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(54) SYSTEM, METHOD AND APPARATUS FOR ELECTRICAL SUBMERSIBLE PUMP WITH INTEGRATED GAS SEPARATOR

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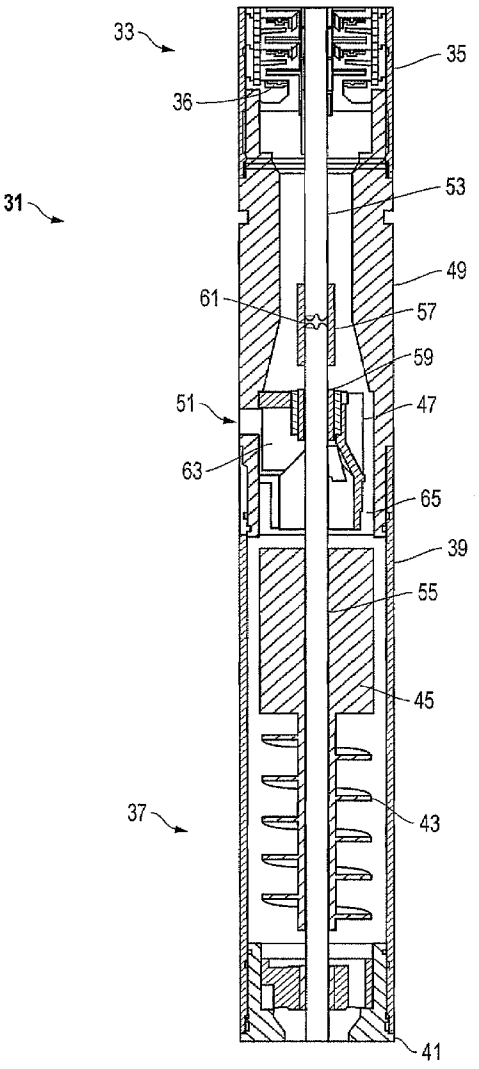
(57) **ABSTRACT**

A combined gas separator and pump in an electrical submersible pump assembly is disclosed. An integral discharge connector threadingly couples the gas separator and pump. The connector contains discharge ports for the discharge of the separated gas. The pump shaft and gas separator shaft are also coupled. Alternatively, a single pump shaft extends from the pump into the gas separator. In another alternative, the gas separator is completely integrated into the pump housing. The pump is modified by removing the intake of the pump and a sufficient number of pump stages to accommodate the gas separator components. A diverter tube is located in the pump housing and the pump housing is modified to include gas exit ports. All of the gas separator components are located in the modified pump housing, and the original pump intake is reattached at its original location.



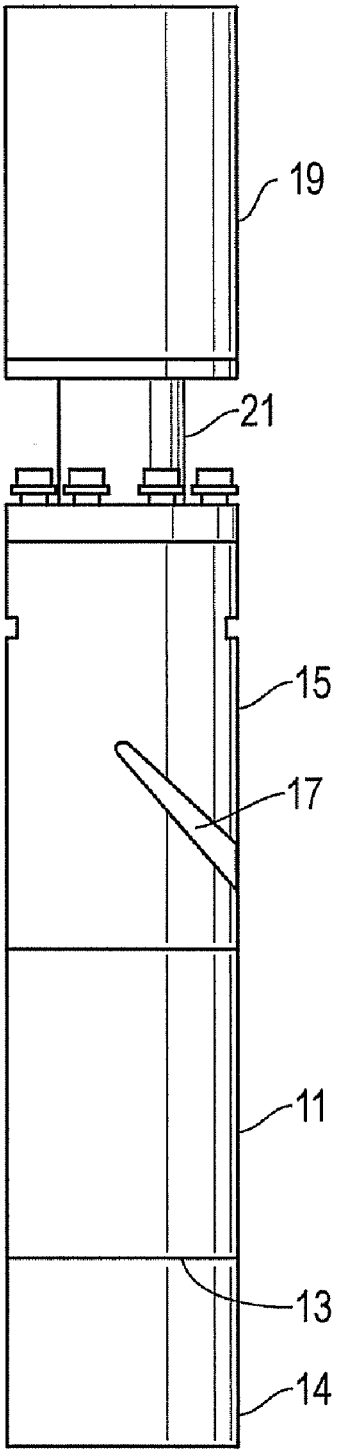


FIG. 1
(Prior Art)

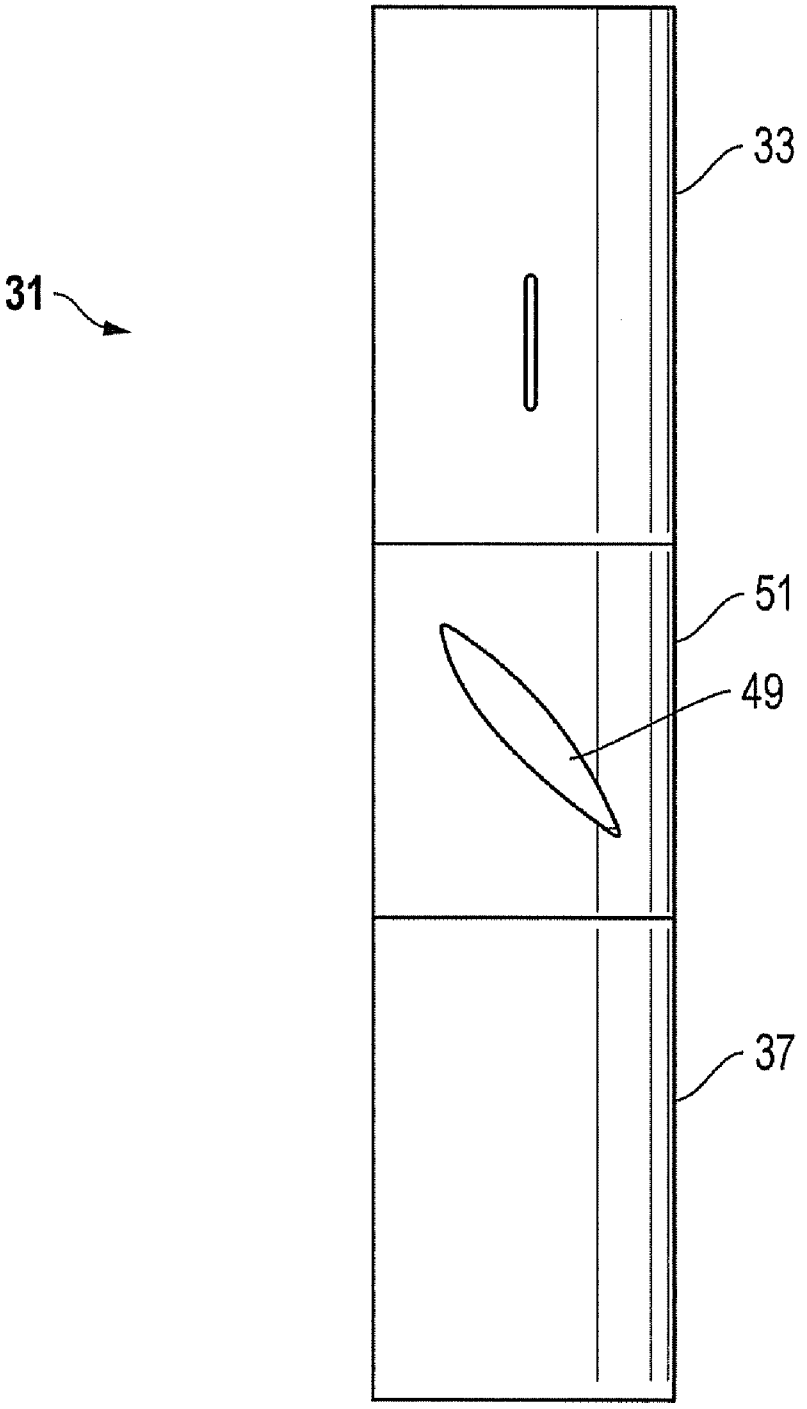


FIG. 2

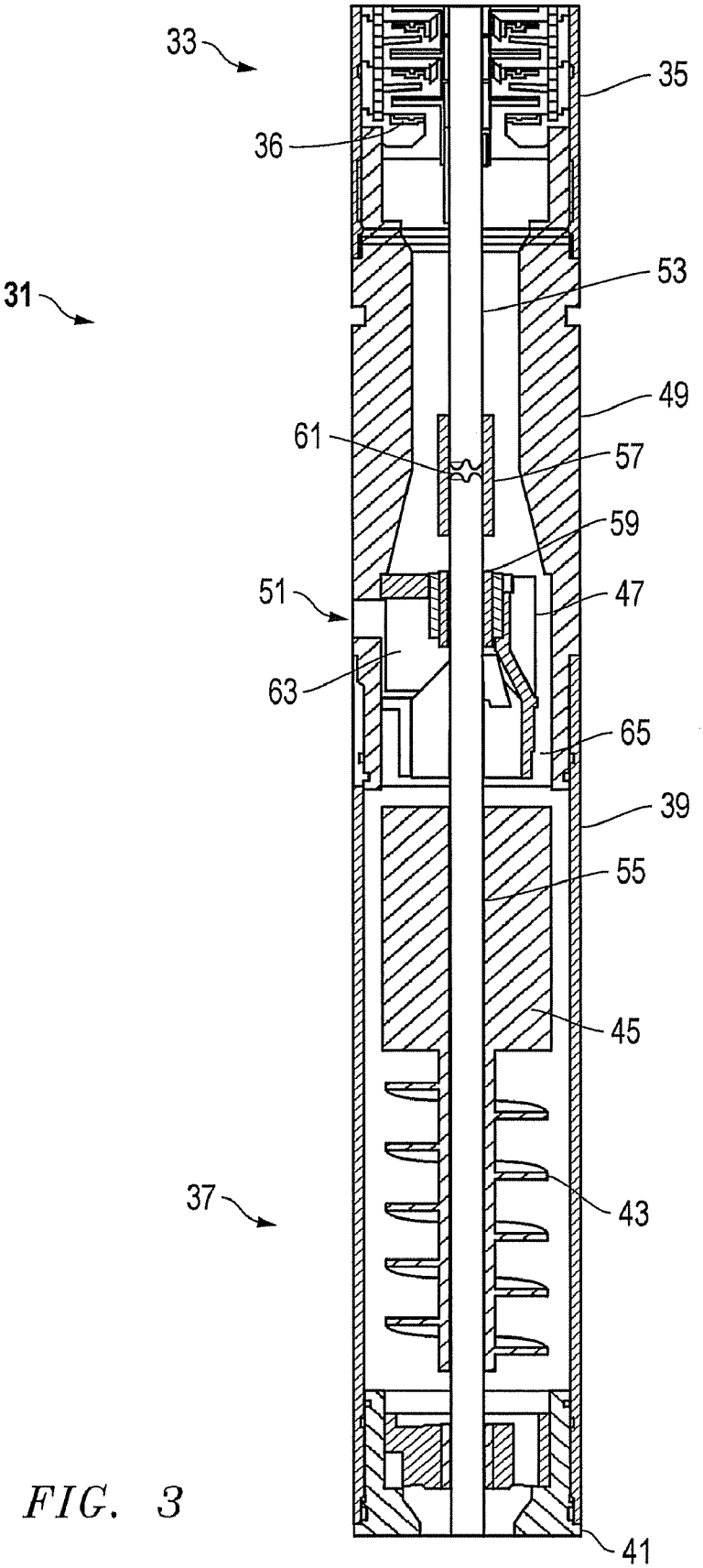


FIG. 3

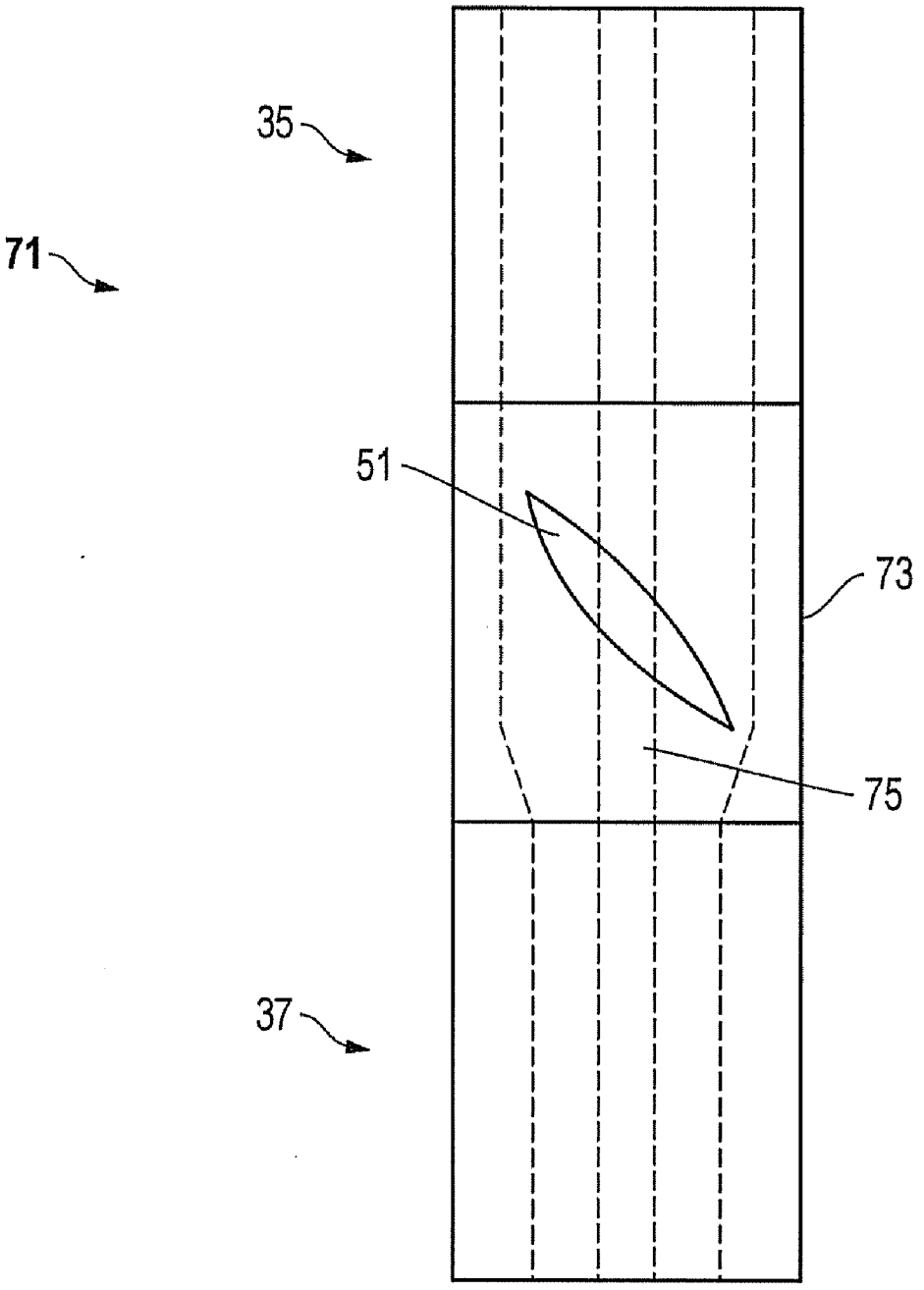


FIG. 4

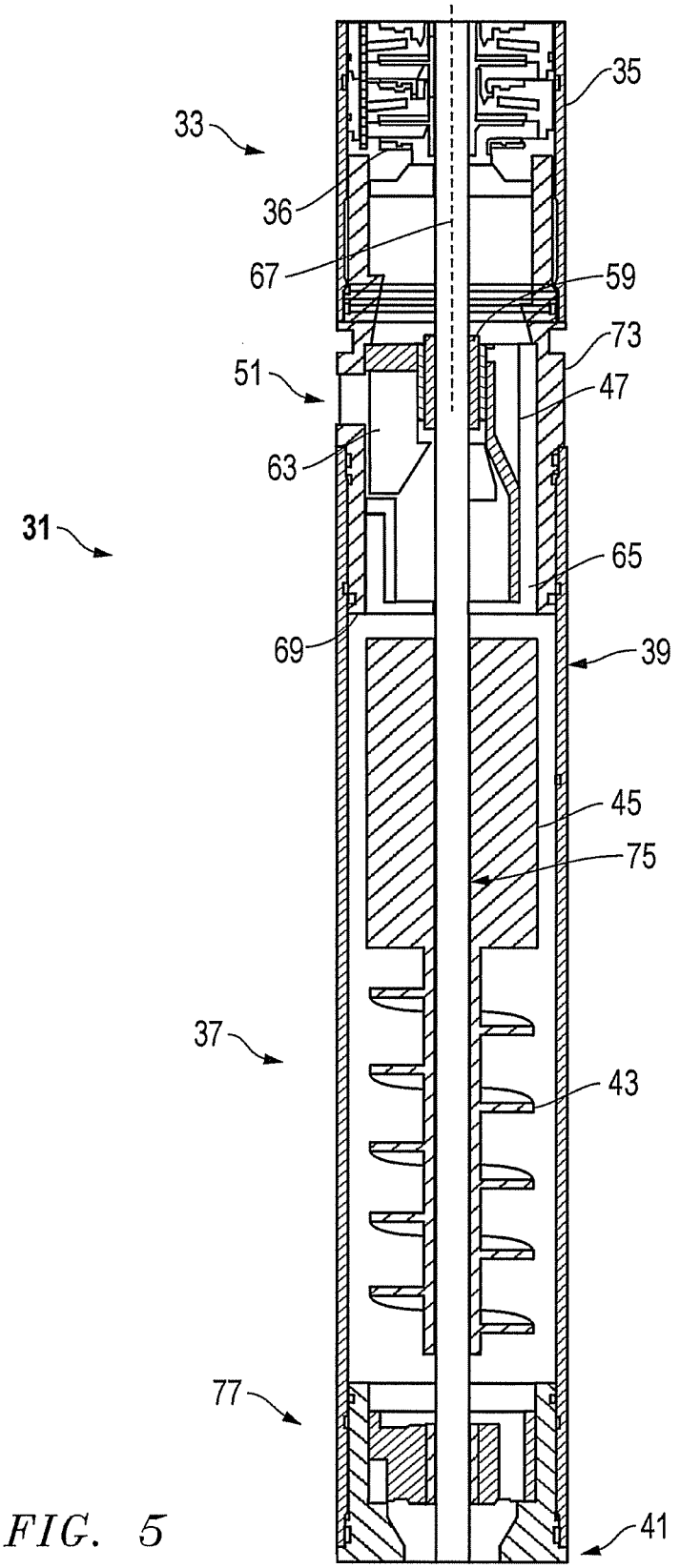


FIG. 5

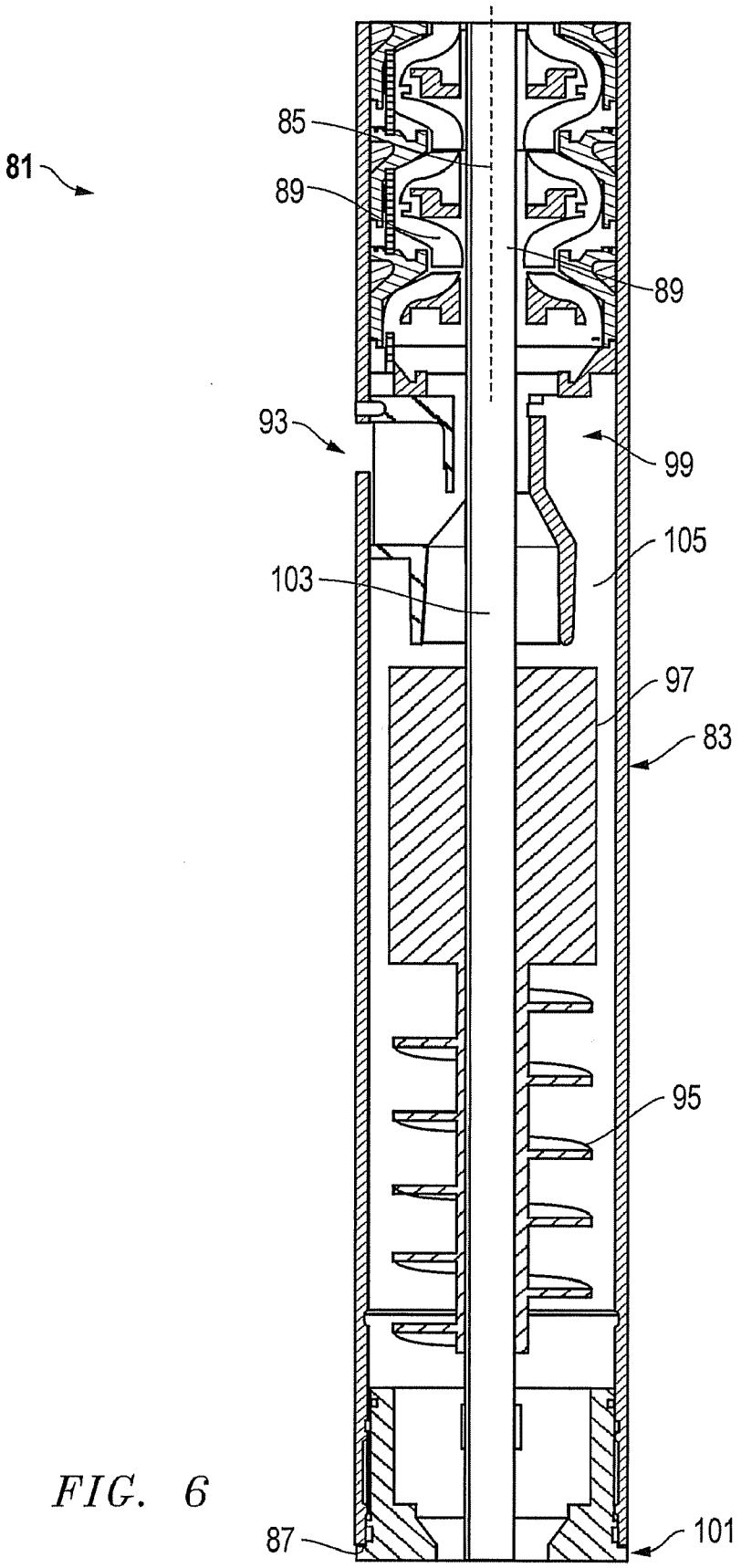


FIG. 6

SYSTEM, METHOD AND APPARATUS FOR ELECTRICAL SUBMERSIBLE PUMP WITH INTEGRATED GAS SEPARATOR

BACKGROUND OF THE INVENTION

[0001] 1. Technical Field

[0002] The present invention relates in general to gas separators for electrical submersible pumps and, in particular, to an improved system, method, and apparatus for integrating a gas separator into an electrical submersible pump assembly.

[0003] 2. Description of the Related Art

[0004] A gas separator is used for separating the mixture of gas and liquid at the intake of a pump at the bottom of a well. Currently, gas separators are constructed in a separate housing that bolts to the bottom of the pump. The gas separator also acts as a fluid intake for the pump after the gas has been separated from the liquid stream.

[0005] For example, as shown in FIG. **1**, a typical gas separator **11** includes an intake **13** at its base (just above seal and motor **14**) where all fluid and gas flows into the pump system. It also includes an integral discharge head **15** that has exhaust ports **17** to exhaust the gas out of the system. The gas separator further includes a flow path for the remaining fluid to be directed into the base of the pump **19**. When installed, the gas separator attaches to the pump via a flanged, bolted connection **21**.

SUMMARY OF THE INVENTION

[0006] Embodiments of a system, method, and apparatus for combining a centrifugal gas separator with a pump in an electrical submersible pump (ESP) assembly are disclosed. The invention uses an integral discharge connector to complete the assembly between the gas separator and pump. The base of the pump and discharge head of the gas separator are replaced with a connector that threads into the housing of the pump on one end and into the housing of the gas separator on the other end. The connector contains discharge ports for the discharge of the separated gas. The standard pump shaft is coupled to the standard gas separator shaft using a conventional coupling. The connector contains a bearing for shaft stabilization.

[0007] In one type of alternate embodiment, a single, longer pump shaft extends from the pump and is used by both the pump and the gas separator. This design eliminates the need for a stub shaft in the gas separator, and eliminates the shaft coupling.

[0008] In another alternate embodiment the gas separator is integrated into the pump housing. A conventional pump for an ESP assembly is converted to have an integral gas separator that requires little modification to the original pump. The pump is retrofitted to allow room for the gas separator internal parts. The pump is modified by removing the intale of the pump, and removing a sufficient number of pump stages to accommodate the gas separator components. A diverter tube is located in the pump housing and holes are drilled in the pump housing for retention pins to prevent rotation of the diverter tube. The pump housing also is modified to include gas exit ports. All of the gas separator components are located in the modified pump housing, and the original pump intake is attached at its original location. This design integrates the gas separator into the housing of the pump, eliminates all connections therebetween, and allows use of a single housing and shaft.

[0009] Advantages of this invention over current technology include the elimination of bolted connections, shorter installation lengths, reduced weight, fewer necessary components, and a reduction in overall product cost.

[0010] The foregoing and other objects and advantages of the present invention will be apparent to those skilled in the art, in view of the following detailed description of the present invention, taken in conjunction with the appended claims and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] So that the manner in which the features and advantages of the present invention are attained and can be understood in more detail, a more particular description of the invention briefly summarized above may be had by reference to the embodiments thereof that are illustrated in the appended drawings. However, the drawings illustrate only some embodiments of the invention and therefore are not to be considered limiting of its scope as the invention may admit to other equally effective embodiments.

[0012] FIG. **1** is a side view of a conventional electrical submersible pump (ESP);

[0013] FIG. **2** is a side view of one embodiment of an integrated gas separator and ESP constructed in accordance with the invention;

[0014] FIG. **3** is a sectional side view of the ESP of FIG. **2** and is constructed in accordance with the invention;

[0015] FIG. **4** is a side view of another embodiment of an integrated gas separator and ESP constructed in accordance with the invention;

[0016] FIG. **5** is a sectional side view of the ESP of FIG. **4** and is constructed in accordance with the invention; and

[0017] FIG. **6** is a sectional side view of third embodiment of an integrated gas separator and ESP constructed in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0018] Referring to FIGS. **2-6**, embodiments of a system, method and apparatus for combining a centrifugal gas separator with a pump in an electrical submersible pump (ESP) assembly are disclosed.

[0019] As shown in FIGS. **2** and **3**, one embodiment of the invention comprises an ESP assembly **31** having a pump **33** having a pump housing **35**. The ESP assembly **31** also includes a centrifugal gas separator **37** having a gas separator housing **39** that, in one embodiment, includes an intake **41**, an auger **43**, a rotor **45** and a diverter **47**. The auger and rotor may be formed as separate components or as a contiguous component. The gas separator also may comprise other types, such as a vortex type having a guide vane. A discharge connector **49** extends between and is threadingly coupled (i.e., rather than bolted) on both ends to the pump housing **35** and the gas separator housing **39**. The discharge connector **49** has a plurality of discharge ports **51** coupled to the diverter **47** for discharging gas separated by the centrifugal gas separator **37**.

[0020] The pump **33** has a pump shaft **53**, the centrifugal gas separator **37** has a gas separator shaft **55**, and the pump shaft **53** is secured to the gas separator shaft **55** with a coupling **57**. The coupling **57** may be located within the discharge connector **49** downstream from the diverter **47**. The discharge connector **49** may contain a bearing **59** for stabilization of the pump shaft **53**, the coupling **57** and the gas separator shaft **55**.

[0021] In the embodiment shown, a downstream end **61** of the gas separator shaft **55** is located in the discharge connector **49**. The diverter **47** has an inner diameter gas passage **63** in communication with the discharge ports **51** in the discharge connector **49**. In addition, an outer diameter liquid passage **65** is located between an outer portion of the diverter **47** and an inner portion of the discharge connector **49**. The diverter **47** may be located completely within an axial length of the discharge connector **49**.

[0022] Another type of ESP assembly **71** is shown in the embodiment of FIGS. **4** and **5**. The pump housing **35** has an axis **67** and an upstream end **69**. A single, longer pump shaft **75** extends in the axial direction beyond the upstream end **69**. The shaft **75** extends through an axially shorter discharge connector **73** and the centrifugal gas separator **37** to a seal section and/or motor **77** depending on the application. In this way the single pump shaft **75** operates the pump **33** and the centrifugal gas separator **37** via motor **77**.

[0023] The centrifugal or rotary gas separator **37** provides active separation of the gas from the liquid. The fluid intake **41** is at the bottom of the separator **37**. In one configuration, fluid is pushed up by the auger **43**, separated by the rotor **45** and moved toward the pump **33**. The separator **37** spins the heavier fluid to the outer diameter region **65** of the separator housing **39**. The lighter fluid (e.g., gas) is conveyed through the inner diameter region **63** near the shaft **55**, **75**. The lighter fluid is then diverted by the diverter **47** out of the discharge ports **51** in the connector **49** that are located upstream from the first pump stage **36**.

[0024] Referring now to FIG. **6**, another embodiment of an electrical submersible pump assembly **81** is shown. Assembly **81** is similar to the preceding embodiments, but incorporates all working components and features of both the pump and the separator into a single continuous pump housing **83**. The pump housing **83** has an axis **85**, an upstream end **87**, a pump shaft **89** that extends in an axial direction, a plurality of pump stages **91**, and a plurality of discharge ports **93** formed through a wall of the pump housing **83**.

[0025] Thus, the centrifugal gas separator is located completely inside an axial length of the pump housing **83**. The components of the separator may include an auger **95** and rotor **97** which are attached or otherwise coupled to the pump shaft **89** for rotation therewith. The pump intake **101** is located adjacent the upstream end **87** of the pump housing **83** upstream from the auger **95** and the rotor **97**.

[0026] A diverter **99** is located between the rotor **97** and the pump stages **89**. The diverter **99** is attached to the discharge ports **93** for discharging gas separated by the centrifugal gas separator through the wall of the pump housing **83**. The diverter **99** has an inner diameter gas passage **103** in communication with the discharge ports **93**. An outer diameter liquid passage **105** is located between an outer portion of the diverter **99** and an inner portion of the pump housing **83**.

[0027] The diverter **99** may be mounted to the pump housing **83** (e.g., via pins inserted through holes formed in the pump housing **83**) to prevent rotation of the diverter **99** relative to the pump housing **83**. The pump shaft **89** extends out of the pump housing **83** beyond the upstream end **87** of the pump housing **83**.

[0028] One embodiment of the invention also comprises a method of integrating a centrifugal gas separator and a pump. The method may comprise providing an electrical submersible pump (ESP) assembly having a pump with a pump housing, a pump shaft, a plurality of pump stages, and a pump intake; removing the pump intake from the pump housing; removing at least one of the pump stages from the pump housing to accommodate components of a centrifugal gas separator; installing the centrifugal gas separator in the pump housing; forming gas discharge ports in a wall of the pump housing in communication with a gas discharge from the centrifugal gas separator; and reinstalling the pump intake on the pump housing such that the centrifugal gas separator is located completely inside an axial length of the pump housing.

[0029] The pump intake may be defined at an original location for the pump intake on the pump housing, and then later securing the pump intake in the original location. The separator components may comprise a diverter, a rotor and an auger on the pump shaft, and then coupling the gas discharge ports in the wall of the pump housing with an inner diameter gas passage in the diverter.

[0030] In other embodiments, the diverter may be mounted to the pump housing to prevent rotation of the diverter relative to the pump housing, and the pump shaft may extend out of the pump housing beyond the upstream end of the pump housing. The diverter may be provided with an inner diameter gas passage in communication with the discharge ports, and an outer diameter liquid passage located between an outer portion of the diverter and an inner portion of the pump housing.

[0031] While the invention has been shown or described in only some of its forms, it should be apparent to those skilled in the art that it is not so limited, but is susceptible to various changes without departing from the scope of the invention.

What is claimed is:

1. An electrical submersible pump (ESP) assembly, comprising:

a pump having a pump housing;

a centrifugal gas separator having a gas separator housing with an intake and a diverter; and

a discharge connector extending between and threadingly coupled to the pump housing and the gas separator housing, the discharge connector having a plurality of discharge ports coupled to the diverter for discharging gas separated by the centrifugal gas separator.

2. An ESP assembly according to claim **1**, wherein the pump has a pump shaft, the centrifugal gas separator has a gas separator shaft, and the pump shaft is secured to the gas separator shaft with a coupling.

3. An ESP assembly according to claim **2**, wherein the discharge connector contains a bearing for stabilization of the pump shaft, the coupling and the gas separator shaft.

4. An ESP assembly according to claim **2**, wherein a downstream end of the gas separator shaft is located in the discharge connector, the diverter has an inner diameter gas passage in communication with the discharge ports in the discharge connector, an outer diameter liquid passage is located between an outer portion of the diverter and an inner portion of the discharge connector.

5. An ESP assembly according to claim **2**, wherein the coupling is located within the discharge connector downstream from the diverter.

6. An ESP assembly according to claim **1**, wherein the diverter is located completely within an axial length of the discharge connector.

7. An ESP assembly according to claim **1**, wherein the pump housing has an axis and an upstream end, the pump has a pump shaft that extends in an axial direction beyond the

upstream end, through the discharge connector, and into the centrifugal gas separator, such that the pump shaft operates the pump and the centrifugal gas separator.

8. An electrical submersible pump (ESP) assembly, comprising:

a pump having a pump housing with an axis, an upstream end, a pump shaft that extends in an axial direction, a plurality of pump stages, and a plurality of discharge ports formed through a wall of the pump housing;

a centrifugal gas separator located completely inside an axial length of the pump housing and having an auger and a rotor coupled to the pump shaft for rotation therewith, and a diverter located between the rotor and the pump stages, the diverter being coupled to the discharge ports for discharging gas separated by the centrifugal gas separator through the wall of the pump housing; and

a pump intake located adjacent the upstream end of the pump housing upstream from the auger and the rotor.

9. An ESP assembly according to claim **8**, wherein the diverter is mounted to the pump housing to prevent rotation of the diverter relative to the pump housing, and the pump shaft extends out of the pump housing beyond the upstream end of the pump housing.

10. An ESP assembly according to claim **8**, wherein the diverter has an inner diameter gas passage in communication with the discharge ports, an outer diameter liquid passage is located between an outer portion of the diverter and an inner portion of the pump housing.

11. A method of integrating a centrifugal gas separator and a pump, comprising:

(a) providing an electrical submersible pump (ESP) assembly having a pump with a pump housing, a pump shaft, a plurality of pump stages, and a pump intake;

(b) removing the pump intake from the pump housing;

(c) removing at least one of the pump stages from the pump housing to accommodate components of a centrifugal gas separator;

(d) installing the centrifugal gas separator in the pump housing;

(e) forming gas discharge ports in a wall of the pump housing in communication with a gas discharge from the centrifugal gas separator; and

(f) reinstalling the pump intake on the pump housing such that the centrifugal gas separator is located completely inside an axial length of the pump housing.

12. A method according to claim **11**, wherein in step (b) the pump intake defines an original location for the pump intake on the pump housing, and step (g) comprises securing the pump intake in the original location.

13. A method according to claim **11**, wherein step (d) comprises attaching a diverter, a rotor and an auger on the pump shaft, and step (e) comprises coupling the gas discharge ports in the wall of the pump housing with an inner diameter gas passage in the diverter.

14. A method according to claim **13**, wherein the diverter is mounted to the pump housing to prevent rotation of the diverter relative to the pump housing, and the pump shaft extends out of the pump housing beyond the upstream end of the pump housing.

15. A method according to claim **13**, wherein the diverter has an inner diameter gas passage in communication with the discharge ports, an outer diameter liquid passage is located between an outer portion of the diverter and an inner portion of the pump housing.

* * * * *