

Description

BACKGROUND OF THE INVENTION

[0001] The subject matter disclosed herein relates to liquid ring compressors, and more particularly, to liquid ring compressors that may be employed to compress wet gases in a subsea environment.

[0002] In subsea processing, oil and/or gas may be processed using equipment located on the sea floor rather than on a fixed or floating platform. Subsea processing may be particularly useful in extreme environments where equipment on the surface may be subjected to harsh conditions. Further, subsea processing may provide increased production, as well as reducing topside equipment expenditures during development. Subsea pumping and/or boosting stations are often used to transport well streams from the sea floor to floating platforms or land based production facilities for further processing. The subsea stations may employ one or more compressors that operate in conjunction with pumps to provide the motive force for transporting the well streams to the surface.

BRIEF DESCRIPTION OF THE INVENTION

[0003] In a first embodiment, a liquid ring compressor includes a shaft, a main body inner casing disposed about the shaft to form a chamber between the shaft and the main body inner casing, an inlet configured to remove a portion of liquid from a wet gas and to direct the wet gas into the chamber, and an impeller rotatably disposed within the chamber and configured to direct a remaining portion of the liquid in the wet gas out towards the main body inner casing to form a liquid ring within the chamber to compress the wet gas.

[0004] In a second embodiment, a liquid ring compressor includes a shaft, an inner casing disposed about the shaft to form a chamber between the shaft and the inner casing, an impeller rotatably disposed within the chamber and configured to direct a liquid out towards the inner casing to form a liquid ring within the chamber to compress a wet gas, apertures configured to remove a portion of the liquid from the liquid ring, a gas outlet coupled to the chamber to direct the compressed wet gas from the liquid ring compressor, and a liquid outlet coupled to the apertures to direct the removed portion of the liquid from the liquid ring compressor.

[0005] In a third embodiment, a subsea compression system includes a liquid ring compressor configured to remove liquid from a wet gas, and a conventional compressor disposed downstream of the liquid ring compressor to compress the wet gas from the liquid ring compressor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] These and other features, aspects, and advantages

of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

FIG. 1 depicts an embodiment of a subsea compression system that may employ a liquid ring compressor;

FIG. 2 is a perspective view of an embodiment of a liquid ring compressor that may be employed in the subsea compression system of FIG. 1;

FIG. 3 is a cross-sectional view of the liquid ring compressor of FIG. 2;

FIG. 4 is a cross-sectional view of another embodiment of a liquid ring compressor that may be employed in the subsea compression system of FIG. 1;

FIG. 5 is a perspective view of an embodiment of a liquid ring compressor that includes liquid removal apertures within an inner casing;

FIG. 6 is a perspective view of another embodiment of a liquid ring compressor that includes liquid removal apertures within an inner casing;

FIG. 7 is a cross-sectional view of an embodiment of a liquid ring compressor that includes liquid removal apertures within an end plate; and

FIG. 8 is a cross-sectional view of another embodiment of a liquid ring compressor that includes liquid removal apertures within an end plate.

DETAILED DESCRIPTION OF THE INVENTION

[0007] 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.

[0008] 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.

[0009] The present disclosure is directed to subsea compression systems that employ liquid ring compressors to compress wet gases that have a significant liquid volume fraction (LVF). According to certain embodiments, the LVF of the wet gases is from 0 to 5 percent, and all subranges therebetween. More specifically, the LVF of the wet gases may be at least 0.1 percent. Further, according to certain embodiments, the LVF of the wet gases may be just slightly greater than 0.1 percent. The liquid within the wet gases is used by the liquid ring compressors described herein to form a liquid ring that provides positive displacement of the wet gases within the liquid ring compressors. At least a portion of the liquid that separates from the wet gases to form the liquid ring may be removed through openings in the liquid ring compressor casing. Accordingly, the liquid ring compressors may be employed to separate liquid from the wet gases, in addition to compressing the wet gases. In certain embodiments, the liquid ring compressors may be employed upstream of conventional compressors, such as centrifugal, radial, or screw compressors, to reduce the amount of liquid that enters the conventional compressors. According to certain embodiments, the liquid ring compressors may be used upstream of conventional compressors to replace vapor-liquid separators, which have increased operational complexity and cost as compared to liquid ring compressors. Further, the liquid ring compressors may be designed to condition the flow of the wet gases that enter the conventional compressors by reducing fluctuations in the amount of liquid that enters the conventional compressors.

[0010] FIG. 1 depicts an embodiment of a subsea compression system 10 that provides pressure for transporting a fluid, such as natural gas, from a production region 12 on the sea or ocean floor 14 to a production facility 16 located on the surface 18. According to certain embodiments, the production region 12 may include one or more wells located on the sea or ocean floor 14. The production facility 16 may be floating on the sea or ocean surface 18 or may be located on land. The compression system 10 may be located at a boosting station 20 that directs fluid from the production region 12 to the production facility 16. The boosting station 20 may be connected to a single well or may be part of a manifold that collects the fluid from multiple wells.

[0011] The compression system 10 includes a liquid ring compressor 22 located upstream from a conventional compressor 24. According to certain embodiments, the conventional compressor 24 may include a centrifugal compressor, a radial compressor, a screw compressor, or a heli-coaxial compressor, among others. In certain embodiments, the conventional compressor 24 may represent multiple stages of conventional compressors. Further, in certain embodiments, the liquid ring compres-

sor 22 may represent multiple stages of liquid ring compressors. Moreover, in other embodiments, the conventional compressor 24 may be omitted. In these embodiments, the compression system 10 may include one or more liquid ring compressors 22 and may exclude conventional compressors 24.

[0012] The compression system 10 receives the production fluid through a flow line 26 that connects the production region 12 to the liquid ring compressor 22. The production fluid entering the liquid ring compressor 22 is a wet gas with a relatively high LVF, which, in certain embodiments may be approximately 0.1 to 5 percent, and all subranges therebetween. According to certain embodiments, it may be desirable for the LVF of the wet gas entering the compression portion of the liquid ring compressor 22 to be just slightly above 0.1 percent. For example, in certain embodiments, it may be desirable for the LVF of the wet gas entering the compression chamber to be between 0.1 and 0.2 percent, or more specifically, between 0.10 and 0.15 percent. However, in other embodiments, the target LVF for the wet gas entering the compression chamber may vary depending on factors, such as the design of the liquid ring compressor, the initial LVF of the wet gas, and operating pressures. According to certain embodiments, if the LVF of the wet gas is greater than just slightly above 0.1 percent, a portion of the liquid may be removed from the wet gas prior to the wet gas entering the compression chamber, as described further below with respect to FIG. 2. For example, in certain embodiments, a portion of the liquid may be removed within an inlet to the liquid ring compressor 22 and/or upstream of liquid ring compressor 22.

[0013] Within the liquid ring compressor 22, at least a portion of the liquid within the wet gas is separated from the wet gas to form a liquid ring that provides for positive displacement of the gas within the production fluid to compress the gas. According to certain embodiments, the gas may be compressed within liquid ring compressor 22. However, in other embodiments, minimal, or no compression may occur within the liquid ring compressor 22. In these embodiments, the liquid ring compressor 22 may be used to primarily separate liquid from the wet gas. The production fluid exiting the liquid ring compressor 22 may have a lower LVF than the wet gas entering the liquid ring compressor 22. According to certain embodiments, the LVF of the wet gas may be reduced by approximately 20 to 100 percent, and all subranges therebetween.

[0014] A flow line 28 is connected to the liquid ring compressor 22 to remove liquid from the liquid ring compressor 22. For example, at least a portion of the liquid from the liquid ring may be directed through the liquid flow line 28 to the production facility 16. In certain embodiments, the amount of liquid removed through the liquid flow line 28 may depend on the LVF of the wet gas entering the liquid ring compressor 22. For example, when the LVF is relatively high, more liquid may be removed than when the LVF is relatively low. Further, when the LVF is fairly low, such as approximately 0.5 to 1 per-

cent or less, no liquid may be removed through the liquid flow line 28. In other embodiments, rather than being connected to the production facility 16, the liquid flow line 28 may be connected to a boost pump that injects the removed liquid into the discharge manifold of the boosting station 20 where the liquid may be combined with the production fluid exiting the boosting station 20.

[0015] The production fluid from the liquid ring compressor is removed through a flow line 30 that directs the production fluid, which is mostly gas, from the liquid ring compressor 22 to the conventional compressor 24. Within the conventional compressor 24, the production fluid is compressed to provide pressure to direct the production fluid from the boosting station 20 to the production facility 16. According to certain embodiments, the boosting station 20 may be designed to compensate for the loss of pressure that occurs along the flow lines 26, 28, and 32. The compressed production fluid exits the conventional compressor 24 through a flow line 32 that directs the compressed production fluid to the production facility 16.

[0016] As shown in FIG. 1, the conventional compressor 24 and the liquid ring compressor 22 are arranged in a vertical configuration and are driven by a common shaft 34 connected to a motor 36, such as a variable speed drive. According to certain embodiments, the conventional compressor 24 and the liquid ring compressor 22 may be contained within a single integrated housing. However, in other embodiments, the conventional compressor 24 and the liquid ring compressor 22 may be contained within separate housings. Further, in certain embodiments, the conventional compressor 24 and the liquid ring compressor 22 may be driven by separate shafts connected by a gearbox. In yet other embodiments, the conventional compressor 24 and the liquid ring compressor 22 each may be driven by a separate shaft and motor.

[0017] In certain embodiments, a bypass flow line 38 may be included within compression system 10 to direct the production fluid from the production region 12 directly to the conventional compressor 24, bypassing the liquid ring compressor 22. The bypass line 38 may be employed when there is a low amount of liquid within the production fluid. However, in other embodiments, the bypass line 38 may be omitted. Further, in certain embodiments, other equipment, such as pumps and controls, among others, may be included within the boosting station 20. The equipment may be connected to power and communication supplies by umbilical connections. For example, in certain embodiments, the boosting station 20 may receive power from an umbilical connected to an onshore or platform power supply.

[0018] FIG. 2 depicts an embodiment of the liquid ring compressor 22. The liquid ring compressor 22 includes a main body 40 and an inlet section 42, which directs the wet gas into the main body 40. The inlet section 42 includes an inner casing 44 disposed within an outer casing 46 to form a chamber 48 between the casings 44 and 46. Production fluid from the flow line 26 (FIG. 1) may

enter the inlet section 42, as generally shown by an arrow 50. In particular, the production fluid may be directed into an interior 52 of the inner casing 44. As the production fluid flows through the interior 52, a portion of the liquid included within the production fluid may flow through openings 54 of the inner casing 44 to flow from the interior 52 into the chamber 48. According to certain embodiments, the inlet section 42 may be disposed at an incline to promote separation of liquid from the production fluid. In certain embodiments, the inlet section 42 may be a toroidal scroll inlet or an inclined riser. The liquid collected within chamber 48 may be removed from the liquid ring compressor 22, as generally shown by an arrow 56. According to certain embodiments, the removed liquid may be directed to the liquid flow line 28, bypassing the main body 40 of the liquid ring compressor 22. However, in other embodiments, the removed liquid may be directed to a separate liquid removal line. Further, in certain embodiments, the removed liquid may be directed into a chamber 70 of the liquid ring compressor 22 where the liquid may be removed from the liquid ring compressor as generally shown by an arrow 88, and as discussed further below. The production fluid from the interior 52 enters the main body 40, as generally shown by an arrow 58.

[0019] The main body 40 includes an outer casing 60 disposed around an inner casing 62 that is disposed around a shaft 64. The inner casing 62 is coupled to the motor shaft 34, shown in FIG. 1, to rotate with respect to the outer casing 60 and the shaft 64. An impeller 66 is located between the shaft 64 and the inner casing 62 and is coupled to the inner casing 62 to allow the impeller 66 to rotate with the inner casing 62, as generally shown by an arrow 67. Plates 68 and 69 are located on the ends of the main body 40 to form a chamber 70 between the outer casing 60 and the inner casing 62. The plate 68 extends from the outer casing 60 to the inner casing 62, and the plate 69 extends from the outer casing 60 to the shaft 64. A plate 71 also extends from the inner casing 62 to the shaft 64 to seal a chamber 72 containing the impeller 66 from the liquid collection chamber 48 within the inlet section 42. For illustrative purposes, a portion of the plate 71 is cut away to show the impeller 66 within the chamber 72. In other embodiments, rather than two separate plates 68 and 71, one continuous plate may extend from the outer casing 60 to the shaft 64. The outer casing 46 of the inlet section 42 may be coupled to the plate 68 and/or to the plate 71 to seal the main body 40 of the liquid ring compressor from the liquid contained within the liquid collection chamber 48 of the inlet section 42.

[0020] The inner casing 44 of the inlet section 42 may be coupled to the shaft 64 of the main body 40 to direct production fluid from the interior 52 of the inlet section 42 to an inlet chamber 74 within the shaft 64. As shown in FIG. 2, the shaft 64 is hollow and includes the inlet chamber 74 and an outlet chamber 76, which are separated by a partition 78. The production fluid flows through

the inlet chamber 74 of the shaft 64 and may flow through openings included in the shaft 64 to enter the chamber 72, as shown generally by an arrow 80. Within the chamber 72, the production fluid, which is mostly gas, may be dispersed between blades of the impeller 66. However, the production fluid also contains a small amount of liquid, which also enters the chamber 72. In certain embodiments, the production fluid may have a LVF of approximately 1.0 to 1.1 percent. However, in other embodiments, the LVF of the production fluid entering the chamber 72 may be smaller or larger depending on factors, such as the design of the liquid ring compressor, the initial LVF of the wet gas, and operating pressures, among others.

[0021] As the liquid flows into the chamber 72, the rotation of the impeller 66 may exert centrifugal force on the liquid, thereby directing the liquid out towards the inner casing 62 to form a liquid ring 96, as shown in FIG. 3. Further, as the impeller 66 rotates, the gas is compressed by the liquid ring formed within the chamber 72. The compressed fluid flows from the chamber 72 through openings in the shaft 64 into the outlet chamber 76, as shown generally by an arrow 82. The compressed fluid then exits the liquid ring compressor 22 through the outlet chamber 76 of the shaft 64, as generally shown by an arrow 84. From the liquid ring compressor 22, the compressed fluid may flow through the flow line 30 to the conventional compressor 24, as shown in FIG. 1.

[0022] According to certain embodiments, as the production fluid is compressed within the chamber 72, liquid within the production fluid may flash to further reduce the LVF of the production fluid. Further, some liquid may become part of the liquid ring formed within the chamber 72. Openings 86, such as slots, are included within the inner casing 62 to remove excess liquid from the chamber 72. For example, excess liquid from the liquid ring may flow through the openings 86 to be collected in the chamber 70 between the inner casing 62 and the outer casing 60. From the chamber 70, the collected liquid may flow through an outlet disposed in the plate 69, as shown in FIG. 3, to exit the liquid ring compressor 22, as generally shown by an arrow 88. In other embodiments, the outlet may be disposed in the outer casing 60. Further, in yet other embodiments, the outlet may be disposed in the plate 68 or in the plate 71. In certain embodiments, the liquid may be directed through the plate 68 or 71 into the liquid collection chamber 48 of the inlet section 42. From the liquid ring compressor 22, the liquid may be directed through the flow line 28, as shown in FIG. 1.

[0023] As shown, the openings 86 are depicted as slots spaced along the inner casing 62. However, in other embodiments, the size, shape, and/or spacing of the openings 86 may vary. For example, in certain embodiments, the openings 86 may be circular, rectangular, or triangular, among others. The openings 86 also may be disposed in a random or patterned configuration. Further, in certain embodiments, the openings 86 may be designed to have a cross-sectional area that is designed to

extract a constant volume or mass flow of liquid from the chamber 72 under constant operating conditions. The location of the openings 86 on inner casing 62 also may be selected so that a desired amount of liquid is extracted under constant operating conditions. Moreover, in certain embodiments, the openings 86 may be strategically placed to stabilize and/or to alter the shape of the liquid ring under particular operating conditions, such as, for example, the maximum possible pressure ratio. Further, operating parameters for the liquid ring compressor 22, such as the backpressure and/or the revolutions per minute of the impeller 66, may be varied to change the amount of liquid that is extracted.

[0024] FIG. 3 is an exploded view of the embodiment of the liquid ring compressor 22 shown in FIG. 2. In this embodiment, the inner casing 62 rotates with the impeller 66 and the production fluid enters the main body 40 through the chamber 74 inside the shaft 64. However, in other embodiments, the shaft 64 may rotate with the impeller and the production fluid may enter the main body 40 through openings in a plate, such as the plate 104, as discussed further below with respect to FIG. 4.

[0025] As shown in FIG. 3, the front plate 71 includes an opening 90 that generally aligns with the shaft 64 to allow the production fluid from the chamber 48 of the inlet section 42 to enter the shaft 64. The rear plate 69 includes an opening 92 that generally aligns with the shaft 64 to allow the compressed production fluid from the outlet chamber 76 of the shaft 64 to exit the liquid ring compressor 22. The rear plate 69 also includes an opening 94 that allows the liquid collected within the chamber 70 to exit the liquid ring compressor 22.

[0026] As shown in FIG. 3, the main body 40 has been sectioned through the casing 60 to show the partition 78 that divides the interior of the shaft 64 into the inlet chamber 74 and the outlet chamber 76. The production fluid enters the shaft through the inlet chamber 74 and flows through openings 98 in the shaft 74 to the chamber 72 formed between the shaft 64 and the inner casing 62. Within the chamber 72, the production fluid is dispersed between blades of the impeller 66. The shaft 64 and the impeller 66 are disposed off center within the inner casing 64 and the liquid ring 96 forms a compression seal with the impeller 66. Accordingly, as the impeller 66 and the inner casing 62 rotate, the spaces between the impeller blades decrease in size, compressing the production fluid disposed between the impeller blades. The compressed production fluid then flows through openings 100 in the shaft 64 to the outlet chamber 76 included within the shaft 64. The compressed production fluid may then exit the outlet chamber 76 through the opening 92 in the rear plate 69.

[0027] FIG. 4 depicts another embodiment of the liquid ring compressor 22. The liquid ring compressor 22 includes a solid shaft 102 that rotates with the impeller 66, as generally shown by an arrow 103. Accordingly, in this embodiment, the impeller 66 is coupled to the shaft 102, rather than to the inner casing 62, which remains station-

ary. A front plate 104 is disposed over the inlet end of the main body 40 and includes an opening 106 for directing the production fluid from the interior 52 of the inlet section 42 to the impeller chamber 72. In certain embodiments, a cone may be used in addition to the plate 104 to direct the production fluid from the inlet section 42 to the chamber 72. The front plate 104 also includes an opening 108 for directing the liquid from the liquid collection chamber 48 of the inlet section 42 into the chamber 70. However, in other embodiments, the opening 108 may be omitted, and the liquid from the liquid collection chamber 48 may not enter the main body 40 of the liquid ring compressor 22.

[0028] As discussed above with respect to FIG. 3, as the impeller 66 rotates within the chamber 72, the liquid forms the liquid ring 96 that may be used in conjunction with the impeller 66 to compress the production fluid. Excess liquid from the liquid ring 96 may flow through the openings 86 in the inner casing 62 to the outer chamber 70. As shown in FIG. 4, the openings 86 are concentrated within a section of the inner casing 62; however, in other embodiments, the openings 86 may be spaced around the circumference of the inner casing 62.

[0029] A rear plate 110 is disposed on the opposite end of the main body 40 from the front plate 104 to allow the liquid and the compressed production fluid to exit the liquid ring compressor 22. The rear plate 110 includes an opening 112 for directing the compressed production fluid from the liquid ring compressor 22 to the flow line 30 (FIG. 1), as well as the opening 94 for directing the liquid from the liquid ring compressor 22 to the flow line 28. The rear plate 110 also includes an opening 114 that allows the solid shaft 102 to extend through the rear plate 110 where the shaft 102 may be coupled to the shaft 34, shown in FIG. 1.

[0030] As may be appreciated, the front and rear plates 104 and 110 are provided by way of example only, and are not intended to be limiting. In other embodiments, multiple plates, baffles, cones, or other fluid directing mechanisms may be employed to direct the production fluid and the liquid to and/or from the liquid ring compressor 22. Further, the locations, shapes, and/or sizes of the openings 106, 108, 112, and 94 may vary. Moreover, in other embodiments, the opening 112 for the compressed production fluid and/or the opening 94 for the liquid may be disposed on the main body 40 of the liquid ring compressor 22, rather than on the rear plate 110. Further, in certain embodiments, the opening 112 for the compressed production fluid and/or the opening 94 for the liquid may be disposed on the front plate 104.

[0031] The shape, size, and/or location of the openings 86 included on the inner casing 62 also may vary. For example, FIGS. 5 and 6 depict alternate openings 116 and 118 that may be included on the inner casing 62 to direct liquid from the liquid ring to the chamber 70. As shown in FIG. 5, the openings 116 includes slots that extend along the length of the inner casing 62 to remove liquid from the liquid ring. As shown in FIG. 6, the open-

ings 118 include circular openings spaced along the inner casing 62. The openings 116 and 118 may be employed in a liquid ring compressor with a rotating inner casing, as shown in FIGS. 2 and 3, or in a liquid ring compressor with a rotating shaft, as shown in FIG. 4. Further, in other embodiments, the openings may be oblong, square, or triangular, among others, and may be disposed at different locations on the inner casing 62.

[0032] The openings for removing liquid from the liquid ring also may be located on the front and/or rear plate, instead of, or in addition to, including openings on the inner casing 62. For example, FIGS. 7 and 8 depict rear plates 120 and 124 that include openings 122 and 126, respectively, that may be employed to remove liquid from the liquid ring. As shown in FIG. 7, the rear plate 120 includes slot shaped openings 122 that are spaced around the inner opening 92 to allow liquid to exit the outer chamber 70 through the rear plate 120. As shown in FIG. 8, the rear plate 124 includes the circular openings 126 that are concentrated within one section of the rear plate 124 to allow liquid to exit the liquid ring compressor 22 directly from the impeller chamber 72.

[0033] The openings 122 and 126 may be employed in liquid ring compressors with rotating inner casings 62 or in liquid ring compressors with rotating shafts 102. Further, the shape, size, and/or location of the openings 122 and 126 may vary. For example, in other embodiments, the openings 122 and 126 may be included on front plates. According to certain embodiments, the location of the openings 122 and 126 may be selected so that liquid is extracted when the liquid ring has reached a predetermined size. Further, in certain embodiments, the locations may be selected so that liquid is extracted under normal operating conditions of the liquid ring compressor without extracting gas from the production fluid. Moreover, in other embodiments, the openings may have another shape, such as circular, oblong, rectangular, or triangular, among others.

[0034] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

[0035] Various aspects and embodiments of the present invention are defined by the following numbered clauses:

1. A liquid ring compressor, comprising:

a shaft;

a main body inner casing disposed about the shaft to form a chamber between the shaft and the main body inner casing;

an inlet configured to remove a portion of liquid from a wet gas and to direct the wet gas into the chamber; and 5

an impeller rotatably disposed within the chamber and configured to direct a remaining portion of the liquid in the wet gas out towards the main body inner casing to form a liquid ring within the chamber to compress the wet gas. 10

2. The liquid ring compressor of clause 1, wherein the inlet comprises a toroidal scroll inlet. 15

3. The liquid ring compressor of clause 1 or clause 2, wherein the inlet comprises an inlet inner casing with an interior configured to receive the wet gas, an inlet outer casing disposed about the inlet inner casing to form a liquid collection chamber therebetween, and openings within the inlet inner casing configured to direct the separated portion of the liquid into the liquid collection chamber. 20 25

4. The liquid ring compressor of any preceding clause, wherein the inlet inner casing is connected to the shaft to direct the wet gas into an inlet chamber within the shaft. 30

5. The liquid ring compressor of any preceding clause, wherein the shaft comprises a hollow shaft, and wherein the main body inner casing is configured to rotate with the impeller. 35

6. The liquid ring compressor of any preceding clause, wherein the shaft is configured to rotate with the impeller and wherein the main body inner casing is configured to remain stationary. 40

7. The liquid ring compressor of any preceding clause, comprising a main body outer casing disposed around the main body inner casing to form a liquid collection volume therebetween. 45

8. A liquid ring compressor, comprising:

a shaft;

an inner casing disposed about the shaft to form a chamber between the shaft and the inner casing; 50

an impeller rotatably disposed within the chamber and configured to direct a liquid out towards the inner casing to form a liquid ring within the chamber to compress a wet gas; 55

apertures configured to remove a portion of the liquid from the liquid ring;

a gas outlet coupled to the chamber to direct the compressed wet gas from the liquid ring compressor; and

a liquid outlet coupled to the apertures to direct the removed portion of the liquid from the liquid ring compressor.

9. The liquid ring compressor of any preceding clause, wherein at least some of the apertures are disposed within the inner casing.

10. The liquid ring compressor of any preceding clause, comprising a pair of end plates disposed on opposite ends of the inner casing, wherein at least some of the apertures are disposed within at least one of the pair of end plates.

11. The liquid ring compressor of any preceding clause, comprising an outer casing disposed about the inner casing to form a liquid collection volume therebetween, wherein the apertures are disposed within the inner casing to direct the removed portion of the liquid from the chamber to the liquid collection volume.

12. The liquid ring compressor of any preceding clause, wherein the inner casing is configured to rotate with the impeller, and wherein the gas outlet comprises an outlet chamber disposed within an interior of the shaft.

13. The liquid ring compressor of any preceding clause, wherein the shaft is configured to rotate with the impeller.

14. A subsea compression system, comprising:

a liquid ring compressor configured to remove liquid from a wet gas; and

a conventional compressor disposed downstream of the liquid ring compressor to compress the wet gas from the liquid ring compressor.

15. The subsea compression system of clause 14, wherein the liquid ring compressor is configured to compress the wet gas.

16. The subsea compression system of clause 14 or clause 15, wherein the liquid ring compressor is configured to reduce variation in an amount of liquid in the wet gas entering the convention compressor.

17. The subsea compression system of any of claus-

es 14 to 16, wherein the conventional compressor comprises a centrifugal compressor.

18. The subsea compression system of any of clauses 14 to 17, wherein the liquid ring compressor and the conventional compressor are driven by a common shaft.

19. The subsea compression system of any of clauses 14 to 18, comprising a gear box coupled to the shaft between the liquid ring compressor and the conventional compressor.

20. The subsea compression system of any of clauses 14 to 19, comprising multiple stages of conventional compressors and/or liquid ring compressors.

Claims

1. A liquid ring compressor (22), comprising:

a shaft (64);
a main body inner casing (62) disposed about the shaft (64) to form a chamber (72) between the shaft (64) and the main body inner casing (62);
an inlet (42) configured to remove a portion of liquid from a wet gas and to direct the wet gas into the chamber (72); and
an impeller (66) rotatably disposed within the chamber (72) and configured to direct a remaining portion of the liquid in the wet gas out towards the main body inner casing (62) to form a liquid ring (96) within the chamber (72) to compress the wet gas.

2. The liquid ring compressor (22) of claim 1, wherein the inlet (42) comprises a toroidal scroll inlet.

3. The liquid ring compressor (22) of claim 1 or claim 2, wherein the inlet (42) comprises an inlet inner casing (44) with an interior (52) configured to receive the wet gas, an inlet outer casing (46) disposed about the inlet inner casing (44) to form a liquid collection chamber (48) therebetween, and openings (54) within the inlet inner casing (44) configured to direct the separated portion of the liquid into the liquid collection chamber (48).

4. The liquid ring compressor (22) of any preceding claim, wherein the inlet inner casing (46) is connected to the shaft (64) to direct the wet gas into an inlet chamber (74) within the shaft (64).

5. The liquid ring compressor of any preceding claim, wherein the shaft (64) comprises a hollow shaft, and wherein the main body inner casing (62) is config-

ured to rotate with the impeller (66).

6. The liquid ring compressor of any preceding claim, wherein the shaft (64) is configured to rotate with the impeller (66) and wherein the main body inner casing (62) is configured to remain stationary.

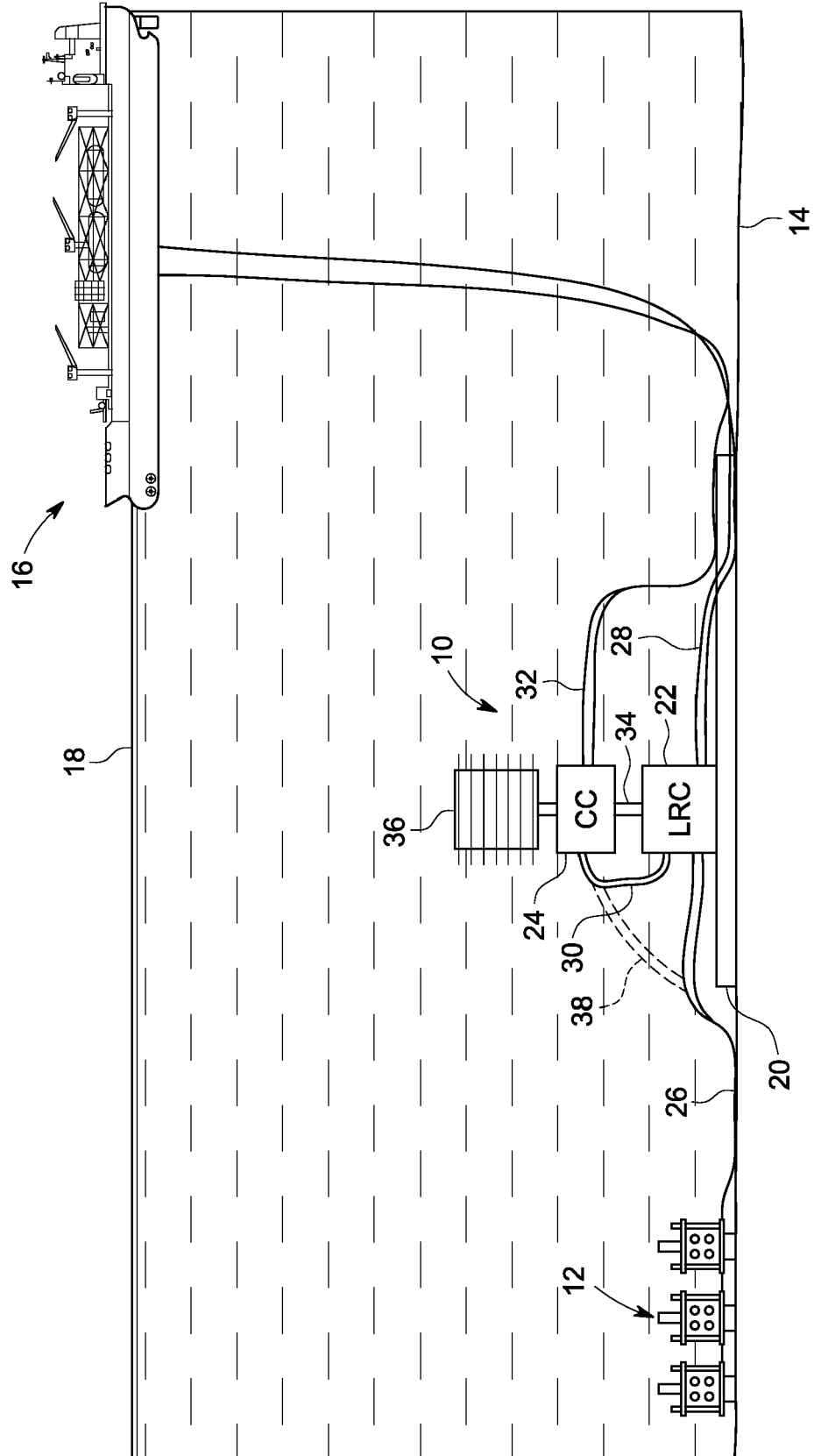
7. The liquid ring compressor of any preceding claim, comprising a main body outer casing (60) disposed around the main body inner casing (62) to form a liquid collection volume (70) therebetween.

8. A liquid ring compressor (22), comprising:

a shaft (64);
an inner casing (62) disposed about the shaft (64) to form a chamber (72) between the shaft (64) and the inner casing (62);
an impeller (66) rotatably disposed within the chamber (72) and configured to direct a liquid out towards the inner casing (62) to form a liquid ring (96) within the chamber (72) to compress a wet gas;
apertures (86, 116, 118, 126) configured to remove a portion of the liquid from the liquid ring (96);
a gas outlet (92, 112) coupled to the chamber (72) to direct the compressed wet gas from the liquid ring compressor (22); and
a liquid outlet (94, 122) coupled to the apertures (86, 116, 118) to direct the removed portion of the liquid from the liquid ring compressor (22).

9. The liquid ring compressor of any preceding claim, wherein at least some of the apertures (86, 116, 118) are disposed within the inner casing (62).

10. The liquid ring compressor of any preceding claim, comprising a pair of end plates (124, 104) disposed on opposite ends of the inner casing (62), wherein at least some of the apertures (126) are disposed within at least one of the pair of end plates.



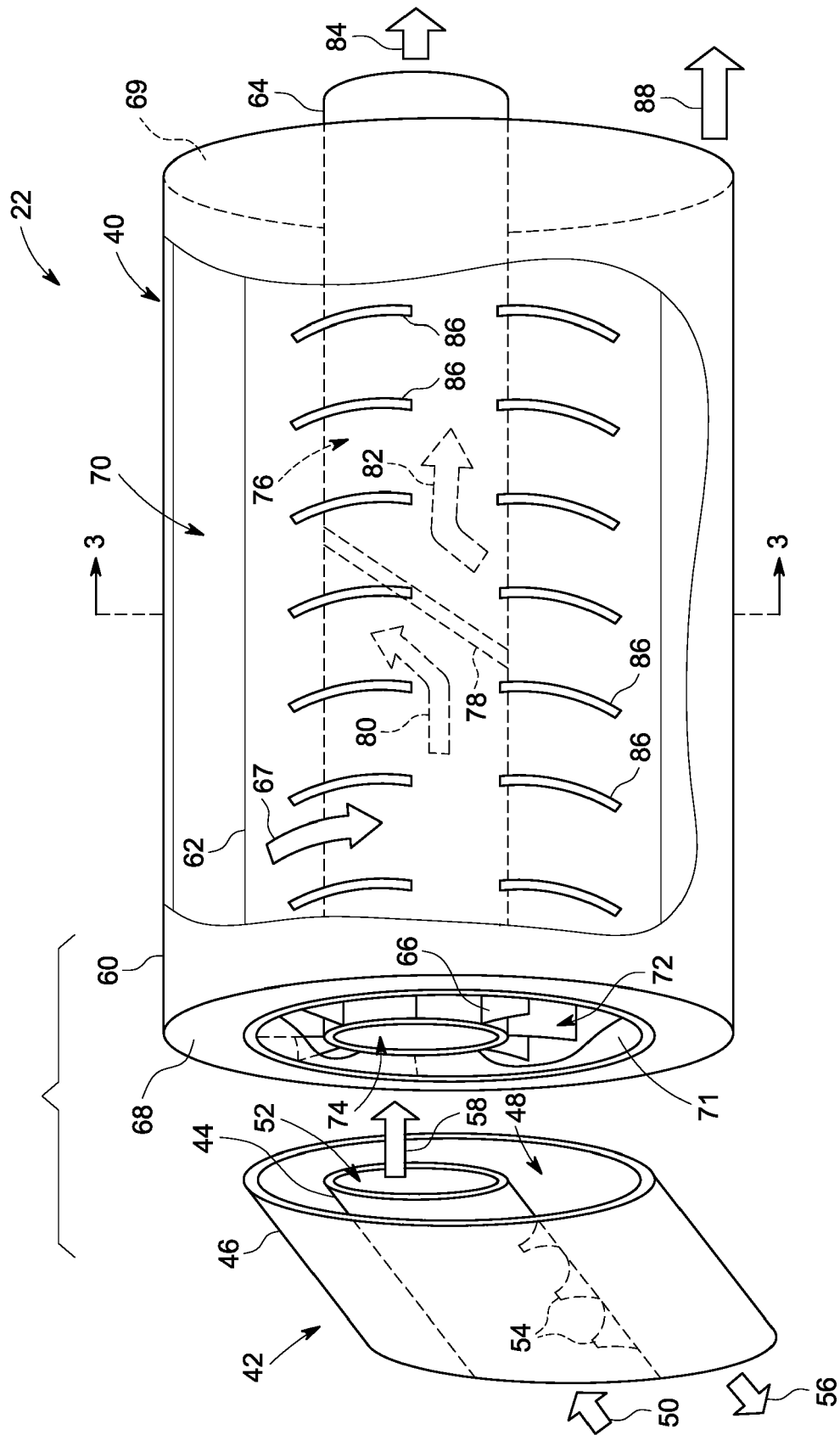


FIG. 2

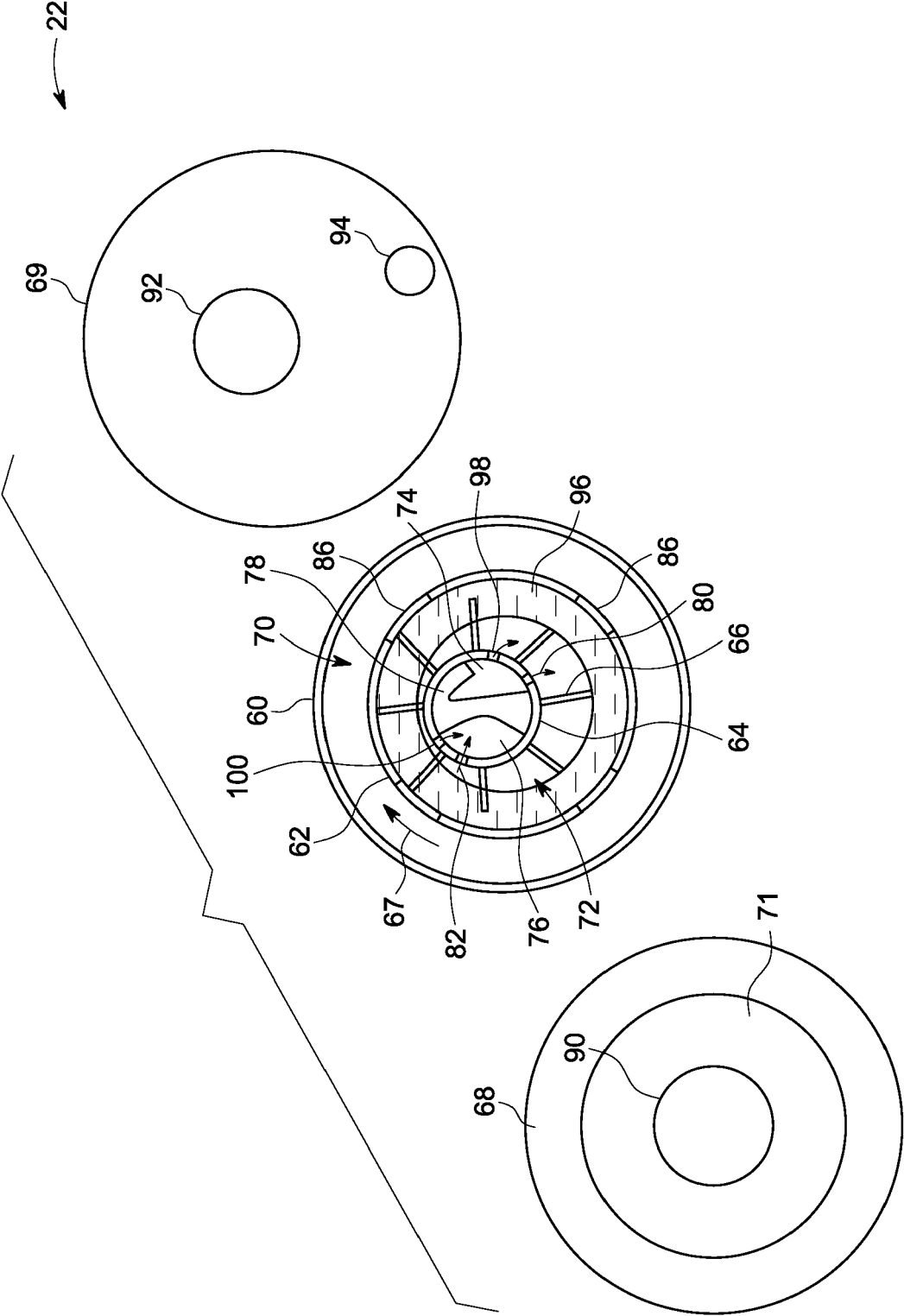


FIG. 3

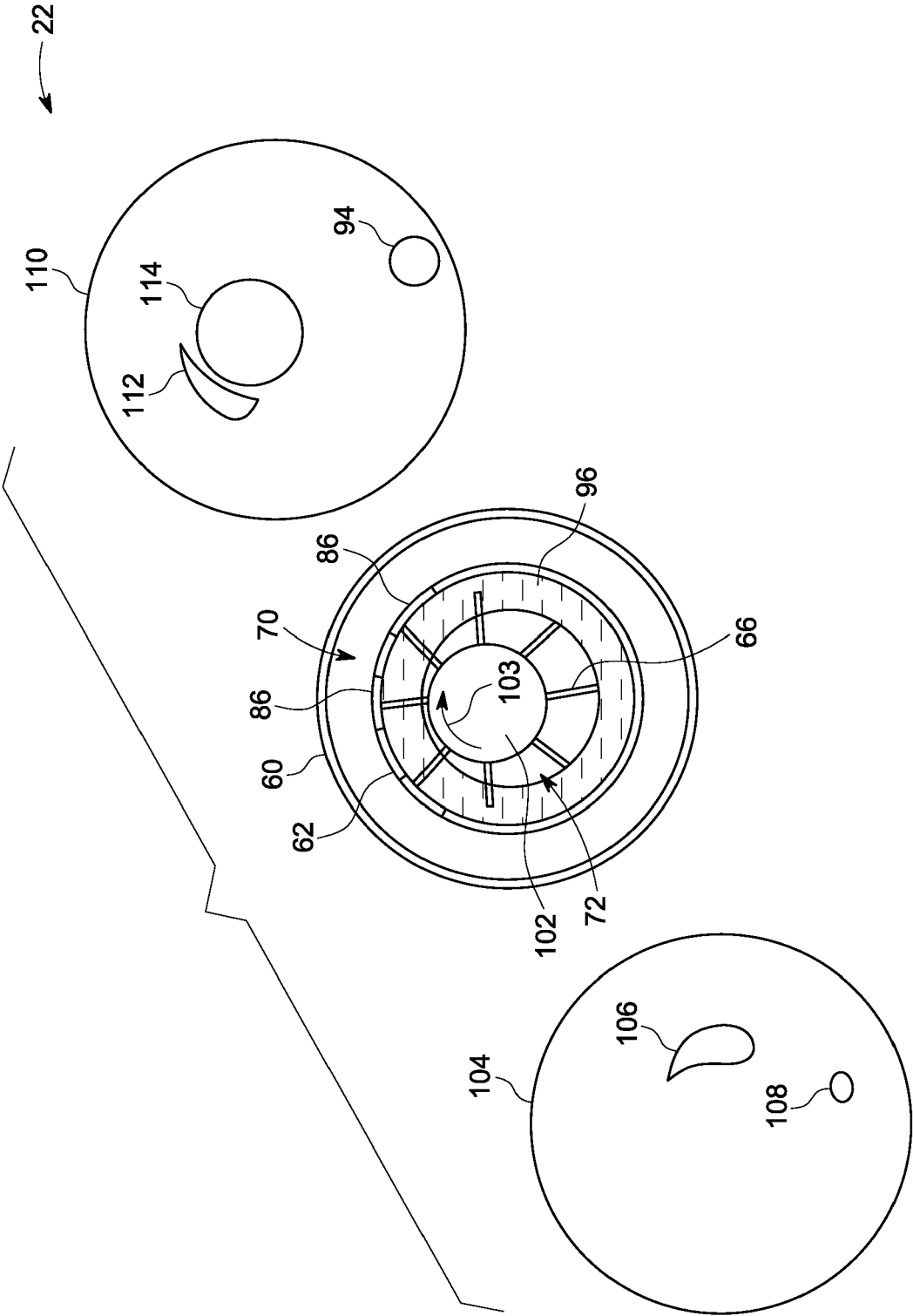


FIG. 4

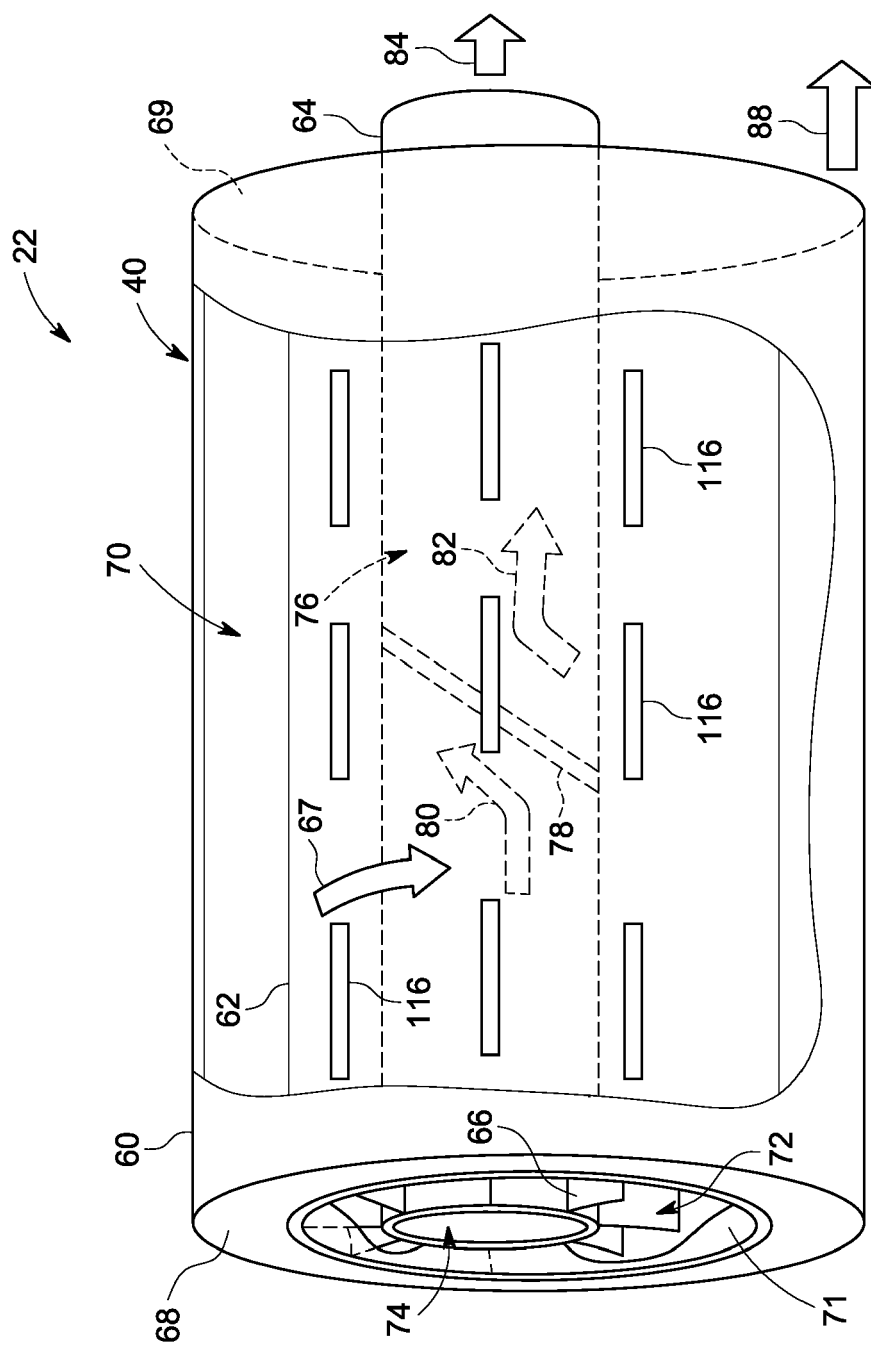


FIG. 5

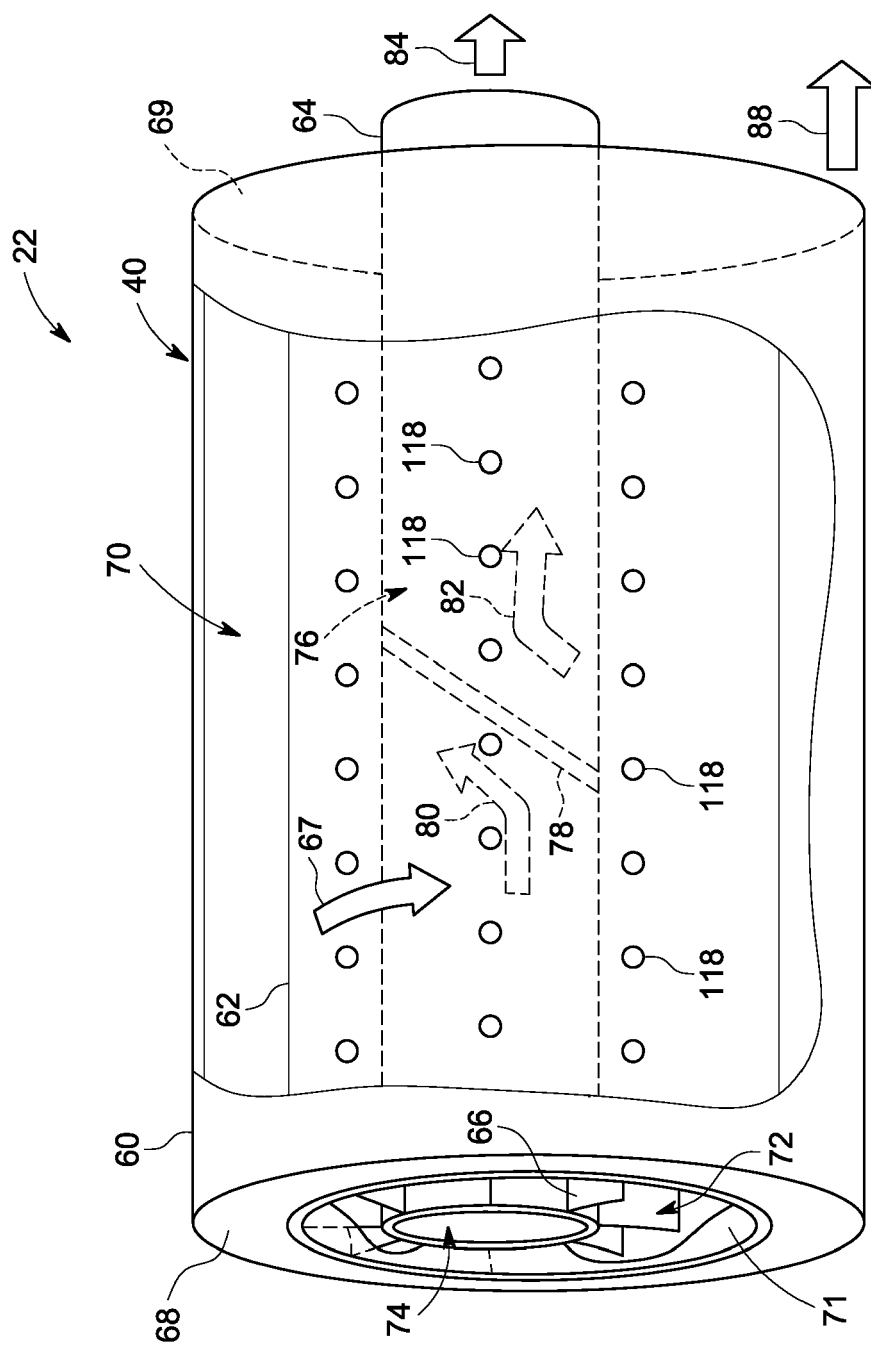


FIG. 6

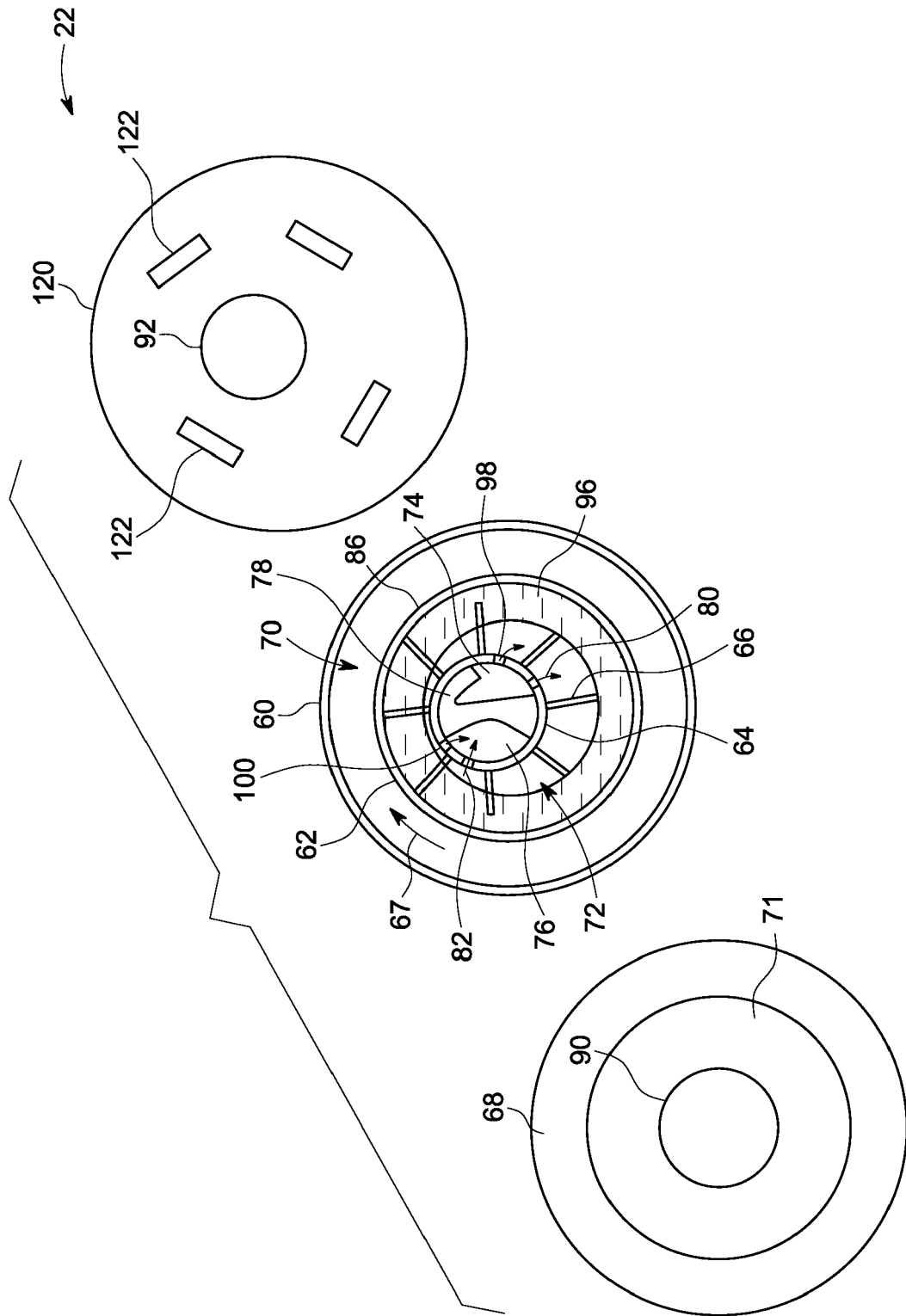


FIG. 7

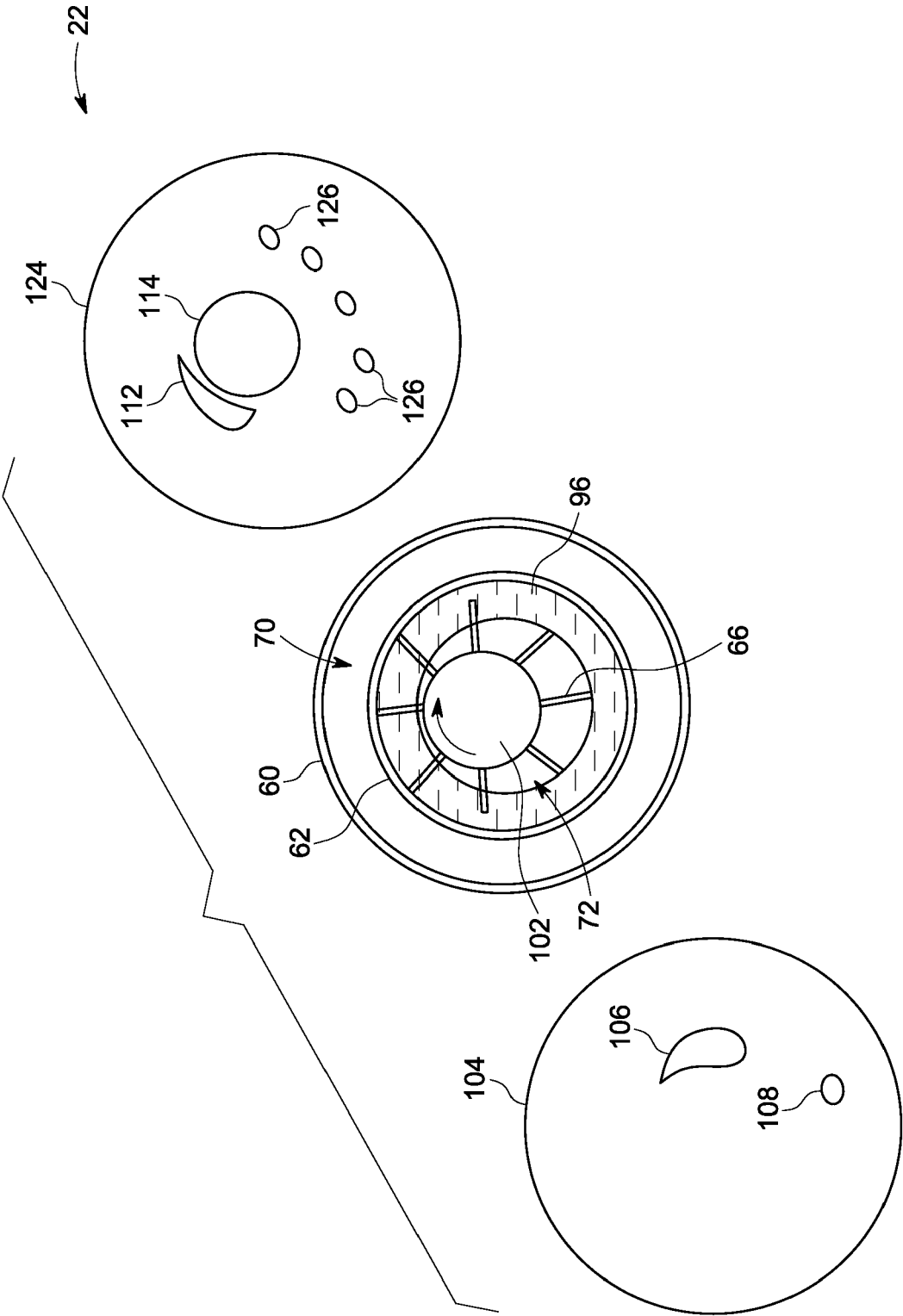


FIG. 8