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(54) **HYDRAULIC POWERED DOWNHOLE PUMP**

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USPC **417/151**

(57) **ABSTRACT**

A hydraulically powered downhole jet pump is designed to provide greater flexibility in operations of wells producing oil, gas and/or water. The pump consists of a housing and a carrier assembly. The housing is attached to an inner threaded tubular member and run inside the well casing to a depth as required for optimal operations. The one piece carrier assembly is inserted and seals into the housing with proper orientation of the carrier assembly outlet ports with the housing outlet ports resulting from the combination of a helically or tapered cut guide on the exterior of the carrier assembly and an inward positioned pin in the housing.

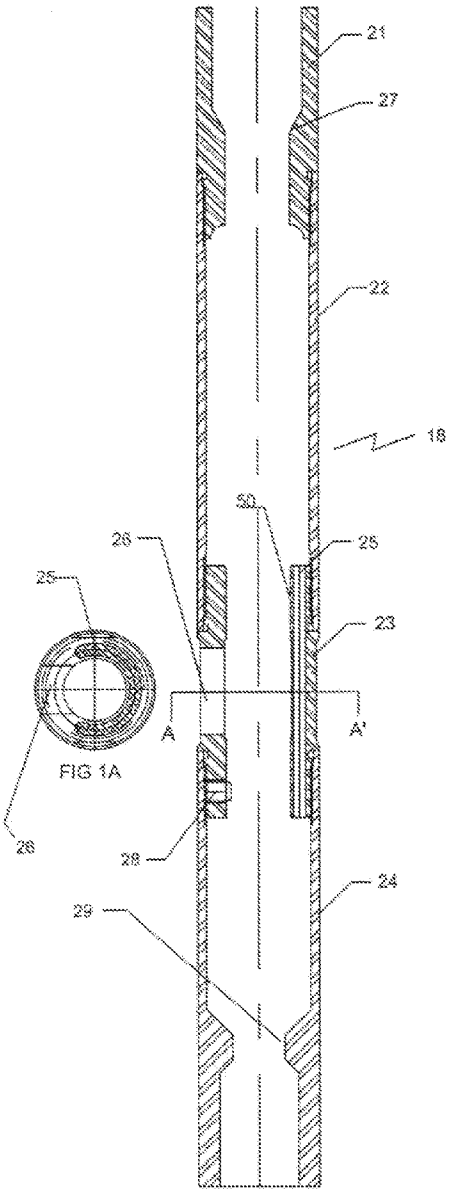

FIG 1A

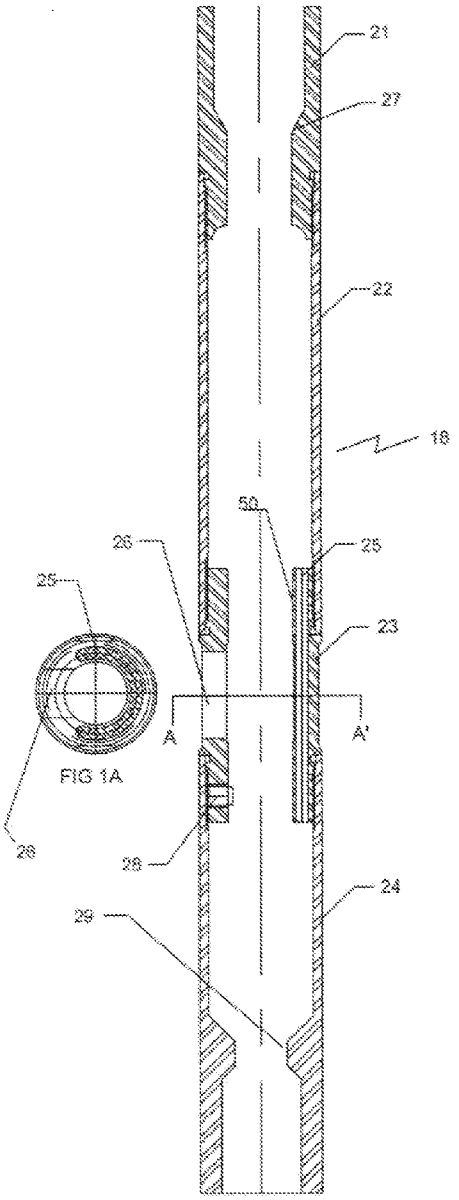

FIG 1A

FIG 1

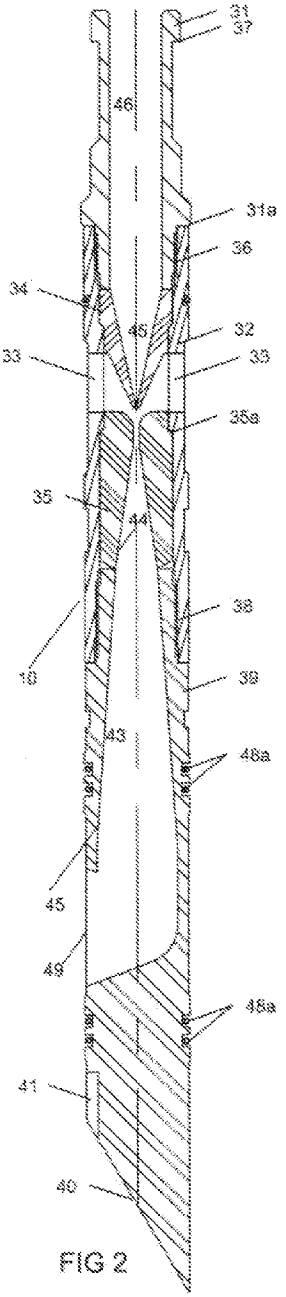

FIG 2

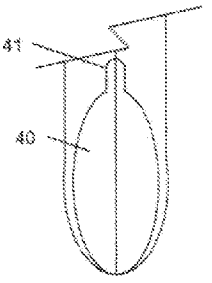

FIG 2A

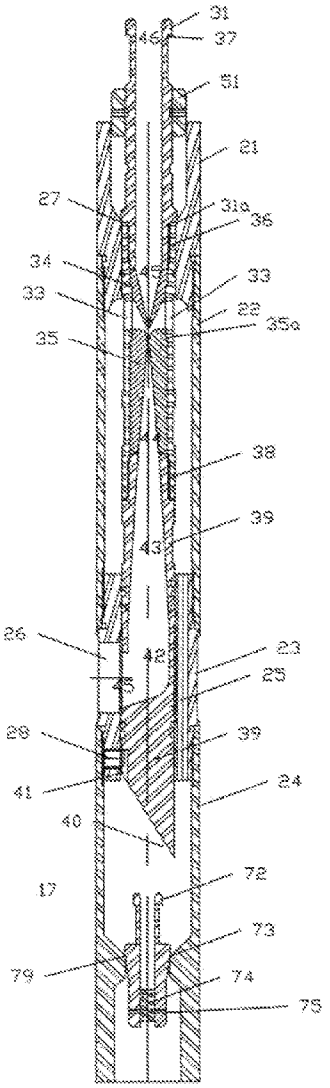
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FIG 3

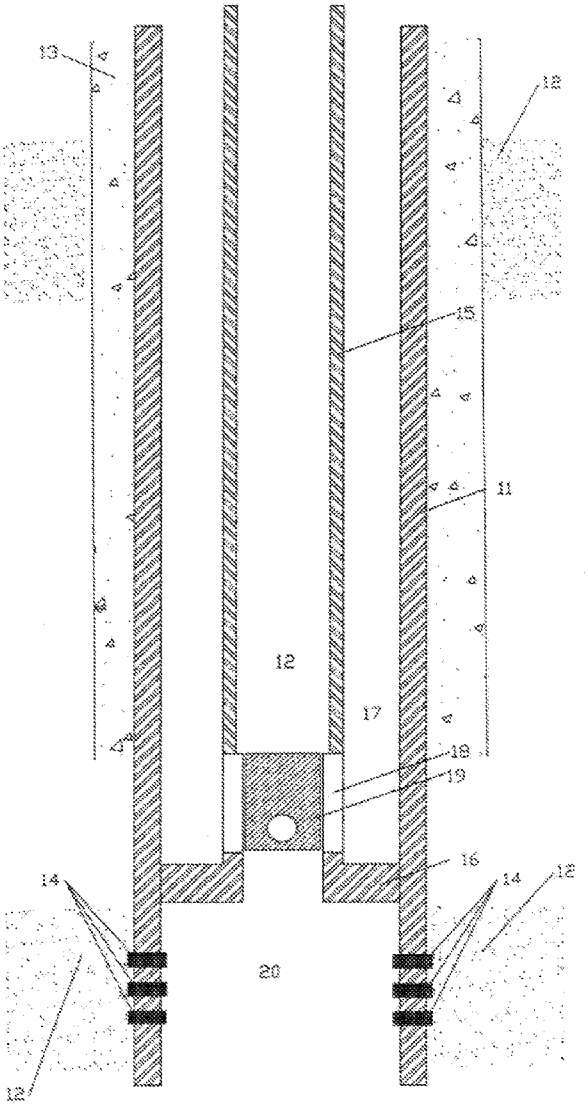
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FIG 5

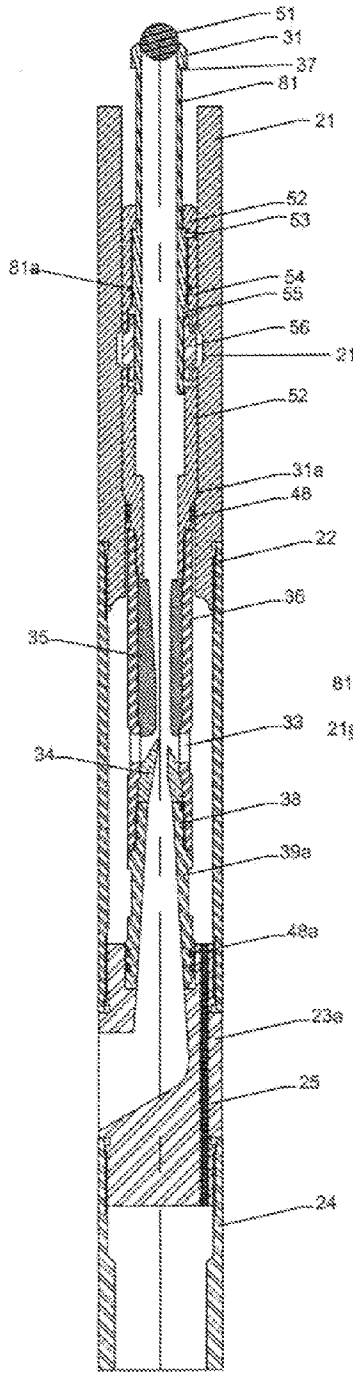

FIG 4

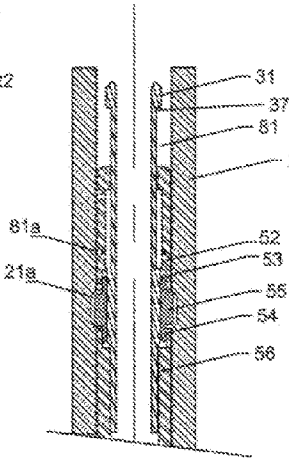

FIG 4a

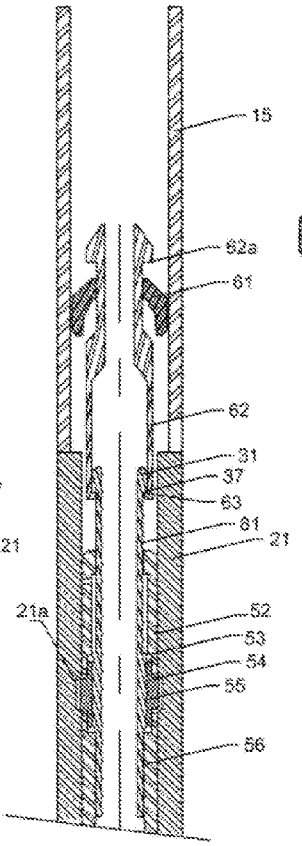

FIG 4b

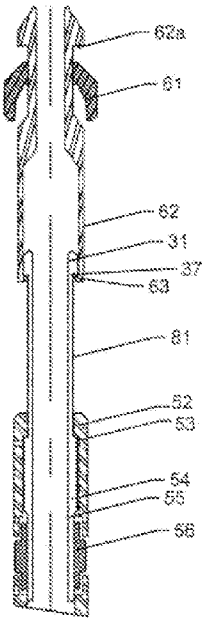

FIG 4c

HYDRAULIC POWERED DOWNHOLE PUMP

BACKGROUND OF INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates to a hydraulically powered jet pump for placement downhole in a well for the purpose of producing fluids (oil, gas, and/or water) from a formation which has special features that provide flexibility and ease of operations in various types of well applications. The operation of a jet pump is well known in the art and as such utilizes high pressure fluid pumped from the surface to a small interior diameter nozzle where the flow is converted to high velocity and lower pressure. As the fluid flow departs the nozzle, pressure at the exit point is greatly reduced thus drawing in fluids from an exterior source such as an oil and gas producing formation. The mixture is then flowed through a mixing tube which has a sequentially increasing interior diameter thus reducing velocity and increasing pressure. As the fluid mixture departs the pump into the well annulus, a sufficient pressure is available to cause the fluid mixture to return to the surface.

[0003] 2. Description of Related Art

[0004] The patent to Coleman U.S. Pat. No. 5,372,190 discloses a jet pump that includes a jet orifice and diffuser portion not numbered in FIG. 9 and a second diffuser member 148 that is attached to a tubular member 164 that includes an alignment edge 166 that cooperates with pin 170. In order to remove the assembly, the jet orifice and diffuser portion must first be removed and then the second member 148 is retrieved using a tool that is lowered by a wire line or coiled tubing and that engages profile 204. The patent to Batho et al U.S. Pat. No. 7,114,572 discloses a jet pump 50 and a subsurface safety valve 52. The patent to Kelly et al U.S. Pat. No. 7,219,737 discloses generally a jet pump 44 that can be moved upwardly in tubing into a retrievable position by fluid injected into the casing of a well. Finally, Jackson U.S. Pat. No. 7,909,089 discloses a jet pump 110 that can be configured to pump well fluid up through a tubing string.

BRIEF SUMMARY OF THE INVENTION

[0005] According to one aspect of an embodiment of the invention, a jet pump includes a housing and a carrier. The housing interior is of a constant diameter so that the carrier can easily be inverted and thus provide a means to use the pump as described above but with high pressure power fluid being conveyed down the annulus between the outer diameter of the inner tubular member and the well casing interior with the power fluid and formation production returning to the surface through the interior of the inner tubular. This flow method is preferred in wells where the produced fluid is corrosive and therefore not desirable to contact the well casing interior or in wells where a failsafe safety shut-in valve is desired or required. This configuration is typically called a "reverse flow" pump and requires wireline operations to run and retrieve.

[0006] The novel design of the reverse flow pump and latching device allows for placement of the pump into the well by simply dropping or pumping the assembly down to seat in the proper position and to latch into position to prevent the pump from being displaced upward when power fluid pressure is applied to the annulus. The novel design of the latching device is critical to the assembly and is activated to the locked position by means of pressure applied to the interior tubing and thus temporarily plugged assembly. In addition to placement and locking of the pump into the proper position, a novel mechanism is also provided that allows for retrieval of the pump without the use of a wireline conveyed pulling tool thus greatly reducing the operating cost normally associated with retrieval of a reverse flow pump.

[0007] The retrieval mechanism consists of a pulling tool with a seal cup positioned above. The mechanism is then pumped down the interior tube until it encounters and latches onto the fishing neck of the pump lock. Pressure is then applied to the annulus and causes an upward force via the seal cups to move the release sleeve upward and release the latching dogs and thus allowing the pump and latch assembly to be forced back to the surface thru continued circulation where the assembly can be captured at the surface and removed for design changes or repairs.

[0008] By developing a carrier which contains the nozzle and mixing tube in a single component, the housing can then be of simple design with enlarged interior diameter versus exterior diameter as compared to other tools on the market. The larger exterior diameter of the carrier therefore allows the use of larger nozzle and mixing tube diameters and thus increased production rates from a formation. For example, existing tools of a 3" to 3.5" outside diameter are limited to production rates in the maximum range of 100 gallons per minute whereas this novel design can easily achieve rates in excess of 200 gallons per minute.

[0009] Another objection for using existing jet pumps is the inability or difficult operations required to obtain access to the producing formation for purposes of evaluation of formation data or modification of the well completion. This novel design allows easy removal of the carrier, standing valve and safety valve from the interior of the inner tubing thus allowing full access through the remaining pump housing and to the wellbore below. Pending well conditions, the carrier, standing valve and safety valve can be removed from the well by reversing the power fluid circulation direction and capturing the tools as they reach the surface. In wells where the formation pressure is low and thereby will not allow reverse circulation, the tools (carrier, standing valve and safety valve) can be removed using a wire and special retrieving tool to provide full access to the wellbore below the pump housing assembly.

[0010] In wells located in hostile or sensitive environments such as the Arctic areas, wildlife refuges and offshore, rules and regulations often require that each well be equipped with a failsafe downhole valve to prevent the flow of oil and gas to the surface in case of a failure of the surface valving or integrity of the well. This tool configuration can include such a device when required or desired and operates by being open only when power fluid pressure is applied and automatically closes anytime power fluid pressure is reduced. Another advantage of the safety device is that there are no depth limits at which the valve can be placed as is the case in safety valves that are operated by a special tubular line run from the surface to the valve and the valve operated by applying pressure to the line and thus to the valve.

[0011] Another feature of this novel design overcomes the typical problem associated with damaging or washing seals such as "O" rings out of their grooves. In standard seal design, there is a requirement to provide some amount of "squeeze" as a seal enters into a bore such that the interference creates the initial seal between the part containing the seal and the receiving device bore. Most seals are activated to an improved "squeeze" when pressure is applied. When passing in and out

of seal bores, each entry and exit of a seal from the bore has potential to damage the seal and eliminate or drastically reduce the interference and the efficiency of the initial seal. The initial seal is critical in order for applied differential pressure to further activate the seat. In the novel design, standard type seal which require some interference fit (squeeze) are replaced with a seal made of a swellable elastomer that does not require an initial squeeze. Swellable elastomers can be provided that increase in size (swell) in the presence of fresh water, salt water, oil or gas. All of these fluids are typically contained in oil or gas wells. By utilizing a swellable elastomer as the seal, there is no need for the seal to be installed at a larger outside diameter than the outside metal diameter of the tool and therefore the seal is not exposed to damage that may result from contact with the well tubing or from flow washing while running the tool into the well. Once the tool is positioned into the bores, swelling of the elastomer automatically creates the squeeze and establishes the initial seal between the inner tool and bore and may be further activated for controlling high pressure thru the application of pressure after some amount of swelling has occurred.

[0012] Another feature of the disclosed invention is to use shape memory materials, such as metals, for seal construction. Shape memory material can be manufactured in a specific shape at a base temperature and then formed into a different shape at a different temperature. It is therefore feasible to manufacture a shape memory material with a size that would create interference between the carrier and housing bore at a temperature such as 150 degree F., typical of even shallow oil and gas wells, but would not have interference at a lower temperature. Once the tool is placed into the housing bore without interference and the well temperature increases to above 150 degrees F., the material returns to the original manufactured shape which does provide interference and thus sealing capability. Using a corrosion resistant metal could greatly enhance the life of the seals in wells where corrosive fluids are produced.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0013] FIG. **1** is a cross sectional view of the housing according to an embodiment of the invention.

[0014] FIG. **1***a* is a view along line A-A of FIG. **1**.

[0015] FIG. **2** is a cross sectional view of the carrier assembly according to an embodiment of the invention.

[0016] FIG. **3** is a cross sectional view of an embodiment of the jet pump assembly.

[0017] FIG. **4** is cross sectional view of a second embodiment of the jet pump assembly.

[0018] FIG. **4***a* is a cross sectional view of the locking mechanism in a locked position.

[0019] FIG. **4***b* is a cross sectional view of a fishing tool engaging the upper portion of the jet pump assembly.

[0020] FIG. **4***c* is a view of the upper portion of the jet pump assembly as pressure is applied from above to pump out the assembly.

[0021] FIG. **5** is a schematic view of a typical well installation.

DETAILED DESCRIPTION OF THE INVENTION

[0022] FIG. **5** shows a typical well construction utilizing a hydraulic jet pump and associated completion equipment. A well normally has a casing string **11** extending from surface to or below the producing formation **12** and is cemented in place as shown at **13**. Slots or perforations **14** in the casing allow flow of production fluids from the formation into the inside of the casing **11**. An additional tubular member, called tubing **15**, extends from surface to a packer **16** which seals the annulus **17** between the tubing **15** and casing **11**. A jet pump housing **18** is run as an integral part of the tubing **15** and is positioned above the packer. The housing accepts the pump carrier **19** with nozzle and mixing tube components and thereby provides the means to artificially lift produced fluids from the lower part **20** of the well to the surface.

[0023] FIG. **1** is a cross section of a housing **18** which is included by threaded means to the tubing **15** and positioned above the packer **16**. A top sub **21** connects the tubing to the housing by various types of threads common for use in oil and gas wells. The top sub is connected by threads to a sleeve **22** used for correct spacing of the various seal bores of the housing. The lower end of the sleeve is connected to the exit port sub **23**. The exist port sub is connected to a lower sub **24** which in turn is connected by threads to the well tubing **15**.

[0024] Included in FIG. **1** is a restricted or smaller inside diameter shoulder **29** for insertion and restriction of a standing valve (not shown). A guide pin **28** extends into the interior of the seal bore of the exit port sub for contact with a helical surface **40** of the lower end of the carrier and thus assuring proper orientation of the carrier when positioned inside the housing.

[0025] As shown more fully in FIG. **3**, an eccentric flow path **25** extends partially around the inside diameter of the exit port sub and provides a means for produced fluids to flow from the formation, thru the interior of the tubing and alongside the carrier to the inlet ports **33** of the carrier when the carrier is in its proper position inside the housing. A port **26** in the exit port sub **23** provides a communication means from the exit flow path **49** of the carrier, thru the exit port sub wall and into the annulus **19** of the well.

[0026] As shown in the cross section of the carrier assembly **10** in FIG. **2**, a fishing neck **31** is provided on the top of the carrier assembly for convenience of retrieval from the well using well known wireline conveyed fishing tools which are designed to latch onto the shoulder **37** and retrieve the carrier assembly from the well. A shoulder **31***a* at the lower end of the fishing neck is slightly larger than the outside diameter of the carrier body **32** and provides a stopping means to properly position the carrier assembly inside the housing as it cannot pass the shoulder **27** of FIG. **1**.

[0027] The body **32** of the carrier is connected by threads **36** to the fishing neck **31** on the upper end and the lower carrier sub **39** on the lower end. Internal to the body are the critical components of the pump, nozzle **34** and mixing tube **35** which are each positioned properly by an interference fit shoulder **34***a* and **35***a* respectively. A series of ports **33** in the wall of the body allow produced fluids to enter into the interior of the body at the outlet end of the nozzle where a low pressure area has been created as a result of the extremely high velocity exiting from the tip of the nozzle. Fluid pumped down the interior of the tubing and into the interior of the carrier **46** passes into the tapered flow path **45** of the nozzle where pressure is decreased and velocity increased as well known in the art. As the fluid exits the tip of the nozzle at high velocity, a responding reduction in pressure occurs thereby pulling produced fluids into the area immediately below the tip of the nozzle. The mixture of fluids enters the mixing tube and flows

down a sequentially larger diameter flow path **44** in the mixing tube. With the increasing interior flow area, velocity is reduced and subsequently pressure increased. The flow continues downward inside the lower carrier body with increasing diameter and turns to exit from the carrier **45** and through the ports of the exit port sub **23** of the housing as shown in FIG. **3** where a sufficient increase in pressure at the exit point can overcome the hydrostatic pressure of the fluids from the depth of the pump to the surface and thereby pump the mixture back to the surface for separation and further processing as may be required to allow sale of the oil and gas and reuse or disposal of the produced water. A tapered lower end of the lower carrier body **40** engages the guide pin **28** extending into the interior of the housing and automatically follows the taper and into the guide slot **41** to properly orient the carrier such that the exit ports of the lower carrier body and exit port sub are aligned.

[0028] In addition to the interference seal achieved at the larger diameter of the fishing neck **31***a* against the top sub restriction **27** an additional seal such as an "O" Ring **34***a* may be provided as a backup sealing mechanism. Additional seals **48***a* are required to seal above and below the exit port of the carrier and the exit ports of the exit port sub **23**.

[0029] Under certain well conditions, a check valve **79** as shown in FIG. **3**, often called a standing valve, is required to prevent produced and power fluids from flowing back into the formation when pumping has ceased. In this configuration, a fish neck **72** is provided to allow retrieval of the standing valve in such cases as access to the formation is desired. A shoulder **73** is provided on the standing valve to prevent the valve from passing through the housing seat **29** and provides a metal to metal seal between the standing valve and the housing. As certain well conditions could exist where formation pressure is lower than the hydrostatic pressure above the standing valve, an equalizing mechanism is provided such as a sealed piston **74** which is held in place by shear pins **75**. When retrieving the standing valve, it is necessary to add an equalizing prong to the fishing tool and mechanically contact the piston to forcefully expel the piston and allow the well pressures to equalize before attempting to retrieve the standing valve.

[0030] FIGS. **4**, **4***a*, **4***b*, and **4***c* depict the sequential operation of an embodiment of the novel reverse flow pump. Once the carrier assembly is positioned against the restricted shoulder **31***a*, a temporary device such as a dissolvable ball **51**, rupture disk or lightweight ball is provided to seal the interior diameter of a sliding sleeve **81** with Seal **81***a* which includes a fishing neck **31** and thereby provides a piston area to generate a force when pressure is applied to shear the retaining pin **53** and move the sleeve and fishing neck downward, forcing the larger diameter shoulder **54** under the dogs **56** whereby the dogs are moved into the groove **21***a* of the top sub **21** of the pump housing, as shown in FIG. **4***a*.

[0031] In this series of depictions, the carrier body **36** containing the nozzle **34** and mixing tube **35** is inverted thereby providing a pumping means wherein the power fluid is pumped down the annulus between the tubing **15** and the casing **11** and produced fluid mixture returns to surface up the tubing.

[0032] FIG. **4***a* shows the assembly locked in position after applying pressure above the pump and forcing the shoulder **54** under the dogs **56** and forcing the dogs outward and into the groove **21***a* of the top sub **21**. A variety of means can be added to the end area of the smaller outside diameter section **55** of the fishing neck **31** to provide some resistance to inadvertent upward movement of the fishing neck during operations of the pump.

[0033] FIG. **4***b* depicts the initial step of retrieval of the pump carrier wherein a standard type fishing tool **62** which is modified to contain a seal cup **61** or other sealing mechanism to at least partially seal between the fishing tool and tubing interior wall. The fishing tool and seat cup are then dropped into the tubing and allowed to fall to the top of the pump or the assembly can be pumped into position. The end of the fishing tool contains dog latching arms and a shoulder **63** that is allowed to expand over the pump fishing neck **31** and latch underneath the fishing neck shoulder **37**. The fishing tool is also provided with a secondary fishing neck **62***a* in case operational problems require that conventional wireline operations are used to retrieve the fishing tool or pump.

[0034] FIG. **4***c* depicts the released position of the pump wherein pressure is applied to the annulus in the same manner as when the pumping operations were active. The applied pressure acting against the seal cup creates an upward force that move the fishing neck **31** and the large diameter section **54** upward and out from under the dogs **55**, allowing the dogs to retract from the groove **21***a* and releasing the locking mechanism to allow upward movement of the entire assembly. Continued circulation of fluids down the annulus and up the tubing causes the tool to be pumped to the surface where a variety of prior art and known methods allows the tool to be captured and removed from the well for repairs, redesign or other modifications.

[0035] Seals **48***a* may be made from a swellable elastomer material or from a shape memory material. As discussed above, the seals may be initially sized so that the seals are not deformed as the carrier assembly is positioned within the housing. Rather, upon exposure to well fluids or elevated temperatures, the seal increases in size to form a seal between the housing and the carrier assembly.

[0036] Although the present invention has been described with respect to specific details, it is not intended that such details should be regarded as limitations on the scope of the invention, except to the extent that they are included in the accompanying claims.

I claim:

1. A jet pump assembly comprising:

a housing adapted to be attached to a tubular string and having an outlet port,

a carrier assembly including a nozzle and a diffuser section, positioned within the housing and having an exterior diameter smaller than the interior diameter of any portion of the housing or tubing whereby the carrier assembly can be removed from the housing as a unit.

2. A jet pump assembly as claimed in claim **1** further including a pin located at a bottom portion of the housing and a tapered surface on a lower portion of the carrier assembly whereby the carrier assembly is properly oriented within the housing.

3. A jet pump assembly according to claim **2** wherein the diffuser section of the carrier assembly includes an outlet which is aligned by the pin and the tapered surface with the housing outlet port.

4. A jet pump assembly according to claim **1** further including a fishing neck provided at a top portion of the carrier assembly.

5. A jet pump assembly according to claim **1** further including a retrievable check valve having a fishing neck positioned within a lower portion of the housing.

6. A jet pump assembly according to claim **1** wherein the housing includes an annular groove in an inner surface of the housing,

a plurality of locking dogs captured by an upper portion of the carrier assembly, and

a removable blocking device temporarily blocking fluid flow through the carrier assembly.

7. A jet pump assembly according to claim **6** wherein the carrier assembly includes at its upper end a sealing mechanism to seal the annulus between the carrier assembly and the tubing interior as the carrier assembly is forced upwardly by fluid pressure.

8. A jet pump assembly according to claim **6** wherein the carrier assembly further includes a fishing neck at an upper portion thereof.

9. A jet pump assembly according to claim **1** further including at least one seal between the housing and the carrier assembly.

10. A jet pump assembly according to claim **9** wherein at least one seal is formed of a swellable elastomer material.

11. A jet pump assembly according to claim **9** wherein at least one seal is formed of a shape memory material.

12. A jet pump assembly according to claim **6** further comprising a sliding sleeve having a fishing neck at its top portion and a shoulder adapter to engage and three outwardly the locking dogs when the sleeve is forced downwardly.

13. A jet pump assembly according to claim **9** further including a groove formed in the housing or the carrier assembly and the seal is located within the groove and sized initially to fit totally within the groove.

* * * * *