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(54) DOWNHOLE JET PUMP

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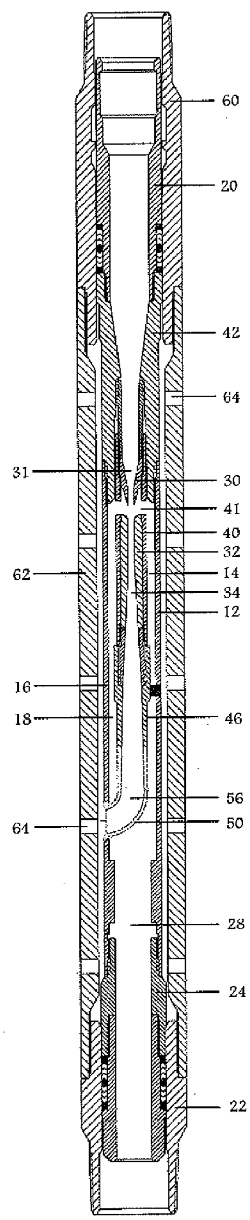
(57) **ABSTRACT**

A downhole jet pump **10** includes an exterior pump housing **12**, the jet nozzle **30**, and a carrier **40**. A diffuser **46** is provided downstream from a mixing tube **32**, and preferably forms a unitary body sealed to the pump housing. An inlet valve **100** passes formation fluid to the pump housing.



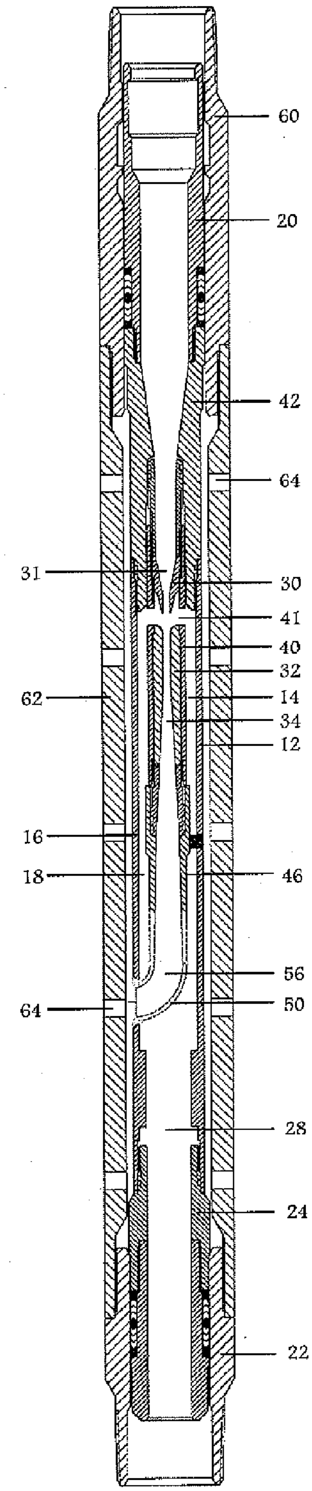

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Fig. 1

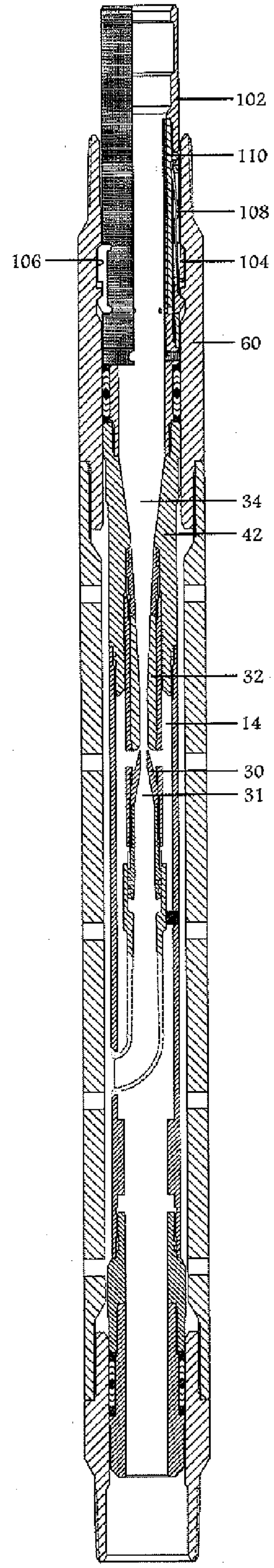
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Fig. 2

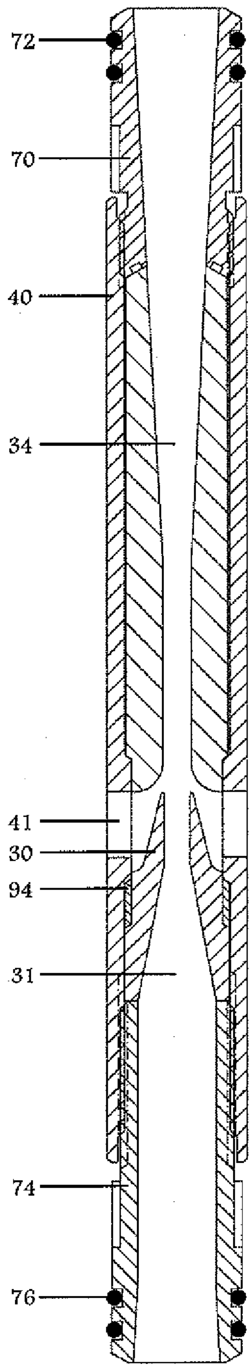

Fig. 3

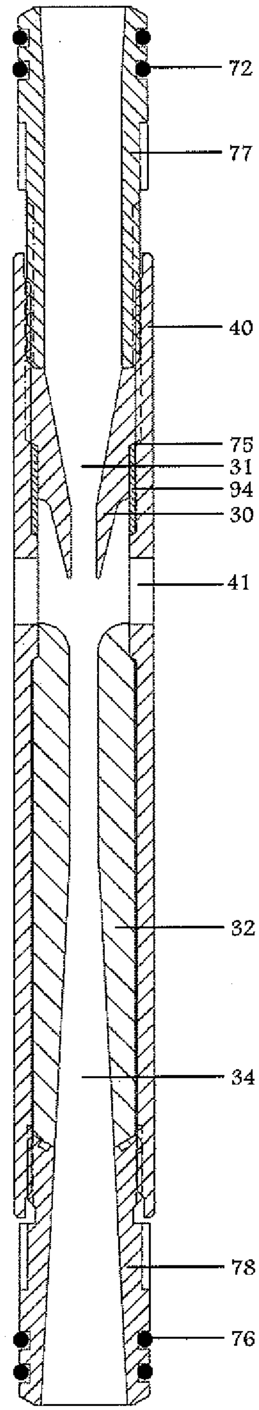

Fig. 4

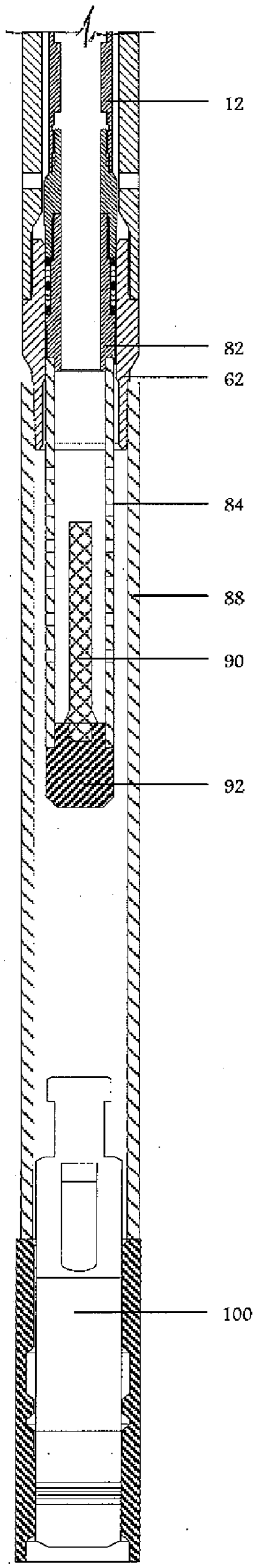

Fig. 5

DOWNHOLE JET PUMP

FIELD OF THE INVENTION

[0001] The present invention relates to jet pumps and, more particularly, to jet pumps commonly used downhole in wells to pump formation fluids or other fluids to the surface. The downhole jet pump as disclosed herein has a comparatively high efficiency and may be operated in either the direct flow or reverse flow modes.

BACKGROUND OF THE INVENTION

[0002] Jet pumps have long been used for recovering hydrocarbons from downhole formations. The potential for jet pumps is enhanced by its relatively low cost compared to artificial lift systems that use reciprocating on rotating rod strings to pump fluids to the surface.

[0003] Various problems have limited the success of jet pumps in the hydrocarbon recovery industry. Jet pumps may be operated in a direct flow mode, where the driving fluid is pumped down the tubing string and to the jet pump, and fluid is pumped by the jet pump to the surface in an annulus between the tubing string and the casing. Alternatively, jet pumps may be operating in the reverse flow mode, wherein the driving fluid is pumped down the annulus to the jet pump, and the formation fluid and driving fluid are pumped to the surface through the tubing string. While direct pump flow is more common than reverse pump flow, the ability to pump in either direction is desired by many operators, and the costs of the jet pumps for accomplishing these goals is unfortunately increased by the large number of different parts conventionally used to maintain both direct flow jet pumps and reverse flow jet pumps.

[0004] Other problems with jet pumps relate to their relatively low efficiency compared to other artificial lift systems for returning hydrocarbons to the surface, the additional costs associated with retrieving pressure or temperature sensors to the surface after the jet pump is retrieved, and techniques which allow adjustment of the axial spacing between the nozzle and the mixing tube which receives fluid from the nozzle.

[0005] Prior art patents directed to jet pumps include U.S. Pat. Nos. 4,858,893, 5,083,609, 5,055,022, and 7,909,089. Another jet pump is disclosed in a Volcanica website under www.youtube.com/watch?v=nDYFpBUBwic. Some of these patents discuss reverse flow to pump a component to the surface, but the pump is not operating as a jet pump during this component retrieval operation.

[0006] The disadvantages of the prior art are overcome by the present invention, and an improved downhole jet pump is hereinafter disclosed.

SUMMARY OF THE INVENTION

[0007] In one embodiment, a downhole jet pump is provided for positioning in a well on a tubular string to pump formation fluids from the well. The jet pump includes an exterior pump housing defining an elongate passageway therein. A jet nozzle has an exterior sealed to the pump housing and increases the fluid velocity of the power fluid transmitted downhole to the jet nozzle. A mixing tube positioned downstream from the jet nozzle has an elongate mixing tube passageway for receiving fluid from the jet nozzle and fluid from the formation. In one embodiment, a diffuser is provided downstream from the jet nozzle and has a lower end passing through a side port in the pump housing.

[0008] These and further features and advantages of the present invention will become apparent from the following detailed description, wherein reference is made to the figures in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a cross-sectional view of one embodiment of a downhole jet pump according to the present invention.

[0010] FIG. **2** is a cross-sectional view of a downhole jet pump similar to that shown in FIG. **1**, with the nozzle and mixing tube reversed for flow to the surface through a tubing string.

[0011] FIG. **3** is a detailed view of pump components configured for a reverse flow.

[0012] FIG. **4** is a detailed view of pump components configured for direct flow.

[0013] FIG. **5** illustrates temperature and/or pressure probe connected to the jet pump, with a standing valve positioned below the probe.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0014] FIG. **1** depicts one embodiment of a downhole jet pump **10** for positioning within a well from a tubular string to pump formation fluid from the well to an annulus surrounding, the tubing string, and then from that annulus up to the surface. Those skilled in the art will appreciate that a downhole jet pump may be used for pumping liquid hydrocarbons from a well, but may also be used for pumping other fluids, such as water, to enhance the production of gas or other valuable fluids. The jet pump is adapted for receiving power fluid from a tubular, and pumping both the power fluid and the formation fluid to the surface. Various functional components of a jet pump may alternatively be arranged for reverse flow, as explained subsequently, so that the power fluid is transmitted down the annulus and the formation fluid and power fluid are recovered at the surface through the tubing string.

[0015] The jet pump **10** includes an exterior pump housing **12** which defines an elongate housing passageway **14** therein extending from an upper portion to a lower portion of the pump housing. The exterior pump housing **12** preferably has a generally outer cylindrical surface **16** and a generally cylindrical inner surface **18** which defines the passageway in the pump housing. Ported sub **62** surrounds pump housing **12**, and is threaded to upper seal sub **60**, which is threaded to the tubing string. The pump housing is thus generally tube or sleeve shaped, with its ends secured to both a top pin **20** and a bottom pin **24**, respectively. The top pin **20** is adapted for sealing engagement with the tubular string. A lower seal sub **22** may be provided at the lower end of the pin **24**, and is threaded to tubular **62**. Pin **24** has a passageway **28** providing an inlet for hydrocarbons into the pump housing when pumping in the direct flow mode.

[0016] FIG. **1** depicts a power fluid jet nozzle **30** with a passageway **31** which becomes axially restrictive in the downward direction, thereby increasing the velocity of power fluid transmitted through the jet nozzle. The jet nozzle **30** is supported on and has an exterior sealed to the carrier **40**, which includes circumferentially spaced ports **41**. A mixing tube **32** within carrier **40** is provided fluidly downstream from the jet nozzle, and has an elongate mixing tube passageway **34**

receiving power fluid from the jet nozzle **30**. A plurality of venturi ports **41** or an axial spacing **38** between the lower end of the nozzle and an upper end of the mixing tube provided immediately below the nozzle **30** allow for entry of formation fluids from within the housing **12** and into the mixing tube **32**. The mixing tube **32** preferably may be formed from a tungsten carbide alloy material to define the mixing tube passageway **34**.

[0017] The pump as shown in FIG. **1** also includes a diffuser **46**. The lower portion **50** of the diffuser includes a substantially circular curved bore **56**. Diffuser **46** has a significant advantage over a cross-over sub, which is used in other jet pumps. A cross-over sub typically has a plurality of relatively small diameter flow paths to pass formation fluid to the jet nozzle, while the diffuser provides a relatively large circumferential flow path **14** between the pump housing and both the diffuser and the mixing tube. An inlet or standing valve **100** as shown in FIG. **5** is provided at the lower end of the pump housing, and is retrievable by a wire line.

[0018] The jet pump **10** as shown in FIG. **1** is thus configured for direct fluid flow, wherein fluid is pumped down the tubing string and passes through the top pin **20** to the nozzle **30**, which increases fluid velocity for the fluid exiting the nozzle **30** and drawing fluid from the annulus **14**, thus drawing in formation fluid so that both the drive fluid and the formation fluid pass through the mixing tube **32** and exit the pump through the outlet from the diffuser **46** and into the annulus between the pump housing **12** and the outer housing **62**. Formation fluid thus enters interior the housing through the flow path provided in the pin **24** and passes upward in the annulus **14** to the surface. Fluid discharged by the pump thus passes upward in the well in the annulus between the casing and the tubing string.

[0019] FIG. **4** shows in greater detail the nozzle **30** and mixing tube **32**. Sub **76** may be threadably connected to carrier **40**, so that nozzle **30** is sandwiched between the lower end of sub **76** and shoulder **75** on the carrier. Carrier **40** includes the circumferentially spaced ports **41** discussed above. The upper end of sleeve **76** includes conventional seals **72** for sealing with the top sub **60**. Lower sub **78** is also threaded to carrier **40**, and includes O-ring seals **76** for sealing with the diffuser **46**.

[0020] FIG. **3** discloses the same nozzle **30** and mixing tube **32**. Sub **76** has been replaced with sub **70**, which contains O-rings **72**. Sub **78** is replaced with sub **74**, and has similar O-rings as **76**. The carrier **40** containing the nozzle **30** and the mixing tube **32** is thus inverted in FIG. **3** compared to FIG. **4** for reverse fluid flow.

[0021] Referring to FIGS. **3** and **4**, the term "carrier" as used herein includes not only the tube **40** which surrounds the jet nozzle **30** and the mixing tube **32**, but also includes the subs **70**, **74**, **77** and **78** each secured to the tube **40** and retrievable with the tube **40**. These subs, which may functionally be considered part of the carrier, include O ring seals **72**, **76** for sealing the carrier to either of the outer subs **60**, **22**, and are retrieved with the tube **40**. The sealing diameter of the subs **70**, **76**, **77**, and **78** are thus substantially the same, so that the carrier with the subs can be inverted from a direct fluid flow configuration as shown in FIG. **4** to the reverse fluid flow configuration as shown in FIG. **3**, while still maintaining sealing engagement between the carrier and the outer subs **60**, **22**.

[0022] FIG. **2** illustrates the pump as shown in FIG. **1** with the jet nozzle and mixing tube inverted from the FIG. **1** embodiment. Except for the inversion of jet nozzle **30** and mixing tube **32** from the FIG. **1** embodiment, the primary components of the pump as shown in FIG. **2** are substantially identical to the components shown in FIG. **1**. Since the jetting force is down for the direct flow FIG. **1** configuration, no additional components are required to maintain the jet nozzle and mixing tube in the position as shown in FIG. **1**. For the FIG. **2** configuration for reverse flow, the jetting force is upward, and accordingly the upper end of the FIG. **2** embodiment has components which retain the jet nozzle and mixing tube as shown in FIG. **2**, and do not allow these components to be pumped upward and instead secure the components in place. More particularly, FIG. **2** shows an upper housing **102** which is adapted for engagement with a tubular string (not shown). Sleeve **100** is positioned radially within housing **102**. Leaf spring **108** or other biasing means bias the dogs **104** into engagement with the annular pocket **106**, thereby retaining the assembly in place. If it is desired to retrieve the inner components in the FIG. **2** embodiment, a conventional tool may be used to unlatch the dogs **104**, so that the sub-assembly including components **102**, **110**, **108** and **104** may be retrieved to a surface while the seal sub **60** and ported sub **62** remain in place.

[0023] FIG. **5** illustrates a lower end of the pump disclosed above, wherein the pump housing **12** includes sleeve **82**, which is sealed to the housing **62**. Coupling **86** connects housing **62** with tubular **88** extending down from coupling **86**. The temperature and/or pressure probe **90** is supported on base **92**, and is supported on the tubular **84**. When the jet pump is retrieved to the surface, probe **90** is also retrieved with the pump, so a separate operation to retrieve the probe is not required. If desired, the standing valve **100** as shown in the bottom of FIG. **5** may subsequently be retrieved by a wire line operation. As previously stated, the pump and the probe may be returned to the surface without pulling the tubular string, so that a work over rig is not required.

[0024] In both the direct flow configuration as shown in FIG. **4** and the reverse flow configuration as shown in FIG. **3**, seals **72**, **76** allow for a limited axial movement of the carrier with the nozzle and the mixing tube, while maintaining sealed engagement with the pump housing. Also, the axial length of a sleeve-shaped insert **94** as shown in FIGS. **3** and **4** may be used to selectively control the axial spacing between the tip of the nozzle **30** and the entrance to the mixing tube **32**. The sleeve-shaped insert **94** thus serves as an adjustment mechanism for adjusting the axial space between the jet nozzle and the mixing tube.

[0025] Comparing FIGS. **3** and **4**, the carrier tube which houses the jet nozzle and the mixing tube may be reversed end to end when switching from a direct pump mode to a reverse pump mode, or vise versa. Additional end couplings may be manufactured, and may be the only components one needs to use the direct pump configuration or the reverse flow pump configuration.

[0026] The jet pump as disclosed herein is well suited for a frac flowback operation, when the jet pump is used to reduce formation pressure required to recover the fluid, including freeing fluids to the surface. Although the jet pump may frequently be operated in the direct flow mode, the easy switch to reverse flow mode may be particularly beneficial for certain applications, including the reliable return of formation sand with the recovered fluid to the surface, and sour gas operations wherein the recovered fluid does not contact the casing. Also, substantially the same pump components may be used for either the direct flow or the reverse flow applications, so that a large inventory of direct flow jet pump components and another inventory of reverse flow jet pump components are not required.

[0027] The entire jet pump as disclosed herein is retrievable to the surface without pulling the tubing string, which may remain in the well during retrieval and reinsertion of a jet pump. Recovery of the jet pump thus need not entail the substantial expense and time of the workover rig to pull the tubing string with the jet pump.

[0028] Although specific embodiments of the invention have been described herein in some detail, this has been done solely for the purposes of explaining the various aspects of the invention, and is not intended to limit the scope of the invention as defined in the claims which follow. Those skilled in the art will understand that the embodiment shown and described is exemplary, and various other substitutions, alterations and modifications, including but not limited to those design alternatives specifically discussed herein, may be made in the practice of the invention without departing from its scope.

What is claimed is:

1. A downhole jet pump for positioning in a well on a tubular string to pump fluids from the well to the surface, comprising:

an exterior pump housing defining an elongate housing passageway therein having a central axis and extending from an upper portion to a lower portion of the pump housing;

a power fluid jet nozzle having an exterior sealed to the pump housing, the jet nozzle having a jet passageway therein for increasing fluid velocity of power fluid transmitted through the jet nozzle;

a mixing tube fluidly downstream from the jet nozzle and having an elongate mixing tube passageway receiving fluid from the jet nozzle;

a diffuser fluidly downstream from the mixing tube and having a curved flow path therein, the diffuser sealed to the exterior pump housing and the flow path in the diffuser being in communication with a throughport in the pump housing, a circumferential spacing between an exterior surface of the diffuser and an interior surface of the pump housing defining a flow path for formation fluid flowing to the jet nozzle; and

a carrier in the pump housing and supporting the jet nozzle and the mixing tube, the carrier including one or more ports for passing formation fluid radially inward to the jet nozzle, the carrier having a first end for sealing with either the pump housing and the diffuser, and an axially opposing second end for sealing with the other of the pump housing and the diffuser, such that the carrier, the jet nozzle, and the mixing tube may be arranged for direct flow or may be inverted in the pump housing for reverse flow.

2. The jet pump as defined in claim **1**, further comprising:

an adjustment mechanism for adjusting an axial position between the jet nozzle with respect to the mixing tube.

3. The jet pump as defined in claim **1**, wherein the adjustment mechanism is a selected axial length sleeve supporting the jet nozzle.

4. The jet pump as defined in claim **1**, further comprising:

a temperature and/or pressure probe supported in the well from the jet pump housing, such that retrieval of the jet pump housing to the surface retrieves the probe.

5. The jet pump as defined in claim **1**, wherein the carrier is sealed to the pump housing and to the diffuser, such that there is limited axial movement of the carrier with respect to the pump housing and the diffuser.

6. The jet pump as defined in claim **1**, further comprising:

an inlet valve below the pump housing for controlling formation fluid flow to the pump housing.

7. A downhole jet pump for positioning in a well on a tubular string to pump fluids from the well to the surface, comprising:

an exterior pump housing defining an elongate housing passageway therein having a central axis and extending from an upper portion to a lower portion of the pump housing;

a power fluid jet nozzle having an exterior sealed to the pump housing, the jet nozzle having a jet passageway therein for increasing fluid velocity of power fluid transmitted through the jet nozzle;

a mixing tube fluidly downstream from the jet nozzle and having an elongate mixing tube passageway receiving fluid from the jet nozzle;

a diffuser fluidly downstream from the mixing tube and having a curved flow path therein, the diffuser sealed to the exterior pump housing and the flow path in the diffuser being in communication with a throughport in the pump housing, a circumferential spacing between an exterior surface of the diffuser and an interior surface of the pump housing defining a flow path for formation fluid flowing to the jet nozzle; and

a carrier in the pump housing radially exterior of both the jet nozzle and the mixing tube and supporting the jet nozzle and the mixing tube, the carrier including an opening for passing formation fluid radially inward to the jet nozzle, the carrier having axially opposing ends each for sealing with either the pump housing or the diffuser, such that the carrier, the jet nozzle, and the mixing tube may be arranged for direct flow or may be inverted in the pump housing for reverse flow.

8. The jet pump as defined in claim **7**, further comprising:

an adjustment mechanism for adjusting an axial position between the jet nozzle with respect to the mixing tube.

9. The jet pump as defined in claim **8**, wherein the adjustment mechanism is a selected axial length sleeve supporting the jet nozzle.

10. The jet pump as defined in claim **7**, further comprising:

a temperature and/or pressure probe supported in the well from the jet pump housing, such that retrieval of the jet pump housing to the surface retrieves the probe.

11. The jet pump as defined in claim **7**, further comprising:

an inlet valve below the pump housing for controlling formation fluid flow within the pump housing.

12. A method of operating a downhole jet pump positioned in a well on a tubular string to pump fluids from the well to the surface, comprising:

providing an exterior pump housing defining an elongate housing passageway therein having a central axis and extending from an upper portion to a lower portion of the pump housing;

positioning a power fluid jet nozzle having an exterior sealed to the pump housing, the jet nozzle having a jet passageway therein for increasing fluid velocity of power fluid transmitted through the jet nozzle;

positioning a mixing tube fluidly downstream from the jet nozzle and having an elongate mixing tube passageway receiving fluid from the jet nozzle;

providing a diffuser fluidly downstream from the mixing tube and having a curved flow path therein, the diffuser sealed to the exterior pump housing and the flow path in the diffuser being in communication with a throughport in the pump housing, a circumferential spacing between an exterior surface of the diffuser and an interior surface of the pump housing defining a flow path for formation fluid flowing to the jet nozzle;

providing a carrier in the pump housing and supporting the jet nozzle and the mixing tube, the carrier including ports for passing formation fluid radially inward to the jet nozzle, the carrier having axially opposing ends each for sealing with either the pump housing and the diffuser, such that the carrier, the jet nozzle, and the mixing tube may be arranged for direct flow; and

inverting the carrier, the jet nozzle and the mixing tube in the pump housing for reverse flow.

13. The method as defined in claim **12**, further comprising: adjusting an axial position between the jet nozzle with respect to the mixing tube.

14. The method as defined in claim **12**, further comprising: supporting a temperature and/or pressure probe in the well from the jet pump housing, such that retrieval of the jet pump housing to the surface retrieves the probe.

15. The method as defined in claim **12**, wherein the carrier is sealed to the pump housing and to the diffuser, such that there is limited axial movement of the carrier with respect to the pump housing and the diffuser.

16. The method as defined in claim **12**, further comprising: positioning an inlet valve below the pump housing for controlling formation fluid flow within the pump housing.

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