Feb. 7, 1956 S. J. E. MARSHALL 2,733,663

DEEP WELL PUMPING APPARATUS

Filed Sept. 20, 1954 3 Sheets-Sheet 1

Fig. 1

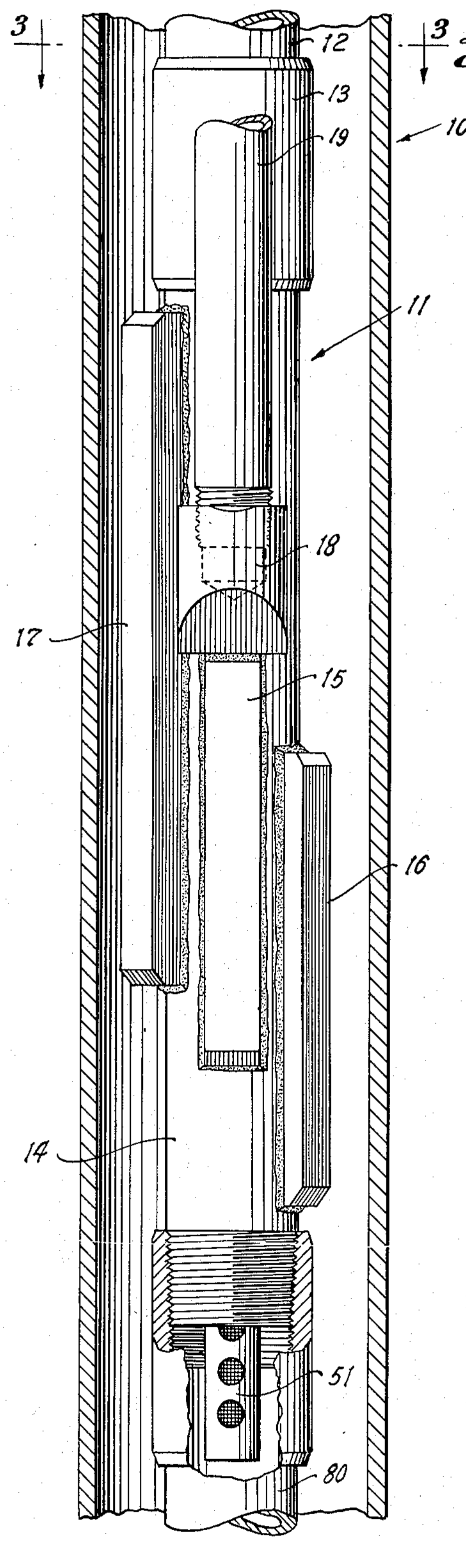

Fig. 2

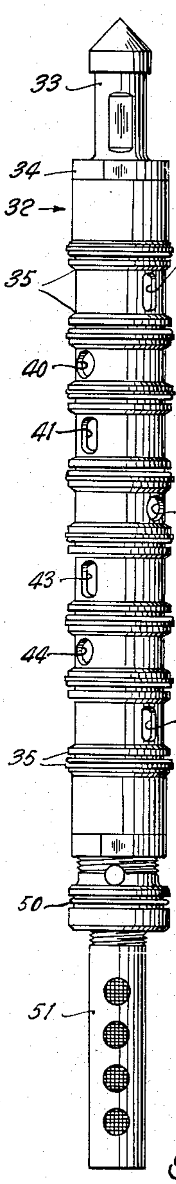

Fig. 3

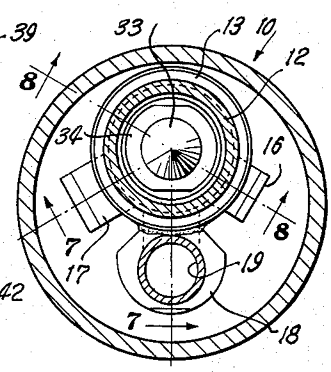

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Fig. 4

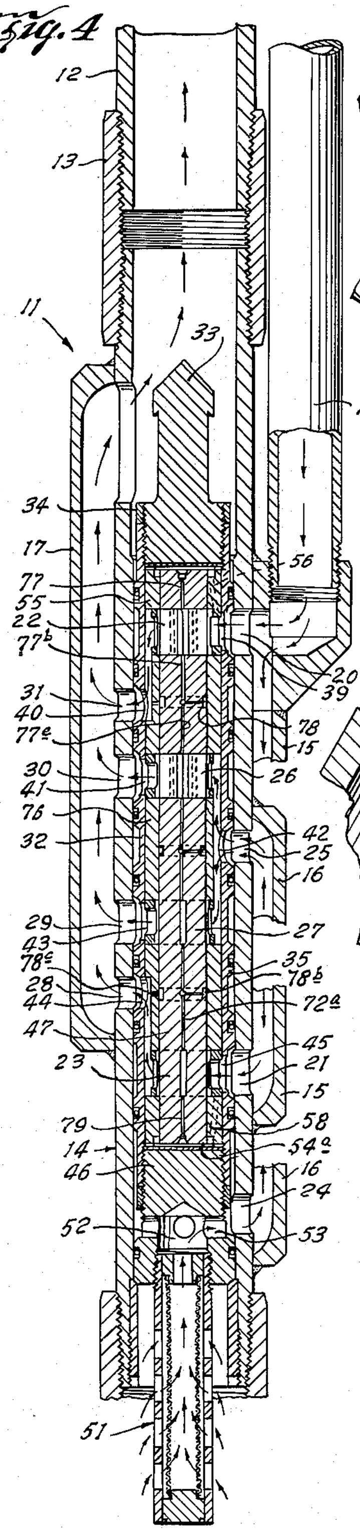


Fig. 5

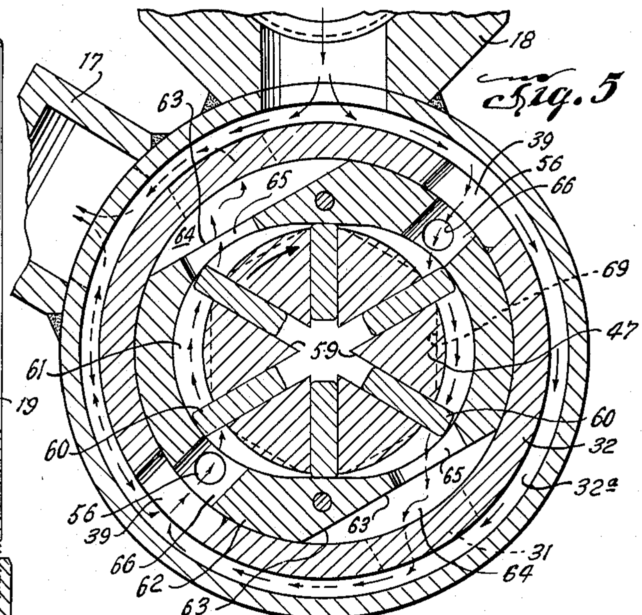
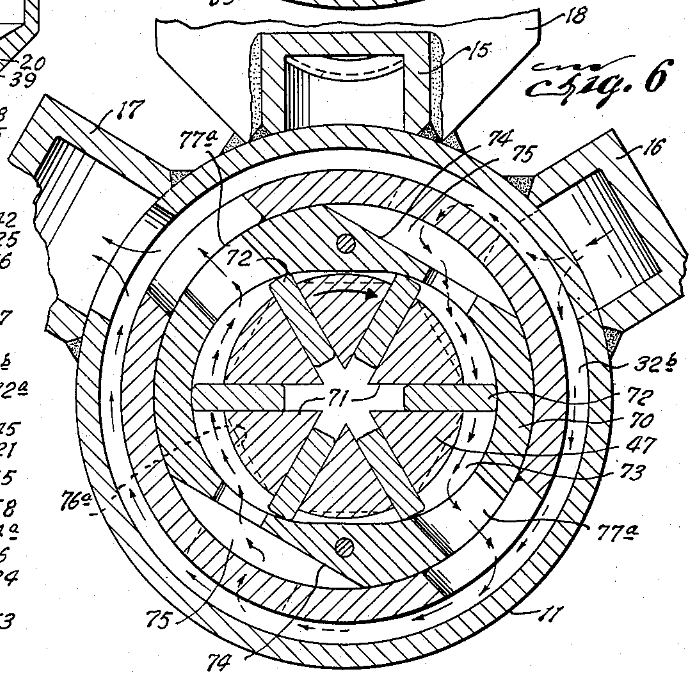


Fig. 6



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DEEP WELL PUMPING APPARATUS

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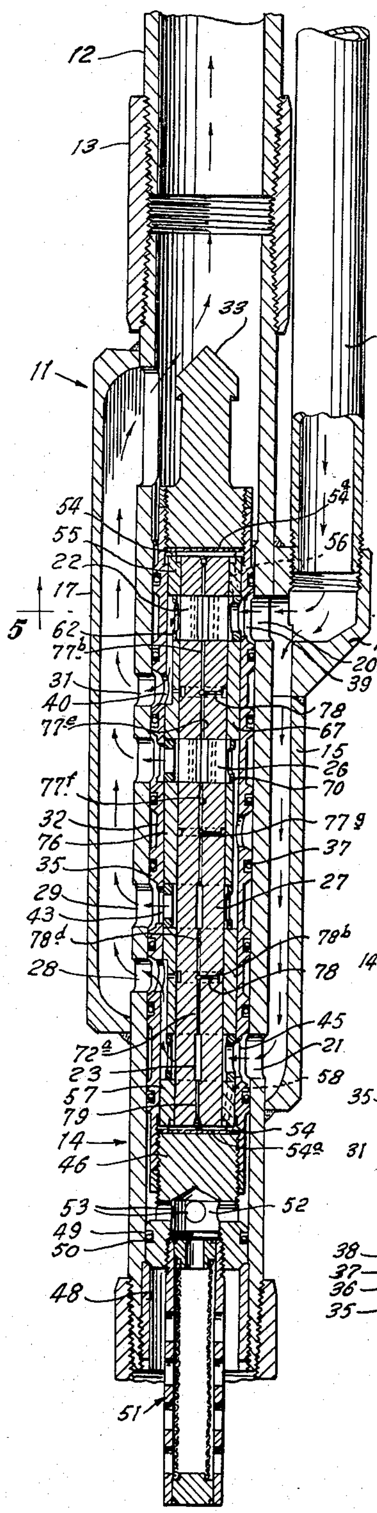

Fig. 7

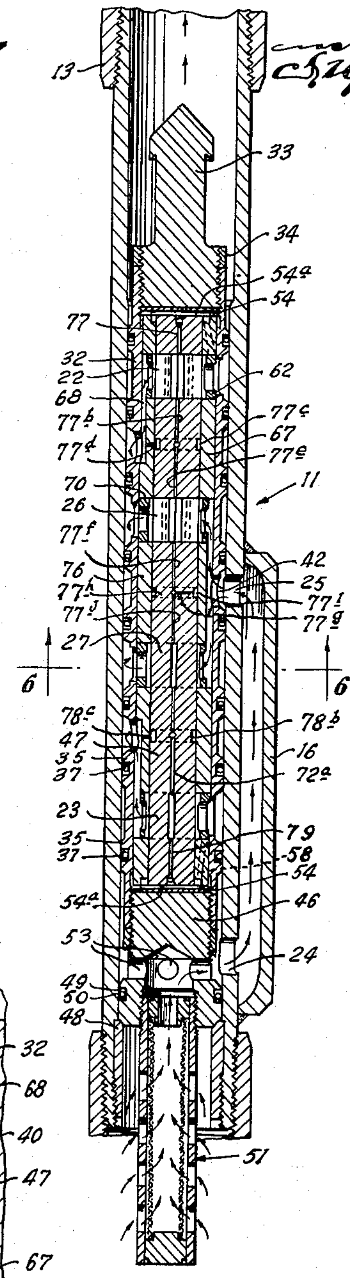

Fig. 8

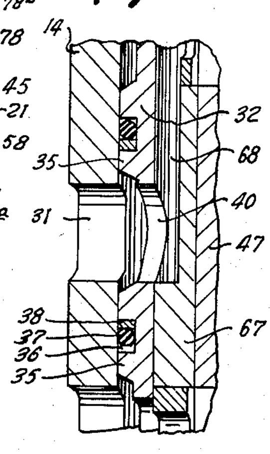

Fig. 9

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DEEP WELL PUMPING APPARATUS

Samuel J. E. Marshall, Dallas, Tex.

Application September 20, 1954, Serial No. 457,121

12 Claims. (Cl. 103—118)

This invention relates to pumps especially adapted to deep well pumping and it has particular reference to a fluid and gas operated mechanism for the continuous recovery of fluids from wells.

The principal object of the invention is to provide a gas or hydraulically operated pump adapted to be lowered into a well through its casing by any conventional running tool suited to the purpose and which is also equipped to retrieve the pump. The said pump has been designed with a view to reducing to the very minimum the number of moving parts and to insure that the moving parts, essentially one or more hydraulic motors and one or more pumps, are protected against undue wear by equalizing the fluid pressures to which these elements would normally be exposed.

Another object of the invention is to provide a deep well pump composed of an elongate manifold casing adapted to be suspended on the tubing string in a well and a pump unit assembly which is lowered by a wire line into the manifold casing subsequent to the establishment of the latter in the well, the said manifold casing being equipped with a landing nipple which is capable of extension to accommodate a pump unit assembly having a greater number of pumps and motors, thus to increase the capacity of the pump as a whole, it being estimated that the capacity of each individual pumping unit of the apparatus is substantially 150 barrels per day.

Another object of the invention is to provide a highly flexible pumping apparatus whose individual hydraulic motors are operated by fluid pumped through macaroni tubing from the surface to enter the pumps through a power fluid manifold in the casing, thus to actuate a rotor carrying both the pumps and motors at a speed sufficient to create pump pressures in excess of the hydrostatic well pressure to insure free and continuous flow of well fluid from the well. The well fluid enters the pumping apparatus through a suction manifold of its casing and commingles with the power fluid in a discharge manifold in its course to the surface, a portion of which fluid is continuously recirculated through the motors.

With the foregoing and other objects in view, the invention has particular reference to certain salient features of accomplishment to become manifest in the course of the following description when considered with the annexed drawings wherein:

Figure 1 is a fragmentary sectional view of a well casing and showing in elevation therein the pumping apparatus of the invention, partly broken away.

Figure 2 is an elevational view of the pump assembly per se.

Figure 3 is a transverse sectional view taken on line 3—3 of Figure 1.

Figure 4 is a more or less schematic view of the pumping apparatus in vertical section in which arrows reveal the course of power and well fluid as the latter is pumped from a well.

Figure 5 is a transverse sectional view taken through one of the fluid motors, on line 5—5 of Figure 7.

Figure 6 is a transverse sectional view taken through one of the pump units on line 6—6 of Figure 8.

Figure 7 is a view similar to Figure 4, taken on line 7—7 of Figure 3 and reveals the recirculation of power fluid through the apparatus.

Figure 8 is a longitudinal sectional view taken on line 8—8 of Figure 3, and

Figure 9 is a fragmentary sectional view showing an enlargement of one of the fluid discharge ports in the shell or body of the pump assembly and the opposing sealing elements.

Continuing with a more detailed description of the drawing, reference is primarily made to Figures 1 and 3 wherein **10** generally indicates the casing of a well into which is suspended the pumping apparatus broadly identified by reference numeral **11** by means of a string of well tubing **12**, the upper end of the apparatus being threaded to receive a collar **13** by which it is connected to the tubing **12**.

Specifically, the apparatus **11** consists of a tubular casing **14** which will be hereinafter referred to as a landing nipple, the said landing nipple having welded or otherwise secured thereto a power fluid manifold **15**, a pump suction manifold **16** and a discharge manifold **17**. The upper fluid manifold **15** is in communication at its upper end with a pipe connection **18** which is, in turn, interiorly threaded to receive the lower end of a string of macaroni tubing **19** through which power fluid from the surface is pumped into the apparatus.

The landing nipple **14** has a pair of high pressure fluid inlets **20** and **21**, both of which are embraced by the power fluid manifold **15**, the upper inlet **20** serving the upper fluid motor **22** while the lower inlet **21** serves the lower fluid motor **23**. Further reference to these motors will be made presently.

The pump suction manifold **16** covers well fluid outlet and inlet ports **24** and **25**, respectively, as shown in Figure 4 and through which well fluid is influenced upwardly by the upper and lower pumps **26** and **27**.

The discharge manifold **17** is considerably longer than either the power fluid manifold **15** or the pump suction manifold **16** and covers the discharge port **28** of the lower motor **23**; the discharge port **29** of the lower pump **27**; the discharge port **30** of the upper pump **26** and the discharge port **31** of the upper motor **22**. The upper end of the manifold **17** communicates with the upper end of the landing nipple **14** from whence the commingled power and well fluids are forced upwardly by the combined pressures of the pumps **26** and **27** to the surface through the tubing **12**.

The pump assembly is composed of a tubular shell or body **32** (Figure 2) which is interiorly threaded at its upper end to receive the exteriorly threaded lower end of a carrier or stem **33**, providing a connection for a suitable running tool on a wire line, not shown, for lowering the pump assembly into and withdrawing the same from the landing nipple **14** while the latter is installed in a well. An annular, internally threaded ring **34** locks the stem in position in the top of the shell **32**.

At longitudinally spaced intervals throughout the length of the shell **32** there is provided an annular boss **35** (Figure 9). Each annular boss has an annular groove **36** therein and within each groove **36** there is arranged an O-ring **37** bearing against a non-extrusion ring **38**. By observing Figures 2, 4 and 7, it will be seen that the packing assembly composed of the O-rings and non-extrusion rings is disposed one on each side of the fluid inlet and outlet openings in the shell **32** defining annular fluid chambers or spaces about the shell when the latter is confined within the landing nipple **14**, such as indicated by reference numerals 32*a* in Figure 5 and 32*b* in Figure 6, opposite the upper motor **22** and the upper pump **26**, respectively. The longitudinally spaced packing assemblies are adapted to resist full pressure of the power fluid circulated through the motors **22** and **23** as well as closing out all pressures at the inlet end of the pump which would tend to interfere with the inflow of fluid from the well.

The shell **32** is provided adjacent its upper end with a port **39** which registers with the high pressure power fluid inlet port **20** of the landing nipple **14**. Immediately below the port **39** is a discharge port **40** which registers with the discharge port **31** of the landing nipple and through which fluid discharges from the upper fluid motor **22** into a discharge manifold **17**. Next below the discharge port **40** of the shell **32** is another discharge port **41** which registers with the discharge port **30** of the landing nipple **14** and which accommodates the upper pump **26**. Below the discharge port **41** is a suction port **42** which registers with the port **25** in the landing nipple to serve both fluid pumps **26** and **27**. A discharge port **43** in the shell **32** registers with the discharge port **29** for the pmp **27** and still another lower port **44** in the shell **32** registers with the fluid motor discharge port **28** which serves the lower motor **23**. A high pressure inlet port **45** in the shell **32** registers with the power fluid inlet port **21** of the landing nipple, as may be seen in Figure 7. All of the described ports are in communication with the annular chambers defined by the O-rings **37** and the walls of the shell **32** and landing nipple **14** and as stated, each of the several ports above mentioned is flanked by O-rings **37** and non-extrusion rings **38** in grooves **36** in the walls of the shell **32**, the O-rings being in sealing engagement with the inner wall surfaces of the landing nipple **14**. The bottom O-ring **37** performs an additional vital function in the sense that it separates the hydrostatic well pressure and the power fluid pressure which latter is greater than the hydrostatic pressure and counters the force thereby imposed, tending to thrust the pump assembly upwardly in the landing nipple **14**.

The lower end of the shell **32** is interiorly threaded to receive the upper threaded end of a base plug **46** for a rotor **47**. The base plug **46** and consequently the rotor **47** is sustained by a sleeve or stop **48** against which the base bears and immediately above the lower end of the base an annular groove **49** is formed to receive an O-ring seal **50**, which closes off hydrostatic pressures originating in the well and insures free upward flow of well fluid through the strainer **51** whose upper end is threaded into the lower end of an axial bore **52** in the base **46** whose upper end is in communication with a plurality of radial passages **53** in the base **46**, all of which communicate with the suction port **24** of the landing nipple **14** so that fluid influenced upwardly from the well by the pumps **26** and **27** may flow through the suction manifold **16**.

The rotor **47** is fabricated from a cylindrical bar or mandrel which is substantially coextensive with the space in the shell **32** between the stem **33** and the rotor base **46**. It is provided, however, that a disc-like bearing **54** be interposed between the upper end of the rotor **47** and the stem **33** and a similar bearing is interposed between the lower end of the rotor and the base **46**. There is sufficient space between these disc-like bearings and adjacent parts to be occupied by fluid under pressure providing a film of oil at the ends of the rotor, thus minimizing friction. The upper end of the rotor **47** is embraced by a sleeve **55** which has a longitudinal fluid by-pass **56**, shown in dotted lines in Figures 4 and 7, which communicates with a diametrical channel **54*a*** in the underside of the upper bearing **54** and permitts high pressure fluid from entrance ports **20** and **39** to enter the small clearance between the bearing **54** and its adjacent parts for the purpose above stated. In like manner, a rotor sleeve **57** embraces the lower end of the rotor **47** and has a bypass **58** which effects communication between the high pressure ports **21** and **45** and the diametrical channel **54*a*** in the lower bearing **54** to introduce a film of oil between the bearing **54*a*** and the lower end of the rotor **47** for the same reasons as explained above.

Against the upper end of the rotor **47** there is provided a group of diametrical, circumferentially spaced slots **59** (Figure 5) which intersect at the longitudinal axis of the rotor. In each of the slots **59** is disposed a vane **60** for radial sliding displacement. The outward movement of these vanes is limited by the walls of the ovate chamber **61** of a rotor cylinder **62**. Diametrically opposed, flattened surfaces **63** in the exterior wall surfaces of the rotor cylinder **62** provide vertical fluid chambers **64** into which power fluid is discharged by the vanes **60** through ports **65** in the walls of the rotor cylinder after having entered through ports **66** from the ports **20** and **39** of the landing nipple **14** and shell **32**, respectively, to actuate the motor **22**.

Disposed immediately below and supporting the rotor cylinder **62** is a rotor sleeve **67**. This sleeve likewise has diametrically opposed, flattened sides as indicated at **68** in Figure 8, thus to define vertical fluid passages for conveying fluid discharged by the motor **22** to the discharge ports **31** and **40** in the landing nipple **14** and shell **32**, respectively, such fluid being conveyed upwardly through the manifold **17** to the tubing **12** along with fluids discharged from the lower motor **23** as well as that discharged from both the pumps **26** and **27**.

It will be observed in dotted lines in Figure 5 that the rotor **47** is actually hexagonal in transverse section through the motors **22** and **23**, thus providing flats **69** between the vanes of the motors. These flats are to provide relief for the fluid between the outer ends of the vanes **60** and the walls of the chamber as they traverse the fluid exhaust ports **65**.

Surrounding the rotor **47** below the rotor sleeve **67** is a pump cylinder **70** (Figure 6). At this point, the rotor **47** is provided with a group of diametrical slots **71** which intersect the longitudinal axis of the rotor and in these slots are slidably disposed blades **72**, operating in the ovate chamber **73** of the pump cylinder **70**. Diametrically opposed flattened sides **74** of this cylinder provide vertical fluid passages **75** by which communication is effected between the two pumps **26** and **27**, there being a third rotor sleeve **76** below the pump cylinder **70**, as may be seen in Figures 4, 7 and 8 and which also has flattened sides to continue the passages **75** to the lower pump **27**.

The rotor **47** is also hexagonal in transverse section through each of the pumps **26** and **27**, as in the case of the motors **22** and **23**, in order to define flats **76*a*** (Figure 6) to relieve fluid which would otherwise be trapped between the vanes **72** and the walls of the chamber **73** as the vanes traverse the discharge ports **77*a*** of the chamber **73**.

The lower motor **23** is identical in construction and operation to the motor **22** just described. Moreover, the lower pump **27** is of the same construction and operates in the same manner as the pump **26** which has been described above, hence it is considered that the detailed description of the upper motor and pump will suffice for the lower motor and pump **23** and **27**, respectively.

It is considered an important characteristic of the invention that the motors **22** and **23** are each aided in their starting action by power fluid introduced behind the vanes **60** by way of axial passages **77** in the rotor **47** which extend axially in the rotor **47** from the diametrical passages **54*a*** in the end bearing plates **54** to the space behind the vanes **60** of the motors **22** and **23**. Fluid thus entering behind the vanes **60** tends to impose an outward radial thrust thereon for the initial starting action of the motors. The fluid is bled from the motors through axial passages **77*b***, from which a part of the fluid escapes through a lateral passage **78** in the rotor **47**, which effects communication between the axial passage **77*b*** and an annular groove **77*c*** (Figure 8) in the external surface of the rotor and from which groove fluid emerges into the fluid discharge passage **68** through the orifice **77*d***. The remaining fluid passing downwardly through the axial passage **77** continues through an axial passage 77*e* (Figure 8) into the space behind the vanes 72 of the upper pump 26 to thus thrust the vanes radially outward. From the pump 26 fluid is bled through an axial passage 77*f* from which part of the fluid moves through a lateral passage 77*g* in the rotor 47 into an annular groove 77*h* in the wall of the rotor by way of an orifice 77*i*, to thus lubricate between the rotor 47 and the rotor sleeve 76. The remaining fluid continues downwardly through an axial passage 77*j* into the space behind the vanes of the lower pump 27 to extend the vanes thereof as in the case of the upper pump 26 and the motor 22.

Fluid under pressure from the power fluid inlet of the lower motor 23 passes through the lower by-pass 58 into the diametrical channel 54*a* of the lower rotor bearing 54, thence through the axial fluid passage 79 and into the space behind its vanes 60 and is bled therefrom through axial fluid passage 72*a* from which a part of the fluid moves through a lateral passage 78 into the annular space 78*b* in the rotor 47 and is released therefrom for discharge through an orifice 78*c* (Figure 8) in the rotor sleeve embracing the rotor 47 between the lower pump and motor 27 and 23, respectively. Communication is effected between the axial passage 72*a* and the lower pump 27 through an axial fluid passage 78*d*.

From the foregoing it will be seen that balanced fluid pressures are maintained on the vanes of both of the motors 22 and 23 as well as on the vanes of both pumps 26 and 27 while at the same time lubricating the space between the rotor sleeves and rotor.

In operation, the manifold casing 11 is run into the well casing 10 on the string of tubing 12 with the macaroni tubing 19 strung with the tubing 12. After the manifold casing 11 has been submerged in the fluid of the well, the pump assembly 32 is run into the manifold casing by means of a wire line to which is attached a running tool adapted for releasable engagement with the stem or pump carrier 33, and the landing nipple 14 is set down on the stop collar 48. A pup joint 80 (Figure 1) is suspended from the lower end of the manifold casing 11 before it is run into the well and below the pup joint is the conventional standing valve, not shown.

Power fluid is pumped from the surface downwardly through the macaroni tubing 19 and this fluid enters the inlet ports to the motors 22 and 23 by way of the manifold 15 and the registering ports 20 and 39 of the landing nipple 14 and shell 32, respectively, and the registering ports 21 and 45 of these elements to serve respectively the upper motor 22 and the lower motor 23. Also, the fluid passes into the motor cylinders 62 by way of its inlet ports 66 to cause the vanes 60 to rotate. At the same time, fluid enters at each end of the rotor 47 by means of the by-passes 56 in the motor cylinders and channels 54*a* of the bearings 54 to equalize the pressures on the ends of the rotor, causing the latter to "float" during its high speed rotation.

Power fluid also enters the space within the rotor 47 rearwardly of the blades or vanes 60 at the same time rotary thrust is applied to revolve the vanes so that the latter are at all times urged operatively outward against the walls of the chamber 61.

Rotation of the rotor 47 by the vanes 60 of both motors 22 and 23 causes the pumps 26 and 27 to create a partial vacuum in the suction manifold 16, to fill which fluid from the well rises through the strainer 51, through the suction manifold 16 and into the inlet ports of both pumps as indicated by the arrows in Figure 8. Fluid elevated by pump suction is discharged into the manifold 17, along with the power fluid discharged by the two motors 22 and 23. The commingled fluids are forced to the surface by the combined pressures developed by the pumps through the tubing 12 and a part of the fluid is recirculated under pressure through the pumping apparatus after having been suitably cleansed to remove foreign matter therefrom.

It is clearly evident from the drawing and the foregoing description that in wells producing considerable salt water along with the oil, it is desirable to increase the capacity of the pump. This is easily accomplished by extending the landing nipple 14 to accommodate two or more of the assemblies shown and described.

Manifestly, the construction as shown and described is capable of some modification, and such modification as may be construed to fall within the scope and meaning of the appended claims is also considered to be within the spirit and intent of the invention.

What is claimed is:

1. In a hydraulic deep well pump, a manifold casing adapted for suspension on a string of tubing in a well and comprising a landing nipple having a power fluid inlet manifold, a well suction manifold and a discharge manifold, each having ports in communication with said landing nipple, a tubular shell slidably mounted in said landing nipple and having ports in communication with the ports of said landing nipple, annular, longitudinally spaced packing means carried by said shell in sealing engagement with the walls of said landing nipple on opposite sides of said ports, an elongate rotor rotatable in said shell, longitudinally spaced fluid actuated vane motors carried by said rotor, longitudinally spaced fluid pumps carried by said rotor, means for introducing power fluid from the surface to said motors through said inlet manifold to actuate the same and to propel said rotor and pumps to influence upward travel of well fluid into and through the ports of said landing nipple, said pumps and into said discharge manifold to commingle with power fluid discharged by said motors in its upward course through said tubing string, means for introducing power fluid into said shell at each end of said rotor at equal pressures to suspend the same in said shell and means for injecting power fluid into said motors to extend the vanes thereof.

2. In a hydraulic deep well pump, an elongate, tubular landing nipple having a power fluid inlet port, a well fluid inlet port and a plurality of fluid motor and pump discharge ports, a manifold embracing said power fluid inlet port, a suction manifold for said well fluid port and a discharge manifold for said discharge ports, a tubular shell slidable into said landing nipple having ports in register with the ports of said landing nipple, packing means carried by said shell in sealing engagement with said landing nipple on opposite sides of each of said ports, a rotor in said shell, a plurality of fluid motors spaced longitudinally in said rotor, each having communication with the manifolds of said power fluid inlet and said discharge ports, said motors each comprising a series of radially movable vanes, a plurality of fluid pumps in said rotor, each comprising radially movable vanes, means for introducing power fluid into the manifold of said power fluid inlet port to actuate said motors to propel said motor and pumps to suck well fluid into said suction manifold through said well fluid inlet port, its manifold and said pumps into said discharge manifold for admixture with the discharge fluid of said motors.

3. The structure of claim 2, and means for the fluid counterbalancing of said rotor by the introduction of power fluid into said shell at each end of said rotor at equal pressures.

4. The structure of claim 2, and means for introducing power fluid under pressure behind the vanes of said fluid motors to effect outward radial displacement thereof as a starting action for said motors.

5. The structure of claim 4, in which the fluid introduced behind the vanes of said motors is released into an annular passage about the rotor for lubricating the walls thereof.

6. A deep well hydraulic pump comprising an elongate, tubular landing nipple having a well fluid inlet port adjacent its lower end and a power fluid inlet port spaced above said well fluid inlet port, a series of fluid

discharge ports, a tubular shell slidable into said landing nipple, annular packing means spaced longitudinally on said shell in sealing engagement with the walls of said landing nipple on opposite sides of each of said ports, an elongate rotor rotatable in said shell, a fluid motor spaced from each end of said rotor, each of said motors comprising vanes movable in radial slots in said rotor, a pair of fluid pumps spaced apart between said motors, each comprising vanes slidable in radial slots in said rotor, means effecting communication between each of said motors and the power fluid inlet ports and said discharge ports, means effecting communication between said well fluid inlet port and said pumps and between said pumps and said discharge ports for the upward passage of fluid from a well, means for introducing power fluid into said power fluid inlet port to actuate said motors to revolve said rotor and to operate said pumps.

7. The structure of claim 6, said rotor having axial fluid passages at each end for the ingress of power fluid into said motors behind their vanes to effect outward radial thrust thereon as a starting action of said motors; said fluid being discharged into annular grooves in said rotor between its walls and said sleeve to lubricate said rotor.

8. The structure of claim 6, and means for by-passing a part of said power fluid into said shell at each end of said rotor in equal pressures to suspend the same for free rotation in said shell.

9. A deep well hydraulic pump comprising an elongate landing nipple having a well strainer on its lower end, an elongate tubular shell slidably disposed in said landing nipple, said shell and said landing nipple having registering power fluid inlet ports, well suction ports communicating with said well strainer, and fluid discharge ports, packing means on said shell in sealing engagement with said landing nipple on opposite sides of each of said ports, an elongate rotor rotatable in said shell, a plurality of fluid vane motors spaced longitudinally in said rotor and having communication with said power fluid inlet ports and said discharge ports, a plurality of fluid pumps spaced longitudinally in said rotor and having communication with said well suction ports and said discharge ports and means for introducing power fluid under pressure into said power fluid inlet ports to actuate said rotor and pumps to influence well fluid upwardly through said suction ports, said pumps and into said discharge ports for admixture with fluid discharged by said motors.

10. The structure of claim 9, and means to floatingly suspend said rotor by power fluid introduced under equal pressures into said shell at each end of said rotor.

11. The structure of claim 9, said rotor having axial fluid passages above and below each of said fluid motors for maintaining internal fluid pressure on the vanes of said motors to impose a starting thrust on said vanes, the fluid being discharged through one of said passages exteriorly of said rotor to lubricate the same between said rotor and shell.

12. The structure of claim 9, and a rotor sleeve embracing said rotor between said fluid motors and said pumps, each formed to define longitudinal and circumferential fluid passages between said shell and said rotor to effect communication between said motors and their respective intake and discharge ports and between each of said pumps and their respective intake and discharge ports and with each other.

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