

[54] **CABLE-SUSPENDED, LINER-SUPPORTED
SUBMERSIBLE PUMP INSTALLATION
WITH LOCKING DISCHARGE HEAD**

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[22] Filed: **Aug. 8, 1972**

[21] Appl. No.: **278,741**

[52] U.S. Cl. **417/360, 417/424, 415/501,**
166/217

[51] Int. Cl. ... **F04d 29/60, F04d 29/62, E21b 23/00**

[58] Field of Search **417/360, 424; 415/501;**
166/206, 209, 217

[56] **References Cited**

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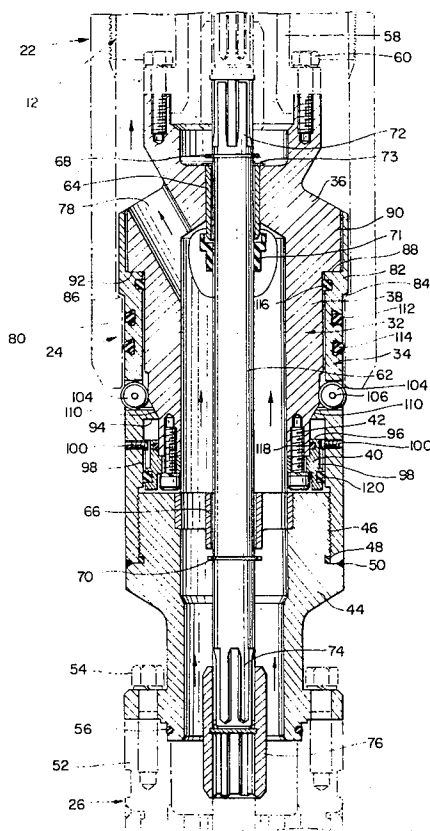
Attorney, Agent, or Firm—Shapiro & Shapiro

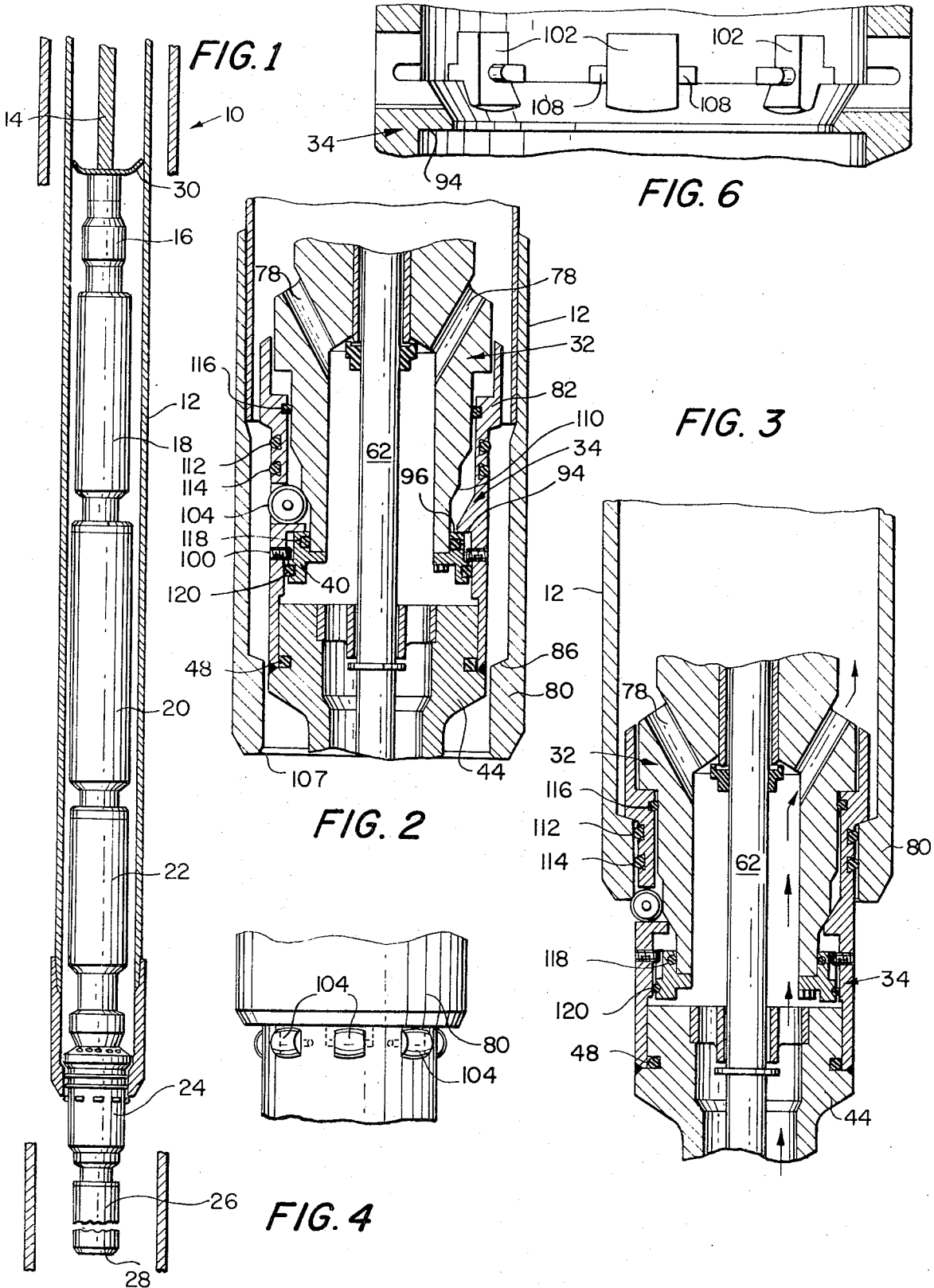
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ABSTRACT

A cable-suspended, submergible electric pump installation has a discharge head provided with a locking device for locking the discharge head at an operative position within a well casing, so that the installation cannot be dislodged by bottom hole pressure. The discharge head may rest upon an annular shoe at the bottom of a cylindrical liner, the locking device having locking elements which engage the lower edge of the shoe, and the discharge head being provided with seals which isolate the locking elements from the high pressure of the pumped fluid within the liner. The locking device operates automatically to lock the discharge head to the shoe and is unlocked automatically when the suspending cable is pulled to retrieve the pump installation. The discharge head provides substantially unrestricted flow of fluid from the pump into the liner and is hydraulically overbalanced, so that bottom hole pressure tends to lock the discharge head more firmly in position.

14 Claims, 12 Drawing Figures





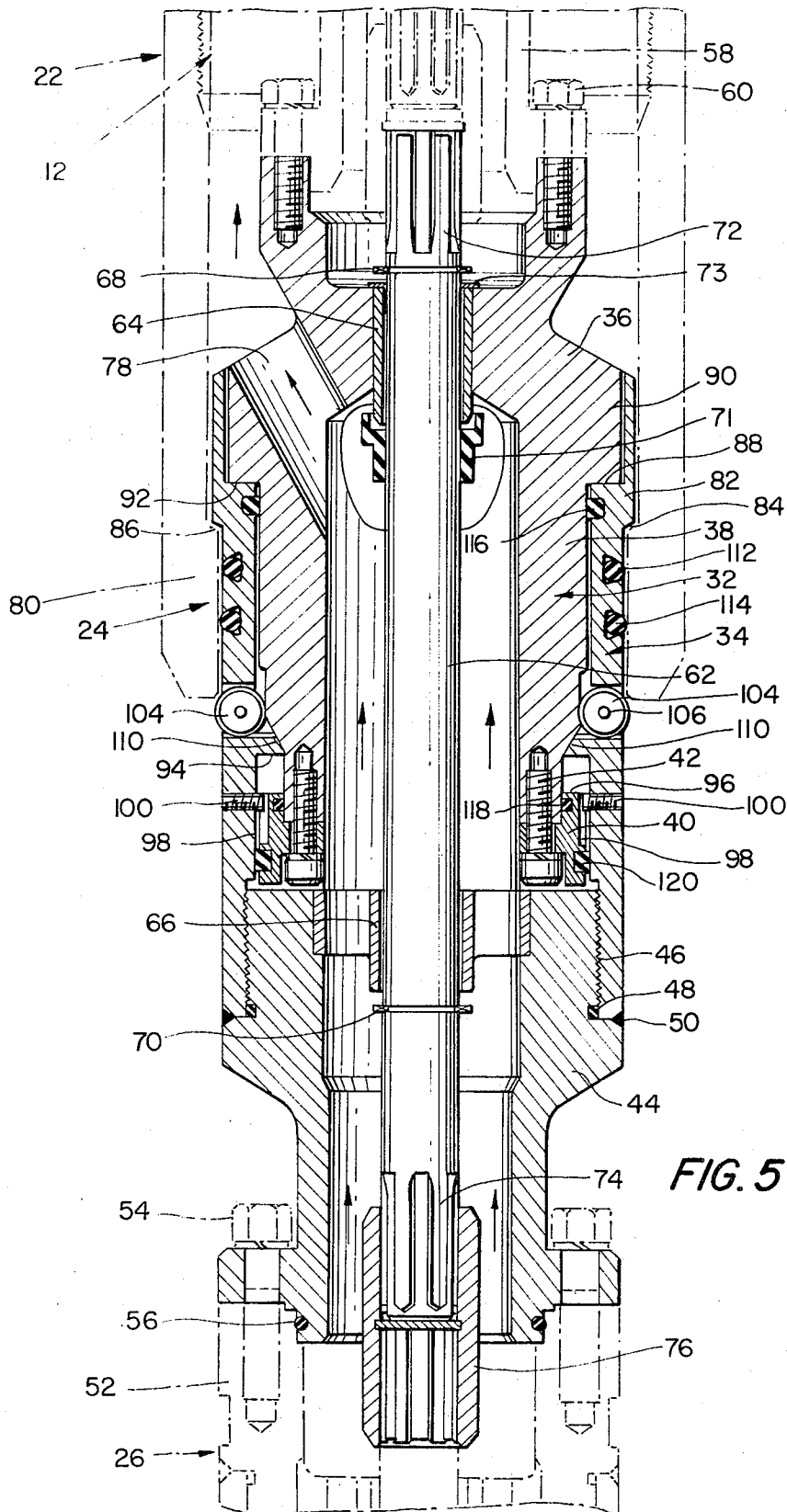
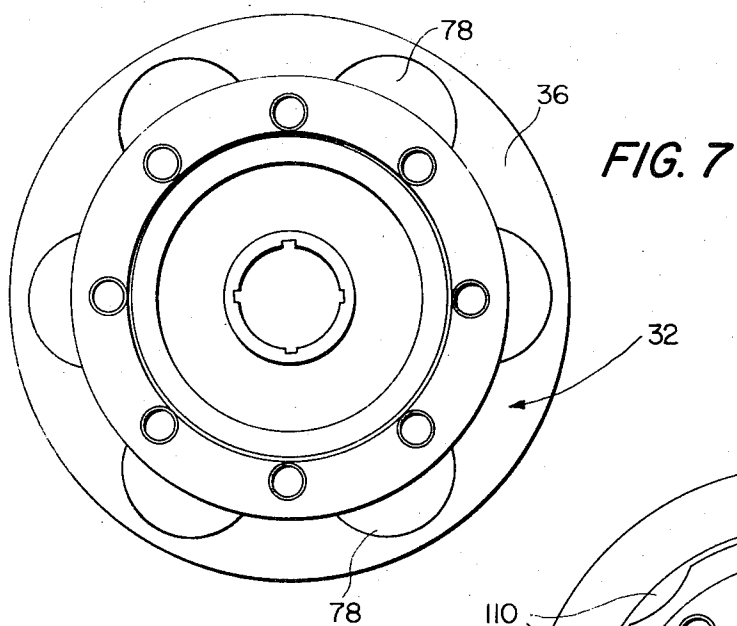
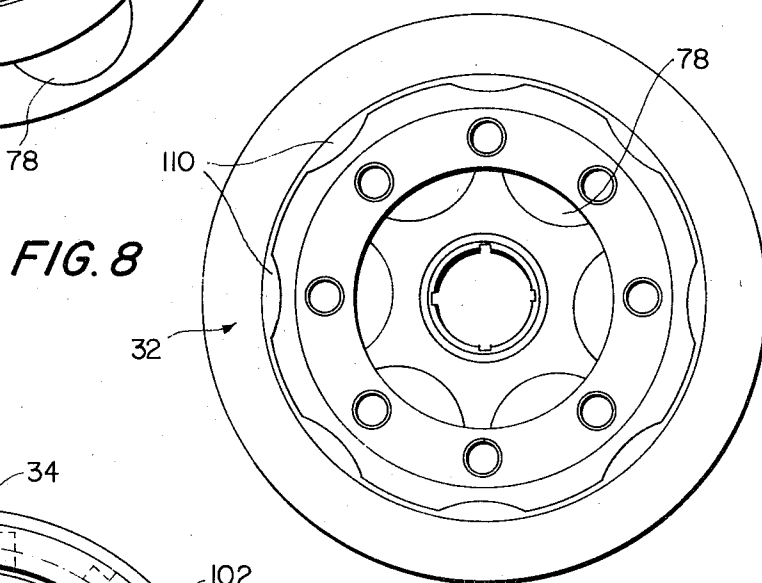
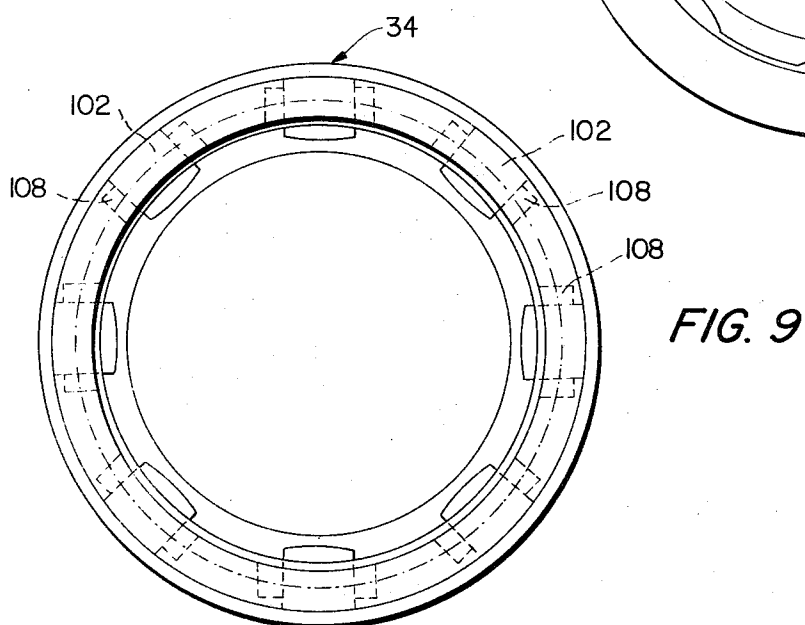


FIG. 5



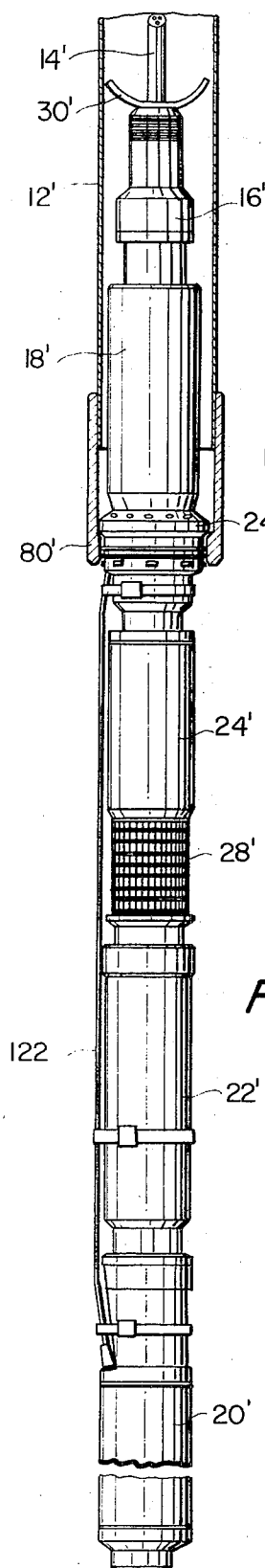


FIG. 10

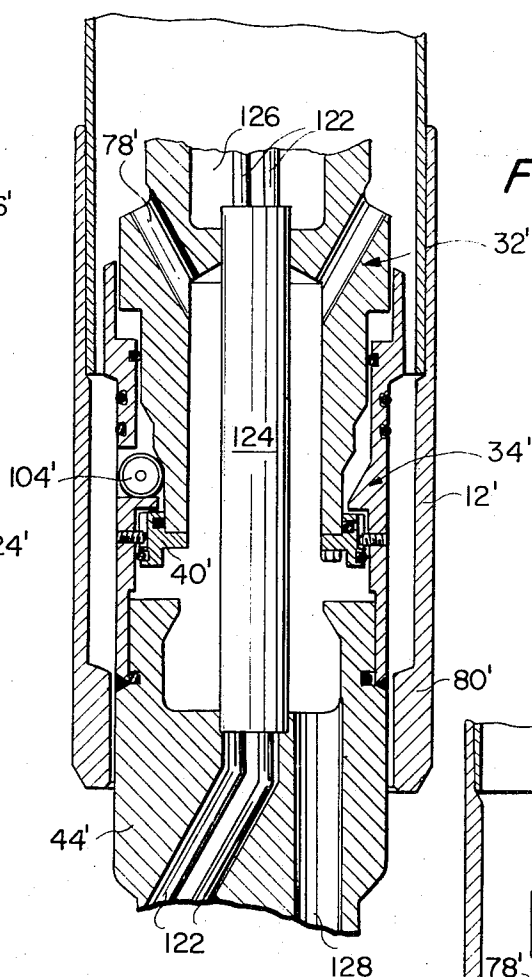


FIG. 11

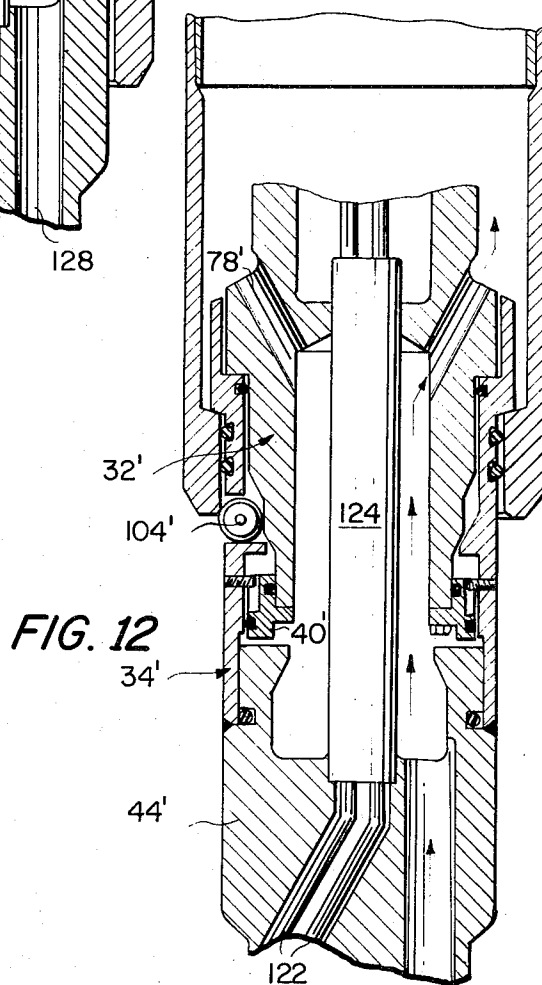


FIG. 12

CABLE-SUSPENDED, LINER-SUPPORTED SUBMERSIBLE PUMP INSTALLATION WITH LOCKING DISCHARGE HEAD

BACKGROUND OF THE INVENTION

This invention is concerned with submersible pump installations and is particularly concerned with an automatically locking pump discharge head.

U.S. Pat. No. 3,672,795, granted June 27, 1972 and assigned to the same assignee as the present application, discloses and claims a cable-suspended, submersible electric pump installation for use in a well casing. A retrievable cylindrical liner encircles the cable and extends into the well casing from ground level to enclose the discharge head of the pump unit, a shoe being provided on the liner to support the installation at a predetermined operative level in the well. The pump intake communicates with the well fluid below the shoe, and the pump discharges to the earth's surface through the liner. The discharge head is provided with sealing means which isolate the high pressure region within the liner from the low pressure region at the pump intake below the liner. Although the invention of the aforesaid prior patent provides many advantages over earlier submersible pump installations, bottom hole well pressure against the exposed surface of the unit below the shoe may tend to expel the unit when the pump is idle.

BRIEF DESCRIPTION OF THE INVENTION

It is accordingly a principal object of the present invention to provide an improved cable-suspended submersible pump installation in which the discharge head of the pump is locked in position at an operative level within the well and is protected against undesired expulsion.

A further object of the invention is to provide improved apparatus which performs the functions of a downhole packer, a discharge packer and a lockdown device within a well casing or liner and which permits substantially unrestricted pumping of fluid at high volumes.

Another object of the invention is to provide apparatus of the foregoing type which is hydraulically overbalanced so that bottom hole pressure tends to lock the device more firmly in position.

Still another object of the invention is to provide apparatus of the foregoing type incorporating seals which isolate the locking elements from the high pressure region to which fluid is pumped.

Yet another object of the invention is to provide apparatus of the foregoing type which has sufficient internal space to accommodate a pump shaft extending from an electric motor at one side of the discharge head to a pump at the opposite side of the discharge head or to accommodate energizing conductors for a motor at the same side of the discharge head as the pump, with the conductors sealed away from the high discharge pressure.

A still further object of the invention is to provide apparatus of the foregoing type capable of being installed, locked and unlocked automatically, and retracted without damage and without the use of sacrificial shear pins or special fishing or wire line tools.

Briefly stated, the present invention employs a submersible pump having a discharge head provided with means for locking the discharge head at an operative

position within a well casing. The installation preferably includes a cylindrical liner within the well casing through which the pump unit is lowered into the casing by means of a cable. When the discharge head reaches the desired position within the well casing a flange of an outer tubular member of the discharge head comes to rest upon an annular shoe of the liner, but an inner member continues to move downwardly to a limited extent. The outer member carries a plurality of locking rollers which are urged outwardly by the continued downward movement of the inner member and which are caused to engage the lower edge of the shoe to lock the discharge head in position. The weight of the apparatus above the inner member is sufficient to urge the inner member downwardly to lock the discharge head in position automatically, but the device may be unlocked by pulling the suspending cable. The discharge head has sufficient internal space to permit substantially unrestricted flow of fluid to the liner from the pump, which is suspended from the outer member of the discharge head below the shoe. The discharge head is hydraulically overbalanced so that the inner member is urged downwardly by bottom hole pressure to maintain the discharge head locked in position, the locking rollers being isolated from the high pressure of the pumped fluid by sealing means. The internal space within the discharge head is sufficient to pass a pump shaft to a motor above the discharge head or to pass electrical energizing conductors to a motor below the discharge head, the conductors being isolated from the high pressure of the pumped fluid.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further described in conjunction with the accompanying drawings, which illustrate preferred and exemplary embodiments, and wherein:

FIG. 1 is a longitudinal sectional view of a pump installation in accordance with the invention shown supported upon a liner within a well casing;

FIG. 2 is a longitudinal sectional view of a discharge head in accordance with the invention showing the relative positions of inner and outer members of the head as the pump installation is lowered into the well;

FIG. 3 is a view similar to FIG. 2, but showing the relative positions of the inner and outer head members after the discharge head has been installed upon the liner;

FIG. 4 is a fragmentary side elevation view illustrating the relationship of locking rollers of the discharge head and a liner shoe;

FIG. 5 is a longitudinal sectional view illustrating the discharge head in greater detail and showing the relationship to adjacent components;

FIG. 6 is a fragmentary longitudinal sectional view illustrating slots formed in the discharge head for receiving the locking rollers;

FIG. 7 is a top plan view of the inner member of the discharge head;

FIG. 8 is a bottom plan view of the inner member of the discharge head;

FIG. 9 is a top plan view of the outer member of the discharge head;

FIG. 10 is a longitudinal sectional view of another pump installation embodiment in accordance with the invention;

FIG. 11 is a longitudinal sectional view of the discharge head of the embodiment of FIG. 10, illustrating

the relation positions of inner and outer members as the discharge head is being lowered into the well; and

FIG. 12 is a view similar to FIG. 11, illustrating the relative positions of the inner and outer members of the discharge head with the discharge head locked upon the liner shoe.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the drawings, and initially to FIG. 1 thereof, the invention is concerned with a submergible pump installation for use in a well, the casing 10 of which is shown fragmentarily. The casing extends downwardly from the usual well head at the earth's surface and preferably, although not necessarily, contains a cylindrical liner 12 spaced inwardly from the casing 10 and approximately coaxial therewith. The liner also extends downwardly from the well head to a level at which the discharge head of the pump is to be located in operative position.

The submergible pump installation is suspended within the well casing, through the liner 12 in the form shown, by a cable or wire line 14. The cable may include weight-supporting strands as well as electrical conductors, the latter preferably being sealed from the fluid within the well. If desired, separate weight-supporting and electrical cables may be employed. The weight-supporting strands are anchored within a cable socket 16, which may be of the type shown in Arutunoff Pat. No. 3,424,485, for example. Suspended collinearly from the cable socket 16 are a pothead or splicing chamber 18, an electric motor 20, a motor protector 22, a discharge head 24, and a centrifugal or turbine pump 26 having an intake at the bottom 28. A rubber sand check is shown at 30. The present invention is concerned with an improved installation of this type, which may be locked in position upon the liner 12 or, alternatively, upon the well casing itself.

As shown in FIG. 5, the discharge head 24 comprises a tubular inner member 32 and a tubular outer member 34. The inner member has a top wall 36, which may be integral with the cylindrical side wall 38. A collar 40 is affixed to the lower end of the inner member by means of screws 42. The outer member has a base 44 affixed to its lower end by means of threads 46, an O-ring seal 48 and a solder seal 50 being provided between the threaded parts. The lower end of the base 44 is secured to the housing 52 of the pump by means of screws 54 and is sealed thereto by an O-ring 56. The upper end of the inner member 32 is secured to the housing 58 of the motor protector by means of screws 60.

The discharged head 24 is hollow, providing adequate space for passing the pump shaft 62, which extends from the motor 20 (FIG. 1) through the motor protector 22 and through the discharge head 24 to the pump 26. The pump shaft is supported in the discharge head by a bushing 64 and by a bearing 66, snap rings 68 and 70 being provided upon the shaft beyond the bushing 64 and the bearing 66, respectively. A shedder is shown at 71 and a thrust bearing at 73. The pump shaft 62 is sectional, the sections being splined as shown at 72 and 74 in FIG. 5 and being connected by means of couplings, such as the coupling 76. At least one of the couplings, such as the coupling associated with splines 72, telescopes to permit a degree of elongation or contraction of the shaft.

The hollow interior of the discharge head 24 provides substantially unrestricted high-volume flow of fluid from the pump through the discharge head to a series of discharge ports 78 in the top wall 36 of the discharge head (see FIGS. 5, 7 and 8), the ports 78 having sufficient cross-sectional area to continue the flow without appreciable restriction.

As taught in the aforesaid U.S. Pat. No. 3,672,795, the liner 12 may be provided with an internal annular shoe 80 for supporting the discharge head 24 at its operative level within the well. The outer member 34 of the discharge head is provided with a flange 82 having a lower surface 84 which engages an upper surface 86 of the shoe 80 when the discharge head is in its operative position.

The inner and outer members of the discharge head are coupled for limited reciprocative movement along the axis of the pump shaft 62. As shown in FIGS. 3 and 5, at one limit of this movement a downwardly facing annular surface 88 of an external flange 90 of the inner member engages an upwardly facing annular surface 92 of an internal shoulder of the outer member. As shown in FIG. 2, at the other limit of this movement, a downwardly facing surface 94 of an internal shoulder of the outer member engages the upper surface 96 of the collar 40. The collar is provided with vertical slots 98 which receive pins 100 fixed to and projecting inwardly from the outer member 34, so that rotational movement of the outer member relative to the inner member about the axis of the pump shaft is prevented.

As shown in FIG. 6, the outer member 34 of the discharge head is provided with a series of circumferentially spaced slots 102 through the wall of the outer member. Each slot receives a roller 104 (see FIGS. 4 and 5). Each roller has oppositely projecting stub shafts 106 which fit within inwardly open notches 108 at opposite sides of the associated slot 102. The rollers are supported in the slots 102 for outward and inward rolling limited by the notches 108 and by the inner member 32, respectively. The rollers 104, although generally cylindrical, are preferably somewhat outwardly convex (the side extremities being slightly arcuate), so that the ends of the rollers are smaller in diameter than the central region of the rollers. The lower extremities of the slots 102 are appropriately contoured as shown in FIGS. 6 and 9. As will be seen hereinafter, the rollers are locking elements, the foregoing configuration facilitating locking and unlocking by rolling movement of the rollers relative to the lower edge of the shoe 80, which is preferably internally chamfered as indicated at 107.

Adjacent to each of the rollers 104, the outer surface of the inner member 32 is provided with a cam or ramp 110 (see FIGS. 5 and 8) for urging the associated roller outwardly when the inner member is moved downwardly within the outer member to the position illustrated in FIGS. 3 and 5. At this time the rollers 104 will project from their slots as shown in FIG. 4. When the inner member is moved upwardly relative to the outer member, as shown in FIG. 2, the rollers 104 are free to move inwardly until they again engage the outer surface of the inner member, at which time the rollers will not project from the outer member.

To install the apparatus of the invention upon a liner 12 of a well, the apparatus is lowered into the liner by means of a cable, such as the cable 14. The weight of the pump 26 suspended from the outer member of the

discharge head is sufficient to move the outer member downwardly with respect to the inner member to the position illustrated in FIG. 2, the pump shaft being elongated slightly by means of the slip coupling previously mentioned. The outer diameter of the pump is less than the inner diameter of the shoe 80 at the bottom of the liner, so that the pump passes through the shoe. However, the flange 82 of the outer member is too large to pass through the shoe and instead seats upon the upper surface 86 of the shoe. The weight of the apparatus affixed to the top of the inner member 32 of the discharge head bears downwardly upon the inner member, and as the cable is lowered a bit more, the inner member moves downwardly within the outer member 34 of the discharge head to the position illustrated in FIG. 3. As the result of this continued downward movement of the inner member, the locking rollers 104 are projected outwardly to engage the lower edge of the shoe 80, as shown in FIG. 3, thereby locking the discharge head upon the shoe. O-ring seals 112-120 isolate the locking rollers from the high pressure pump discharge within the liner. The top surface of the inner member of the discharge head exposed to the bottom hole well pressure (communicated through the discharge head and ports 78) has greater area than the lower surface of the inner member which may be subjected to substantially the same pressure. The discharge head is thus hydraulically overbalanced, a condition which ensures that bottom hole pressure urges the inner member of the discharge head downwardly to lock the discharge head more firmly in position upon the liner shoe. Expulsion of the discharge head due to bottom hole pressure is therefore prevented. Nevertheless, when it is desired to retrieve the pump installation from the liner, pulling the suspending cable will first move the inner member of the discharge head upwardly relative to the outer member, releasing the locking rollers 104 for inward movement and unlocking the discharge head from the liner.

FIGS. 10-12 illustrate an embodiment of the invention in which the motor 20' is below the pump 24' instead of above the pump as in the embodiment of FIG. 1. Primed reference characters designate parts similar to those previously described. In the modified embodiment energizing conductors 122, which may be part of cable 14' or a separate electrical cable, extend through the interior of the discharge head 24' instead of the pump shaft. A tube 124 is sealed within the hollow interior of the discharge head, so that the conductors 122 are not exposed to the high pressure within the discharge head. The conductors pass through tube 124 to an upper chamber 126 which communicates with the splicing chamber 18', also isolated from the high pressure region within the liner 12'. Fluid from the pump 24' passes through a passage 128 to the interior of the discharge head and then through the discharge head ports to the liner in the manner previously described.

In both of the embodiments described, the discharge head is capable of supporting the weight of the submersible pump installation, the cable, and the fluid column above the discharge head. The discharge head provides a retractable seal or packer capable of withstanding either or both the fluid column pressure and the bottom hole pressure and capable of preventing recirculation of the pumped fluid. The locking device prevents expulsion of the discharge head due to bottom

hole pressure. Locking and unlocking are accomplished automatically in conjunction with the usual lowering and raising of the suspension cable, without requiring additional operations, without destruction, and without the use of sacrificial shear pins or special fishing or wire line tools. The locking elements (and the motor energizing conductors in one embodiment) are isolated from the high pressure pumped fluid, avoiding the deleterious effects of corrosion and foreign matter. The discharge head provides sufficient internal area to permit large volume flow with minimum friction loss and turbulence, while also providing space to accommodate either the pump shaft or the motor leads. Although the invention has been described in conjunction with a well casing liner, the shoe which mates with the discharge head may be provided directly upon the casing.

While preferred embodiments of the invention have been shown and described, it will be apparent to those skilled in the art that changes can be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the appended claims.

The invention claimed is:

1. Apparatus for providing a suspended pump installation in a well casing, comprising a submersible pump having a discharge head, means for suspending the pump in the well casing, said discharge head having means for automatically locking the head within the well casing when the head is lowered to its operative position and having means for sealing the head within the well casing at said position to provide a high pressure region above the sealing means and a low pressure region below the sealing means, said discharge head having a discharge port at the high pressure region and said pump having an intake at the low pressure region, said discharge head having an outer member and an inner member coupled to the outer member for limited reciprocative movement, said outer member having means for supporting it in said well casing at said operative position, said locking means comprising locking elements and means for projecting said locking elements from said discharge head toward said well casing in response to downward movement of said inner member relative to said outer member when said outer member is supported at said operative position, said discharge head having additional sealing means between said outer and inner members for isolating said locking elements from the high pressure discharge of said pump while permitting relative reciprocation between said outer and inner members.

2. Apparatus in accordance with claim 1, wherein said pump is driven by an electric motor and is suspended from said outer member.

3. Apparatus in accordance with claim 2, wherein said motor is located below said discharge head and is connected to energizing conductors passing through said head but isolated from the fluid therein.

4. Apparatus in accordance with claim 2, wherein said motor is located above said discharge head and is connected to said pump by a shaft passing through said head.

5. Apparatus for providing a suspended pump installation in a well casing, comprising a submersible pump having a discharge head, means for suspending the pump in the well casing, said discharge head having means for automatically locking the head within the

well casing when the head is lowered to its operative position and having means for sealing the head within the well casing at said position to provide a high pressure region above the sealing means and a low pressure region below the sealing means, said discharge head 5 having a discharge port at the high pressure region and said pump having an intake at the low pressure region, said discharge head having an outer member and an inner member coupled to the outer member for limited reciprocative movement, said outer member having 10 means for supporting it in said well casing at said operative position, said locking means comprising locking elements and means for projecting said locking elements from said discharge head toward said well casing in response to downward movement of said inner member 15 relative to said outer member when said outer member is supported at said operative position, said inner member having a top surface exposed to the pressure in said well casing and of greater area than a bottom surface of the inner member also exposed to pressure in the well casing, whereby the pressure in said well casing urges said inner member downwardly relative to said outer member when said discharge head is supported at its operative position.

6. Apparatus for providing a suspended pump installation in a well casing, comprising a submergible pump having a discharge head, means for suspending the pump in the well casing, said discharge head having means for automatically locking the head within the well casing when the head is lowered to its operative position and having means for sealing the head within the well casing at said position to provide a high pressure region above the sealing means and a low pressure region below the sealing means, said discharge head 25 having a discharge port at the high pressure region and said pump having an intake at the lower pressure region, said discharge head having an outer member and an inner member coupled to the outer member for limited reciprocative movement, said outer member having means for supporting it in said well casing at said operative position, said locking means comprising locking 30 elements and means for projecting said locking elements from said discharge head toward said well casing in response to downward movement of said inner member relative to said outer member when said outer member is supported at said operative position, a liner extending downwardly in said casing and spaced inwardly from said casing, said liner having an inwardly directed annular shoe, and said means for supporting said outer member in said well casing comprising a 35 flange engageable with said shoe, said shoe having an inner diameter larger than the outer diameter of the pump, whereby the pump may pass through said shoe, said sealing means comprising seals externally of said outer member engageable with an inner surface of said shoe, said locking elements comprising a plurality of rollers engageable with the lower edge of said shoe when projected from said discharge head to lock the discharge head to the shoe.

7. Apparatus for providing a suspended pump installation in a well casing, comprising a submergible pump having a discharge head, means for suspending the pump in the well casing, said discharge head having means for automatically locking the head within the well casing when the head is lowered to its operative position and having means for sealing the head within the well casing at said position to provide a high pres-

sure region above the sealing means and a low pressure region below the sealing means, said discharge head having a discharge port at the high pressure region and said pump having an intake at the low pressure region, said discharge head having an outer member and an inner member coupled to the outer member for limited reciprocative movement, said outer member having means for supporting it in said well casing at said operative position, said locking means comprising locking elements and means for projecting said locking elements from said discharge head toward said well casing in response to downward movement of said inner member relative to said outer member when said outer member is supported at said operative position, said locking elements comprising rollers supported in slots of said outer member for inward and outward rolling movement.

8. Apparatus in accordance with claim 7, wherein said rollers are generally cylindrical but have a central region of larger diameter than the end regions for facilitating engagement with and disengagement from a cooperating locking shoe.

9. Apparatus in accordance with claim 1, wherein said inner member is hollow and has a top wall with a port therethrough providing substantially unrestricted fluid flow through said discharge head.

10. Apparatus in accordance with claim 1, wherein said inner member has a collar for suspending said outer member therefrom at one limit of the reciprocative movement of said outer member relative to said inner member.

11. Apparatus in accordance with claim 10, wherein said outer member has a shoulder for suspending said inner member therefrom at the opposite limit of the reciprocative movement.

12. Apparatus in accordance with claim 1, further comprising means for preventing rotation of said outer member about said inner member.

13. Apparatus in accordance with claim 1, wherein said means for suspending said pump comprises a cable having means for suspending said inner member therefrom, said inner member being free for said limited reciprocative movement relative to said outer member, the weight on said inner member being sufficient to move said inner member downwardly within said outer member when said outer member is supported at said operative position.

14. Apparatus for providing a suspended pump installation in a well casing, comprising a submergible pump having a discharge head, means for suspending the pump in the well casing, said discharge head having means for automatically locking the head within the well casing when the head is lowered to its operative position and having means for sealing the head within the well casing at said position to provide a high pressure region above the sealing means and a low pressure region below the sealing means, said discharge head 55 having a discharge port at the high pressure region and said pump having an intake at the low pressure region, said discharge head having an outer member and an inner member coupled to the outer member for limited reciprocative movement, said outer member having means for supporting it in said well casing at said operative position, said locking means comprising locking elements and means for projecting said locking elements from said discharge head toward said well casing in response to downward movement of said inner mem-

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ber relative to said outer member when said outer member is supported at said operative position, and an annular shoe having means for supporting the same in said casing, said means for supporting said outer member in said well casing comprising a flange engageable with said shoe, said shoe having an inner diameter larger than the outer diameter of the pump, whereby the pump may pass through the shoe, said sealing

means comprising seals externally of said outer member engageable with an inner surface of said shoe, said locking elements comprising a plurality of rollers engageable with the lower edge of said shoe when projected from said discharge head to lock the discharge head to the shoe.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,853,430
DATED : Dec. 10, 1974
INVENTOR(S) : O'Rourke

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 36, change "prefered" to --preferred--.

Column 2, line 41, change "adcordance" to --accordance--.

Column 3, line 50, change "discharged" to --discharge--.

Column 4, line 60, change "Fig." to --FIG.--.

Column 4, line 42, change "extrmities" to extremities--.

Claim 4, line 1, change "Appasratus" to --Apparatus--.

Claim 6, line 12, change "lower" to --low--.

Claim 8, line 2, change "cylinddrical" to --cylindrical--.

Signed and Sealed this

twenty-fifth Day of November 1975

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks