and directs the fluid out of the system 10 through the opening 70.

[0028] As explained above, the co-axial flow device 60 increases the efficiency of the compression system 10 by efficient routing of the fluid into and out of the system 10. A fluid loses momentum/energy when it encounters an obstacle that changes its direction of travel. Accordingly, a system may therefore work more to compensate for losses in fluid momentum as the fluid moves around obstacles (e.g., turns and bends through pipes). The additional work increases a system's energy consumption/input reducing the system's overall efficiency. As seen in FIG. 3, the co-axial flow device 60 efficiently routes the fluid in the two directions 69 and 75 (i.e., one direction for entering and another direction for exiting the system 10). Specifically, the co-axial flow device 60 enables movement of a fluid in two directions (e.g., 69 and 75), while simultaneously reducing the number of turns the fluid encounters as it travels through the co-axial flow device 60. Indeed, the co-axial flow device 60 turns (e.g., via a gradual bend or curve) the fluid once (i.e., changes the direction of travel from the radial direction 69 to the axial direction 73 as the fluid travels through the first cavity or fluid passage 64), while enabling the fluid to flow unimpeded in a second direction (i.e., in axial direction 75 through the second cavity or flow passage 68). As a result, the co-axial flow device 60 improves the efficiency of the compression system 10 by routing fluid in two directions through one component and reducing obstacles to the fluid flow.

[0029] In addition, the co-axial flow device 60 increases system 10 efficiency by reducing sharp angles. As illustrated, the co-axial flow device 60 includes an outer wall 81 (e.g., annular wall) with an interior surface 82 surrounding the first cavity or flow passage 64. The interior surface 82 improves fluid movement with the annular scooped base 84 (e.g., curved annular surface) and the annular sloping surface 86 (e.g., curved annular surface). As illustrated the scooped base 84 has a u-shaped or concave cross-section, which extends circumferentially about the cylindrical member 66 between the member 66 and the outer wall 81. The sloping surface 82 also extends circumferentially about the cylindrical member 66, and generally increases in diameter in the axial direction 73. In operation, as fluid enters the co-axial flow device 60 through the

first opening 70, the annular scooped base 84 scoops and turns (e.g., gradually turning) the fluid towards the valve(s) 80, as indicated by arrows 83. As the fluid travels towards the valve(s) 80, the sloping surface 86 gradually channels the fluid into the valve(s) 80. Accordingly, the fluid does not encounter sharp angles or surfaces that might abruptly decrease or stop fluid momentum. Likewise, in embodiments where the fluid flow is in the opposite direction (i.e., from the valve(s) 80 to the opening 70), the interior surface 82 improves fluid flow. Specifically, the sloping surface 86 will allow the fluid to gradually expand into the cavity 64, while the rounded base 84 scoops and turns the fluid towards the opening 70 and out of the co-axial flow device 60. Furthermore, and as explained above, the cylindrical member 66 improves fluid flow by providing a direct path for fluid flow (i.e., no turning of the fluid) between the opening 76 and the valve(s) 80. Moreover, the cylindrical member 66 provides transition zones 88 and 90 to improve fluid flow at the openings 74 and 76. Specifically, transition zone 88 improves fluid flow between the diameter 92 at the opening 76 and the smaller diameter 94 in a central portion 98 of the cylindrical member 66. In particular, the transition zone 88 defines a curved annular transition, which may be described as an outwardly curved portion 85 and an inwardly curved portion 87 extending circumferentially about the passage 68. Furthermore, the transition zone 90 provides a smooth transition between the diameter 94 and the larger diameter 96 of the opening 74. Again, the bore 90 defines a curved annular transition, which may be described as an outwardly and/or inwardly curved portion 89 extending circumferentially about the passage 68. Accordingly, as fluid flows through the second cavity or fluid passage 68, the fluid does not encounter abrupt surfaces that could decrease or stop fluid momentum.

[0030] The co-axial flow device 60 couples to and seals with fluid carrying conduits and the compression system 10 with flanges 100, 102, and 104. As explained above, the openings 70 and 76 may function as inlets or outlets. Accordingly, the flange 100 may connect to a conduit supplying fluid while the flange 102 connects to a fluid conduit that carries fluid away from the compression system 10. In other embodiments, the flange 102 may connect to a

fluid supply, while the flange 100 connects to a conduit that carries fluid away from the compression system 10. The flange 104 connects the co-axial flow device 60 to the compression cylinder 12, enabling the valve(s) 80, resting in the opening 72, to seal between the first cavity 64 and the second cavity 68, to block fluid at a first pressure from mixing with fluid at a second pressure. Specifically, the valve(s) 80 seal against the interior surface 82 of the co-axial flow device 60 and against a gasket 106 resting in a gasket groove 108 surrounding the opening 74. In this manner, the valve(s) 80 block fluid traveling in the first cavity 64 from contacting the fluid traveling in the second cavity 68.

[0031] FIG. 4 is a cross-sectional view of a co-axial flow device (e.g., toroidal volute) 130 in fluid communication with a compression cylinder 132 via a concentric valve 134. As illustrated, the co-axial flow device 130 enables the system 10 to use the concentric valve 134, and thus move fluid into and out of the compression cylinder with a single valve. Moreover, the co-axial flow device 130 enables the system 10 to easily substitute different types of valves between the volute 130 and the compression cylinder 132. As explained above, the co-axial flow device 130 includes a body 136 and a cylindrical member 138. The cylindrical member 138 extends through a first cavity or fluid path 140 in the body 136. The volute 130 enables fluid to enter and exit through openings 142, 144, and 146. In the present embodiment, fluid enters the volute 130 through the opening 144. After passing through the opening 144, the fluid enters a second cavity or flow passage 148 within the cylindrical member 138. As indicated by arrow 143, the cylindrical member 138 guides the fluid through flow passage 148 and into the concentric valve 134. As indicated by arrow 145, the concentric valve 134 rests within the opening 146 and enables the fluid to exit the volute 130 and enter the compression cylinder 132. In the compression cylinder 132, the compression system 10 compresses the fluid from a first pressure to a second pressure. The compression of the fluid to a second pressure forces the fluid back through the concentric valve 134 and into the volute 130, as indicated by arrow 147. However, the concentric valve 134 discharges the fluid into the first cavity or fluid pathway 140 instead of the second cavity or fluid pathway 148.

The first cavity 140 then guides the fluid out of the volute 130 through opening 142, as indicated by arrow 149.

[0032] In another embodiment, the fluid may flow in the opposite direction through the volute 130. That is, the fluid may enter through opening 142 and travel through the cavity 140 and the concentric valve 134 into the compression cylinder 132. The compression cylinder 132 may then compress the fluid, forcing the fluid back through the concentric valve 134 and into the second cavity 148 in the cylindrical member 138, where the fluid exits the volute 130 through the opening 144.

[0033] FIG. 5 is a cross-sectional view of the co-axial flow device 130 (e.g., toroidal volute) in fluid communication with the compression cylinder 132 through a series of discharge and suction valves 160. As mentioned above, the co-axial flow device 130 enables the system 10 to easily substitute different types of valves between the volute 130 and the compression cylinder 132. In FIG. 4, the system 10 uses a concentric valve 134, while in FIG. 5 the system uses discharge and suction valves 160. In still other embodiments, the compression system 10 may use a plate with a series of one way check valves (e.g., poppet valves) between the volute 130 and the compression cylinder 132. As explained above, the fluid enters the volute 130 through the opening 144. After passing through the opening 144, the fluid enters a second cavity or flow passage 148 within the cylindrical member 138, as indicated by arrow 143. The cylindrical member 138 guides the fluid through the volute 130 to the suction valve 162. The suction valve 162 enables fluid to exit the volute 130 and enter the compression cylinder 132, as indicated by arrow 145. In the compression cylinder 132, the compression system 10 compresses the fluid from a first pressure to a second pressure, and then discharges the fluid at a second pressure through one or more discharge valves 164, as indicated by arrows 147. As illustrated, the system 10 includes a single annular discharge valve 164, which is disposed in a coaxial or concentric arrangement around the valve 162. However, in other embodiments, the volute 130 may include multiple discharge valves 164 spaced apart from one another in an annular arrangement around the

cylindrical member 138 in the opening 146. The discharge valve(s) 164 enables the fluid to exit the compression cylinder 132 into the volute 130. However, the discharge valve(s) 164 discharges the fluid into the first cavity or fluid pathway 140 instead of the second cavity or fluid pathway 148. The first cavity 140 then guides the fluid out of the volute 130 through opening 142, as indicated by arrow 149.

[0034] In another embodiment, the fluid may flow in the opposite direction through the volute 130. In an embodiment with a reversed flow configuration, the discharge and suction valves are reversed. That is, the fluid may enter through opening 142 and pass through the cavity 140 and suction valve(s) into the compression cylinder 132. The compression cylinder 132 may then compress the fluid, forcing the fluid through discharge valves and into the second cavity 148 in the cylindrical member 138, where the fluid exits the volute 130 through the opening 144.

[0035] FIG. 6 is a cross-sectional view of a piston 180 in a first position drawing fluid through a co-axial flow device 182 (e.g., toroidal volute) into a compression cylinder 184 according to an embodiment. The co-axial flow device 182 increases the efficiency of compression system 10 by reducing dead volume in the cavity 185 of the compression cylinder 184 (i.e., the volume in a compression cylinder untouched by a piston). As illustrated, the co-axial flow device 182 couples to and holds the valve(s) 186 against a cylinder end 188 of the compression cylinder 184. With the valve 186 at the end 188 of the cylinder 184, the piston 180 is able to compress and move substantially all of the fluid between the piston and the valve(s) 186 out of the cavity 185.

[0036] As explained above, FIG. 6 illustrates the piston 180 in a first position. In the first position, fluid enters the co-axial flow device 182 through the inlet 190 and into a first cavity or flow passage 192. As indicated by arrow 191, the fluid flows through the cavity 192 and through the valve(s) 186 and into the cavity 185 of the compression cylinder 184 for compression by the piston 180. In FIG. 7, the piston 180 is in a second position. As the piston 180 moves from the first

position to the second position, the piston 180 compresses and forces fluid out of the compression cylinder 184, as indicated by arrow 197. As the fluid exits the compression cylinder 184, the fluid flows through the valve(s) 186 and into a cylindrical member 196. The momentum of the fluid carries it through the second cavity or flow passage 198 of the cylindrical member 196, and out of the co-axial flow device 182 through outlet 200. As illustrated in FIG. 7, when the piston 180 reaches the second position, the piston 180 is able to force all or substantially all of the fluid out of the compression cylinder 184. Thus, each stroke of the piston 180 is more efficient in moving fluid through compression system 10. Moreover, the co-axial flow device 182 enables this efficiency by facilitating flow into and out of compression cylinder 184 through one end (i.e., 188) of the compression cylinder 184.

[0037] FIG. 8 is an elevational view of an exemplary poppet assembly 220. As illustrated in FIG. 8, the poppet assembly 220 includes a poppet 222, housing 224 with a mounting portion, such as a threaded surface 226, which enables the poppet assembly 220 to mount in a plate. The poppet assembly 220 may also include a cap 228 and an impact bushing 230 coupled to the housing 224. In such an embodiment, the poppet 222 may open and close against the impact bushing 230 to selectively control unidirectional flow of a fluid through the housing 224, and thus into and out of the toroidal volute discussed above.

[0038] While the invention may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the following appended claims.

CLAIMS

1. A system, comprising:
a compressor, comprising:
a cylinder comprising a chamber, a first axial end portion, and a second axial end portion; and
a piston disposed within the chamber of the cylinder, wherein the piston is configured to reciprocate along a cylinder axis between the first and second axial end portions; and
a co-axial flow device coupled to the compressor, wherein the co-axial flow device comprises a first wall disposed about a first passage along an axis, a second passage disposed about the first wall along the axis, and a second wall disposed about the second passage along the axis, wherein the first passage comprises a first axial opening in fluid communication with the chamber while the piston moves in a first axial direction, and the second passage comprises a second axial opening in fluid communication with the chamber while the piston moves in a second axial direction opposite from the first axial direction.
2. The system of claim 1, wherein the first passage comprises a central axial passage, and the second passage comprises an annular outer passage.
3. The system of claim 2, wherein the first and second walls comprises first and second concentric annular walls.
4. The system of claim 2, wherein the first axial opening comprises a central axial opening, and the second axial opening comprises an annular axial opening disposed about the central axial opening.
5. The system of claim 4, wherein the first passage comprises a third axial opening, and the first and third axial openings are disposed at opposite end portions of the first passage.

6. The system of claim 5, wherein the second passage comprises a radial opening through the second wall.

7. The system of claim 6, wherein the co-axial flow device comprises an annular scoop extending between the first and second walls, and the annular scoop has a U-shaped curve from the first wall to the second wall.

8. The system of claim 7, wherein the co-axial flow device comprises a first tapered annular transition along the first wall at the first axial opening, a second tapered annular transition along the first wall at the second axial opening, or a third tapered annular transition along the first wall at the third axial opening, or a combination thereof.

9. The system of claim 8, comprising a valve assembly disposed between the piston and the first and second axial openings.

10. The system of claim 1, wherein the co-axial flow device comprises a scoop extending circumferentially about the axis between the first and second walls, and the scoop has a U-shaped curve from the first wall to the second wall.

11. The system of claim 1, wherein the co-axial flow device comprises a first tapered transition along the first wall at the first axial opening, a second tapered transition along the first wall at the second axial opening, or a third tapered transition along the first wall at a third axial opening of the first passage, or a combination thereof.

12. The system of claim 1, comprising a valve assembly disposed between the piston and the first and second axial openings.

13. The system of claim 1, wherein the valve assembly comprises a first valve disposed between the first axial opening and the piston, and a second valve disposed between the second axial opening and the piston.

14. The system of claim 13, wherein the first valve comprises a first one-way valve and the second valve comprises a second one-way valve, and the first and second one-way valves are configured to enable flow in opposite axial directions relative to the axis of the co-axial flow device.

15. The system of claim 1, comprising a drive coupled to the compressor.

16. A system, comprising:

a valve assembly comprising a first one-way valve and a second one-way valve, wherein the first one-way valve is configured to enable fluid flow in a first axial direction, and the second one-way valve is configured to enable fluid flow in a second axial direction opposite from the first axial direction; and

a co-axial flow device comprising a first wall disposed about a first passage along an axis, a second passage disposed about the first wall along the axis, and a second wall disposed about the second passage along the axis, wherein the first passage comprises a first axial opening in fluid communication with the first one-way valve, and the second passage comprises a second axial opening in fluid communication with the second one-way valve.

17. The system of claim 16, wherein comprising a compressor coupled to the co-axial flow device.

18. The system of claim 16, wherein the first wall comprises a first annular wall, the first passage comprises a central axial passage having the first axial opening and a third axial opening opposite from the first axial opening, the second wall comprises a second annular wall, the second passage comprises an annular outer passage having the second axial opening and a radial opening

through the second wall, and the co-axial flow device comprises an annular scoop extending between the first and second walls.

19. A method, comprising:

reciprocating a piston in a cylinder of a compressor between first and second axial end portions; and

routing a fluid in a first axial direction through a first opening in a first passage of a co-axial flow device as the piston moves in a first axial direction; and

routing the fluid in a second axial direction through a second opening in a second passage of the co-axial flow device as the piston moves in a second axial direction opposite from the first axial direction, wherein the co-axial flow device has a first wall disposed about the first passage along an axis, the co-axial flow device has the second passage disposed about the first wall along the axis, and the co-axial flow device has a second wall disposed about the second passage along the axis.

20. The method of claim 19, wherein the first wall comprises a first annular wall, the first passage comprises a central axial passage having the first axial opening and a third axial opening opposite from the first axial opening, the second wall comprises a second annular wall, the second passage comprises an annular outer passage having the second axial opening and a radial opening through the second wall, and the co-axial flow device comprises an annular scoop extending between the first and second walls.