MULTISECTION DOWNHOLE SEPARATOR AND METHOD

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ABSTRACT

A downhole separator has first and second separation sections each with a housing defining an interior cavity divided into a first chamber and a second chamber by a flow restricting bearing housing. Each separation section has an internal pump that pumps production fluid into the first chamber and to the bearing housing. The bearing housing limits flow into the second chamber and releases pressure on gas in the production fluid entering the second chamber, separating gas from liquid. A vortex generator in the second chamber segregates the liquid to the outside and the gas to the inside of the second chamber. The bearing housing of the upstream separation section has a greater capacity than the bearing housing of the downstream separation section.
MULTISECTION DOWNHOLE SEPARATOR AND METHOD

[0001] This application is a continuation-in-part of Ser. No. 12/567,933 filed Sep. 28, 2009.

TECHNICAL FIELD

[0002] The present invention relates to separators for oil and gas wells, and more particularly to a multisection, downhole, gas and liquid separator and a downhole method of separating gas and liquid from production fluid.

BACKGROUND ART

[0003] Liquids are substantially incompressible fluids while gases are compressible fluids. The production fluid in an oil or gas well is generally a combination of liquids and gases. In particular, the production fluid for methane production from coal formation includes the gas and water. Pumping such production fluid is difficult due to the compressibility of the gas. Compression of the gas reduces the efficiency of the pump and the pump can cavitate, stopping fluid flow.

[0004] Downhole gas and liquid separators separate the gas and liquid in the production fluid at the bottom of the production string, before pumping the liquid up the production string, and thereby improve the efficiency and reliability of the pumping process. In some cases, the waste fluids from the production fluid may be reinjected above or below the production formation, eliminating the cost of bringing such waste fluids to the surface and the cost of disposal or recycling.

[0005] U.S. Pat. No. 5,673,752 to Scudder et al. discloses a separator that uses a hydrophobic membrane for separation. U.S. Pat. No. 6,036,749 to Ribeiro et al., and U.S. Pat. No. 6,382,317 to Cobb disclose powered rotary separators. U.S. Pat. No. 6,066,193 to Lee discloses a separator system having at least two separators with different internal diameters to provide different fluid capacities.

[0006] U.S. Pat. No. 6,155,345 to Lee et al. discloses a separator divided by flow-through bearings into multiple separation chambers. U.S. Pat. No. 6,761,215 to Morrison et al. discloses a rotary separator with a restrictor that creates a pressure drop. U.S. Pat. No. 7,461,692 to Wang discloses a separator having multiple separation stages with each separation stage having a rotor and each rotor having an inducer and an impeller.

DISCLOSURE OF THE INVENTION

[0007] A downhole separator includes at least two separation sections. Each of the separation sections has a housing defining an interior cavity, a means for restricting fluid flow, an internal pump and a vortex generator. The means for restricting fluid flow includes a housing defining an interior cavity, a means for restricting fluid flow, an internal pump and a vortex generator. The means for restricting fluid flow limits the fluid flow into the second chamber which releases the pressure on the gas, allowing the gas bubbles to expand and separate from the liquid. The vortex generator segregates the liquid to the outside and gas to the inside of the second chamber. The number of separation sections, and the size of the means for restricting for each separation section are selected based on the required pumping rate of the well and the gas content of the production fluid entering each separation stage. The capacity of the means for restricting in each separation section controls the capacity of that separation section. Upstream separation sections have higher capacity due to the higher gas content and therefore the higher mass being pumped through the separation section.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Details of this invention are described in connection with the accompanying drawings that bear similar reference numerals in which:

[0009] FIG. 1 is a side elevation view of a separator embodying features of the present invention.

[0010] FIG. 2 is a side cut away view of the first separation section of the separator of FIG. 1.

[0011] FIG. 3 is a partially cut away view of the head of a separation section of the separator of FIG. 1.

[0012] FIG. 4 is a partially cut away view of a diffuser of a pumping stage of a separation section of the separator of FIG. 1.

[0013] FIG. 5 is a partially cut away view of an impeller of a pumping stage of a separation section of the separator of FIG. 1.

[0014] FIG. 6 is a partially cut away view of the bearing housing a separation section of the separator of FIG. 1.

[0015] FIG. 7 is a side cut away view of the second separation section of the separator of FIG. 1.

[0016] FIG. 8 is a side cut away view of the first separation section of the separator of FIG. 1 with an alternative internal pump and vortex generator.

[0017] FIG. 9 is a side cut away view of the second separation section of the separator of FIG. 1 with an alternative internal pump and vortex generator.

DETAILED DESCRIPTION OF THE INVENTION

[0018] Referring now to FIGS. 1 and 2, a separator embodying features of the present invention includes a lower, upstream first separation section 11 and an downstream second separation section 12. The first separation section 11 includes a housing 14, a base 15, and a head 16. The housing 14 is a hollow, elongated, cylinder defining an interior cavity 17. The housing 14 has spaced, internally threaded lower and upper ends 19 and 20.

[0019] Describing the specific embodiments herein chosen for illustrating the invention, certain terminology is used which will be recognized as being employed for convenience and having no limiting significance. For example, the terms “top”, “bottom”, “up” and “down” will refer to the illustrated embodiment in its normal position of use. “Inward” and “outward” refer to radially inward and radially outward, respectively, relative to the axis of the illustrated embodiment of the device. “Upstream” and “downstream” refer to normal direction of fluid flow during operation. Further, all of the terminology above-defined includes derivatives of the word specifically mentioned and words of similar import.

[0020] The base 15 has an upper portion 22, an intermediate portion 23 and a lower portion 24. The upper portion 22 is an externally threaded, hollow, cylinder sized and shaped to thread into the lower end 19 of housing 14, and includes an upwardly opening, centered, generally cylindrical upper cavity 26. The intermediate portion 23 has an exterior surface 27 that, in the illustrated embodiment, extends downwardly and inwardly from the upper portion 22 and has a centered lower bearing aperture 28 extending downward from the upper cav-
ity 26. A lower bearing 30 is mounted in the lower bearing aperture 26. A plurality of circumferentially arranged inlet ports 29 extend from the exterior surface 27 upwardly and inwardly into the upper cavity 26. The lower portion 24 is hollow and generally cylindrical, and extends downward from the intermediate portion 23 to an outwardly projecting flange 31, with a lower cavity 32 extending from the lower bearing aperture 28.

[0021] Referring to FIG. 3, the head 16 includes an upper portion 34, an intermediate portion 35 extending downwardly from the upper portion 34, and a lower portion 36 extending downwardly from the intermediate portion 35. The upper portion 34 is generally cylindrical and includes a plurality of spaced, radially arranged, upwardly extending, threaded studs 38. An external, circumferential channel 39 extends around the head 16 between the upper portion 34 and the intermediate portion 35. The intermediate portion 35 is externally threaded, and sized and shaped to thread into the upper end 20 of the housing 14. An upwardly opening, inwardly and downwardly tapering, generally conical upper cavity 40 extends through the upper portion 34 and the intermediate portion 35.

[0022] The lower portion 36 has a downwardly and inwardly tapering exterior surface 41, and a downwardly opening, downwardly and outwardly tapering lower cavity 42 that connects to the exterior surface 41 at a lower end 43. An upper bearing aperture 44 extends between the upper cavity 40 and the lower cavity 43, and has an upper bearing 45 mounted therein. A plurality of circumferentially arranged liquid outlet ports 47 extend upwardly and inwardly from the exterior surface 41 to the upper cavity 40. A plurality of circumferentially arranged gas outlet ports 48 extend upwardly and outwardly from the lower cavity 42 to the channel 39.

[0023] Referring again to FIG. 2, the first separation section 11 includes an internal pump 50 with first and second pumping stages 51 and 52, a first sleeve 53, a means for restricting flow 54, and a second sleeve 56, with each having a cylindrical exterior sized and shaped to fit into the interior cavity 17 of the housing 14, and with each being assembled into the interior cavity 17 in the above listed order from the base 15 to the head 16. In the illustrated embodiment the means for restricting fluid flow 54 is a bearing housing 55. Other means for restricting fluid flow 54 are suitable for the present invention.

[0024] The first and second pumping stages 51 and 52 each include an impeller housing 58 and a diffuser 59 sized and shaped to fit into the interior cavity 17 of the housing 14, and an impeller 60. As shown in FIG. 4, the diffuser 59 includes a diffuser aperture 62 extending upwardly through the center of diffuser 59, a cylindrical outer wall 63, and a plurality of spaced, radially arranged, upwardly, inwardly and helically extending passages 64 between the diffuser aperture 62 and the outer wall 63, with the passages 64 being separated by radial fins 65. Referring again to FIG. 2, the impeller housing 58 and diffuser 59 define an impeller cavity 67. FIG. 5 shows the impeller 60 having a hub 69 and a plurality of spaced, radially arranged, upwardly, outwardly and helically extending passages 70 around the hub 69.

[0025] The bearing housing 55, as shown in FIG. 6, is generally cylindrical with an intermediate bearing aperture 72 and a plurality of spaced, radially arranged passages 73 extending through the bearing housing 55. An intermediate bearing 74 is mounted in the intermediate bearing aperture 72. Passages 73 are configured to restrict fluid flow so that bearing housing 55 divides the interior cavity 17 into an upstream, first chamber 75 and a downstream, second chamber 76. In the illustrated embodiment the passages 73 extend upwardly, inwardly and helically, so that the passages 73 initiate vortex generation in the production fluid as the production fluid flows into the second chamber 76.

[0026] By way of example, and not as a limitation, the bearing housing 55 can be a bearing housing that would normally be used to stabilize a long shaft in a well pump. Such bearing housings are available in different capacities to compliment the capacity of the well pump. The bearing housing 55 has a selected capacity that is less than the capacity of the first and second stages 51 and 52, to provide pressure build-up in the first chamber 75, to limit fluid flow into the second chamber 76, and to generate a pressure drop in fluid entering the second chamber 76. Referring back to FIG. 2, the first and second third sleeves 53 and 56 are each relatively thin walled hollow cylinders. The first sleeve 53 spaces the bearing housing 55 from the pump 50. The second sleeve 56 spaces the bearing housing 55 from the head 16.

[0027] An elongated cylindrical shaft 78 extends through the interior cavity 17 with a splined lower end 79 extending into the lower cavity 32 of the base 15 and a spaced, splined upper end 80 extending into the upper cavity 40 of the head 16. Lower, intermediate and upper bearing journals 81, 82 and 83 are sized and spaced along the shaft 78 to fit the lower, intermediate and upper bearings 30, 74 and 45, respectively. A keyway 84 extends longitudinally along shaft 78 with a key 85 mounted therein. The impellers 60 mount on the shaft 78 with the hub 69 secured on shaft 78 by key 85. A vortex generator 87 is shown in FIG. 2 as a paddle assembly 88 positioned in the second chamber 76 and having a hub 89 on shaft 78 secured by key 85 and a plurality of spaced vertical paddles 90 that extend radially from the hub 89. Other styles of vortex generator, such as spiral or propeller, are also suitable. The second chamber 76 is elongated, and the vortex generator 87 is positioned near the bearing housing 55 and spaced from the head 16 to allow more time for gas to separate from the liquid in the production fluid.

[0028] Referring to FIG. 7, the second separation section 12 includes a housing 92, a base 93, and a head 94. The housing 92 and the head 94 are the same shape and configuration as the housing 14 and the head 16 of the first separation section 11, with the housing 92 defining an interior cavity 95. The housing 92 has spaced, internally threaded lower and upper ends 96 and 97. The head 94 has an upper bearing 98.

[0029] The base 93 has an upper portion 99, an intermediate portion 100 and a lower portion 101. The upper portion 99 is an externally threaded, hollow, cylinder sized and shaped to thread into the lower end 96 of housing 92, and includes an upwardly opening, centered, generally cylindrical upper cavity 103. The intermediate portion 100 has an exterior surface 104 that, in the illustrated embodiment, extends downwardly and inwardly from the upper portion 99 and has a centered lower bearing aperture 105 extending downward from the upper cavity 103. A lower bearing 106 is mounted in the lower bearing aperture 105. The lower portion 101 is hollow and generally cylindrical, and extends downward from the intermediate portion 100 to an outwardly projecting flange 107, with a lower cavity 108 extending from the lower bearing aperture 105. A plurality of circumferentially arranged inlet ports 109 extend from the lower cavity 108 upwardly into the upper cavity 103.
The second separation section 12 includes an internal pump 112 with first and second pumping stages 113 and 114, a first sleeve 115, a means for restricting flow 116, and a second sleeve 118, with each having a cylindrical exterior sized and shaped to fit into the interior cavity 95 of the housing 92, and with each being assembled into the interior cavity 95 in the above listed order from the base 93 to the head 94. In the illustrated embodiment the means for restricting fluid flow 116 is a bearing housing 117. Other means for restricting fluid flow 116 are suitable for the present invention.

The first and second pumping stages 113 and 114 are the same in configuration as the first and second pumping stages 51 and 52 of the first separation section 11, with each having an impeller housing 120 and a diffuser 121 sized and shaped to fit into the interior cavity 95 of the housing 92, and an impeller 122. The bearing housing 117 supports an intermediate bearing 124, and divides the interior cavity 95 into an upstream, first chamber 125 and a downstream, second chamber 126.

By way of example, and not as a limitation, the bearing housing 117 can be a bearing housing that would normally be used to stabilize a long shaft in a well pump. Such bearing housings are available in different capacities to complement the capacity of the well pump. The bearing housing 117 has a selected capacity that is less than the capacity of the first and second stages 113 and 114, to provide pressure build-up in the first chamber 125, to limit fluid flow into the second chamber 126, and to generate a pressure drop in fluid entering the second chamber 126.

An elongated cylindrical shaft 128 extends through the interior cavity 95 with a splined lower end 129 extending into the lower cavity 108 of the base 93 and a spaced, splined upper end 130 extending through the head 94. Lower, intermediate and upper bearing journals 132, 133 and 134 are sized and spaced along the shaft 128 to fit the lower, intermediate and upper bearings 106, 124 and 98, respectively. A keyway 135 extends longitudinally along shaft 128 with a key 136 inserted therein. The impellers 122 mount on the shaft 128. A vortex generator 139 is shown as a paddle assembly 140 positioned in the second chamber 126 and having a hub 141 on shaft 128 secured by key 136 and a plurality of spaced vertical paddles 142 that extend radially from the hub 141. Other styles of vortex generator, such as spiral or propeller, are also suitable. The second chamber 126 is elongated, and the vortex generator 139 is positioned near the bearing housing 117 and spaced from the head 94 to allow more time for gas to separate from the liquid in the production fluid.

A coupler 143 connects the upper end 80 of the shaft 78 of the first separation section 11 to the lower end 129 of the shaft 128 of the second separation section 12. As shown in FIG. 1, the studs 38 on the head 16 of the first separation section 11 connect to the flange 107 on the base 93 of the second separation section 12 to connect the first separation section 11 to the second separation section 12. In a typical installation of the separator 10 mounts between a motor on the base 15 of the first separation section 11 and a well pump secured to the head 94 of the second separation section 12. The impeller 60 of the first pumping stage 51 of the first separation section 11 pulls production fluid in through the inlet ports 29 and increases the velocity of the production fluid. The diffuser 59 of the first pumping stage 51 of the first separation section 11 converts the increased velocity into pressure. The impeller 60 of the second pumping stage 52 of the first separation section 11 pulls the pressurized production fluid from the first pumping stage 51 and increases the velocity of the production fluid. The diffuser 59 of the second pumping stage 52 of the first separation section 11 converts the increased velocity of the pressurized production fluid into additional pressure, forcing the production fluid into the first chamber 75 of the first separation section 11.

The passages 73 in the bearing housing 55 limit the flow of production fluid through the bearing housing 55 between the first and second chambers 75 and 76, and thereby generate a pressure drop and rapid expansion of the production fluid entering the second chamber 76. The rapid expansion of the production fluid causes gas in the production fluid to expand and separate from liquid in the production fluid. From the bearing housing 55 the liquid and gas travel upward to the vortex generator 87. The paddles 90 push the liquid and gas in a circular direction and thereby centrifugally segregate the liquid at the outside and the gas at the inside of the second chamber 76. The liquid passes upwardly to the liquid outlet ports 47 and into the inlet ports 109 in the base 93 of the second separation section 12. Gas passes upwardly to the gas outlet ports 48 and out of the first separation section 11 at the channel 39 into the well annulus.

The second separation section 12 separates any gas remaining in the production fluid by the same process, and the production fluid flows from the second separation section 12 into the well pump. The capacity of the separator 10 is selected based on the required pumping rate and the gas content of the production fluid. The capacity of the separator 10 is determined by the capacity of the first and second separation sections 11 and 12. The capacity of each of the first and second separation stages 11 and 12 is determined by the size and number of pumping stages and the restriction of the bearing housing.

Although two pumping stages are shown for each of the first and second separation stages 11 and 12, additional pumping stages can be added. Two or more pumping stages provide higher pressures and more effective separation. The capacity of each of the first and second separation stages 11 and 12 is selected separately. The first separation section 11 separates a portion of the gas in the production fluid and vents this gas to the well annulus, and therefore the mass of the production fluid that flows into the second separation section 12 is less than the mass of the production fluid that enters the first separation section 11. The capacity of the first separation section 11 is selected to be greater than the capacity of the second separation section 12.

The capacity of the first separation section 11 will generally be selected to be greater than the capacity of the second separation section 12 by selecting a bearing housing 55 for the first separation section 11 with a capacity that is greater than the capacity of the bearing housing 117 of the second separation section 12. The number and capacity of the pumping stages in each separation section is selected to build up pressure in the first chamber. The capacity of the bearing housing in each separation section is selected to limit the fluid flow into the second chamber to be not greater than the fluid flow out of the second chamber to assure that the second chamber will not overfill with fluid, and that a pressure drop will be generated. The fluid flow out of the second chamber is the gas exiting through the gas outlet ports and the fluid being pulled out of the second chamber through the liquid outlet ports by the next downstream pump, whether that pump is in the next separation section or that pump is the well pump.
As an example, in a well pumping 1500 BPD where the production fluid is generally a mixture of water and gas, the first and second pumping stages would each have a 6000 BPD capacity, the bearing housing for the first separation section would have a capacity of 2500 BPD and the bearing housing for the second separation section would have a capacity of 1000 BPD. As an example, in a well pumping 1500 BPD where the production fluid is generally a mixture of oil and gas, the first and second separation sections would each include five pumping stages with a capacity of 6000 BPD each, the bearing housing for the first separation section would have a capacity of 3000 BPD and the bearing housing for the second separation section would have a capacity of 1500 BPD.

More than two separation sections can be used in the separator. As an alternative structure for connecting the first and second separation stages and chambers, the upper portion of the head of the first separation section can be externally threaded, the studs on the head to the first separation section and the base of the second separation section can be eliminated, and the upper portion of the head of the first separation section can thread directly into the lower end of the housing of the second separation section.

A method of separating gas and liquid from production fluid in a well, embodying features of the present invention, includes providing connected first and second separation sections each having a first and second chamber, pumping production fluid into the first chamber of the first separation section, limiting flow of production fluid into the second chamber of the first separation section, generating a pressure drop in the production fluid as the fluid passes between the first and second chamber of the first separation section, generating a vortex in the second chamber of the first separation section, pumping production fluid from the second chamber of the first separation section into the first chamber of the second separation section, limiting flow of production fluid into the second chamber of the second separation section, generating a pressure drop in the production fluid as the fluid passes between the first and second chamber of the second separation section, and generating a vortex in the second chamber of the second separation section. More particularly, the first step of the method includes providing, for each of the first and second separation sections, a plurality of pumping stages, connected first and second chambers, a bearing housing between the first and second chambers, a rotary paddle in the second chamber, and gas outlet ports and liquid outlet ports connected to the second chamber, with the bearing housing having a plurality of restrictive passages extending helically between the first and second chambers. The next step includes pumping the production fluid into the first chamber of the first separation section. The next step includes limiting fluid flow of the production fluid into the second chamber of the first separation section. The next step includes passing the production fluid through the passages in the first separation section to generate a pressure drop in the production fluid as the production fluid flows into the second chamber to separate the gas and the liquid. Passing the production fluid through the passages also imparts a helical flow to the production fluid and thereby initiates generation of a vortex. The next step includes rotating the paddle to continue vortex generation to further separate the gas and the liquid. The gas is then diverted out of the second chamber through the gas outlet ports, and the liquid is diverted out of the second chamber through the liquid outlet ports into the second separation section. The steps of the first separation section are repeated in the second separation section.

FIG. 8 shows the first separation section with an alternative internal pump and an alternative vortex generator. The internal pump is an inducer having an elongated, cylindrical hub and a pair of opposed blades that project radially from the hub in a helical around the hub. The hub is mounted on shaft and secured on shaft by key, so that the inducer rotates with shaft. The length of the inducer, the number of blades and the angle of the blades can vary. The vortex generator includes a pair of spaced paddle assemblies, each having a hub on shaft and secured by key, and a plurality of spaced vertical paddles that extend radially from the hub.

FIG. 9 shows the second separation section with an alternative internal pump and an alternative vortex generator. The internal pump is an inducer having an elongated, cylindrical hub and a pair of opposed blades that project radially from the hub in a helical around the hub. The hub is mounted on shaft and secured on shaft by key, so that the inducer rotates with shaft. The length of the inducer, the number of blades and the angle of the blades can vary. The vortex generator includes a pair of spaced paddle assemblies, each having a hub on shaft and secured by key, and a plurality of spaced vertical paddles that extend radially from the hub.

The inducer in the first separation section pumps production fluid through the first chamber to the bearing housing. The bearing housing restricts the fluid flow into the second chamber, so that as the fluid enters the second chamber the pressure on the gas is released, allowing the gas bubbles to expand and separate from the liquid. The paddles push the liquid and gas in a circular direction and thereby centrifugally segregate the liquid at the outside and the gas at the inside of the second chamber. The liquid passes upwardly to the liquid outlet ports and into the inlet ports in the base of the second separation section. Gas passes upwardly to the gas outlet ports and out of the first separation section at the channel along the well annulus.

The second separation section separates any gas remaining in the production fluid by the same process, and the production fluid flows from the second separation section into the well pump. The capacity of the first separation section is controlled by the capacity of the bearing housing, and the capacity of the second separation section is controlled by the capacity of the bearing housing. The capacity of the bearing housing of the first separation section restricts the fluid flow rate from the first chamber to the second chamber to a selected first flow rate. The capacity of the bearing housing of the second separation section restricts the fluid flow rate from the first chamber to the second chamber to a selected second flow rate.

The well pump is connected downstream of the second separation section, pulling fluid out of the second chamber through the head and pumping the fluid to the surface. The capacity of the bearing housing of the second separation section is selected to maintain a reduced pressure in the second chamber. If the capacity of the bearing housing is too large, the second chamber will fill up and the pressure will increase, inhibiting separation of
the gas from the liquid. If the capacity of the bearing housing 117 is too small, the well pump will pull separated gas as well as liquid from the second chamber 126. The capacity of the bearing housing 55 of the first separation section 11 is selected in a similar manner, to maintain a reduced pressure in the second chamber 76.

[0047] The first separation section 11 processes all of the production fluid that is pulled into the separator 10. The production fluid processed by the second separation section 12 equals the production fluid processed by the first separation section 11 minus the gas separated by the first separation section 11. Therefore the first flow rate needs to be greater than the second flow rate, and the capacity of the first separation section 11 is selected to be greater than the capacity of the second separation section 12. The capacity of the second separation section 12 is reduced relative to the first separation section 11 by selecting a bearing housing 117 for the second separation section 12 with a capacity that is smaller than the capacity of the bearing housing 55 of the first separation section 11. Modification of the housing sizes, housing inner diameters or the internal pumps is not required to provide reduced capacity in the second separation section 12 relative to the first separation section 11.

[0048] A method of separating gas and liquid from production fluid in a well, embodying features of the present invention, includes the steps of providing a first separation section with connected first and second chambers, pumping the production fluid into the first chamber of the first separation section, restricting flow of the production fluid from the first chamber into the second chamber of the first separation section to a selected first flow rate, generating a vortex in the second chamber of the first separation section to further separate the gas and the liquid, providing a second separation section connected to the first separation section and having connected first and second chambers, pumping the production fluid from the second chamber of the first separation section into the first chamber of the second separation section, restricting flow of the production fluid from the first chamber into the second chamber of the second separation section to a selected second flow rate that is less than the first flow rate, and generating a vortex in the second chamber of the second separation section, to further separate the gas and the liquid.

[0049] The step of restricting flow of the production fluid into the second chamber of the first separation section can also include the steps of providing a bearing housing between the first and second chambers with the bearing housing having a plurality of restrictive passages extending between the first and second chambers, and passing the production fluid through the passages. The step of restricting flow of the production fluid into the second chamber of the second separation section can also include the steps of providing a bearing housing between the first and second chambers with the bearing housing having a plurality of restrictive passages extending between the first and second chambers, and passing the production fluid through the passages. The bearing housing in the first separation section has a selected capacity and the bearing housing in the second separation section has a selected capacity that is less than the capacity of the bearing housing in the first separation section. The step of generating a vortex in the second chamber of the first separation section can include the steps of providing a pair of spaced paddle assemblies and rotating the paddle assemblies. The step of generating a vortex in the second chamber of the second separation section can include the steps of providing a pair of spaced paddle assemblies and rotating the paddle assemblies.

[0050] Although the present invention has been described with a certain degree of particularity, it is understood that the present disclosure has been made by way of example and that changes in details of structure may be made without departing from the spirit thereof.

What is claimed is:
1. A downhole gas and liquid separator for a well comprising:
an upstream, first separation section and a downstream, second separation section in flow communication with said first separation section, said first and second separation sections each including:
first and second chambers,
an internal pump, for pumping production fluid through said first chamber, and into said second chamber, and
means, positioned a between said first and second chambers, for restricting fluid flow to release pressure on gas in said production fluid and to separate gas and liquid as said production fluid enters said second chamber, and
a vortex generator in said second chamber to centrifugally separate said fluid into gas and liquid,
wherein said means for restricting fluid flow of said first separation section has a selected capacity and said means for restricting fluid flow of said second separation section has a selected capacity that is smaller than said capacity of said means for restricting fluid flow of said first separation section,
whereby said first separation section separates a first portion of gas from said production fluid and said second separation section separates a remaining portion of gas from said production fluid.
2. The separator as set forth in claim 1 wherein said internal pump in at least one of said first and second separation sections includes an inducer.
3. The separator as set forth in claim 1 wherein said internal pump of in at least one of said first and second separation sections includes an impeller.
4. The separator as set forth in claim 1 wherein said first and second separation sections each include a driven rotary shaft extending through said first and second chambers.
5. The separator as set forth in claim 4 wherein said vortex generator includes a pair of spaced paddle assemblies on said shaft.
6. The separator as set forth in claim 4 wherein said means for restricting fluid flow is a bearing housing that has a bearing that stabilizes said shaft.
7. The separator as set forth in claim 6 wherein said bearing housing has a plurality diagonally extending passages between said first and second chambers that restrict fluid flow and propel said production fluid into said second chamber in a diagonal direction, and thereby initiate vortex generation.
8. The separator as set forth in claim 6 wherein said second chamber is elongated and said vortex generator is positioned near said bearing housing,
whereby said production fluid has increased time to separate before exiting said second chamber.
9. The separator as set forth in claim 1 wherein:
said first and second separation sections each include an elongated housing having a first and second end, a base and a head, said base attaching to said first end and
including inlet ports, and said head attaching to said second end and including gas and liquid outlet ports, and said inlet ports in said base of said second separation section connect to said liquid outlet ports in said head of said first separation section.

10. A downhole gas and liquid separator for a well comprising:

a first separation section having a housing with a first end and a spaced second end, a base at said first end with inlet ports and a head at said second end with gas and liquid outlet ports, said first separation section having a first chamber and a downstream second chamber, an inducer for pumping production fluid through said first chamber and into said second chamber, a bearing housing positioned between said first and second chambers that restricts fluid flow to release pressure on gas in said production fluid and to separate gas and liquid as said production fluid enters said second chamber, and a vortex generator in said second chamber to centrifugally separate said fluid into gas and liquid, said first separation section having a driven rotary shaft connecting to and rotating said inducer and said vortex generator, said bearing housing having a selected capacity, and

a second separation section having a housing with a first end and a spaced second end, a base at said first end connected to said liquid outlet ports of said first separation section and a head at said second end with gas and liquid outlet ports, said second separation section having a first chamber and a downstream second chamber, an inducer for pumping production fluid through said first chamber, and into said second chamber, a bearing housing positioned between said first and second chambers that restricts fluid flow to release pressure on gas in said production fluid and to separate gas and liquid as said production fluid enters said second chamber, and a vortex generator in said second chamber to centrifugally separate said fluid into gas and liquid, said second separation section having a driven rotary shaft connecting to and rotating said inducer and said vortex generator, said bearing housing having a selected capacity that is less than said capacity of said bearing housing in said first separation section, whereby said first separation section separates a first portion of gas from said production fluid and said second separation section separates a remaining portion of gas from said production fluid.

11. A method of separating gas and liquid from production fluid in a well comprising the steps of:

providing a first separation section with connected first and second chambers,
pumping said production fluid into said first chamber of said first separation section,
restricting flow of said production fluid from said first chamber into said second chamber of said first separation section to a selected first flow rate,
generating a vortex in said second chamber of said first separation section, to further separate said gas and said liquid,
providing a second separation section connected to said first separation section and having connected first and second chambers,
pumping said production fluid from said second chamber of said first separation section into said first chamber of said second separation section,
restricting flow of said production fluid from said first chamber into said second chamber of said second separation section to a selected second flow rate that is less than said first flow rate, and
generating a vortex in said second chamber of said second separation section, to further separate said gas and said liquid.

12. The method as set forth in claim 11 wherein:
said step of restricting flow of said production fluid into said second chamber of said first separation section includes the steps of:
providing a bearing housing between said first and second chambers with said bearing housing having a plurality of restrictive passages extending between said first and second chambers,
passing said production fluid through said passages, and
said step of restricting flow of said production fluid into said second chamber of said second separation section includes the steps of:
providing a bearing housing between said first and second chambers with said bearing housing having a plurality of restrictive passages extending between said first and second chambers, and
passing said production fluid through said passages.

13. The method as set forth in claim 12 wherein said bearing housing in said first separation section has a selected capacity and said bearing housing in said second separation section has a selected capacity that is less than said capacity of said bearing housing in said first separation section.

14. The method as set forth in claim 11 wherein:
said step of generating a vortex in said second chamber of said first separation section includes the steps of:
providing a pair of spaced paddle assemblies and rotating said paddle assemblies, and
said step of generating a vortex in said second chamber of said second separation section includes the steps of:
providing a pair of spaced paddle assemblies and rotating said paddle assemblies.