March 2, 1965 J. W. HARRIS ETAL 3,171,355

WELL PUMP

Filed March 14, 1963

Fig. 1

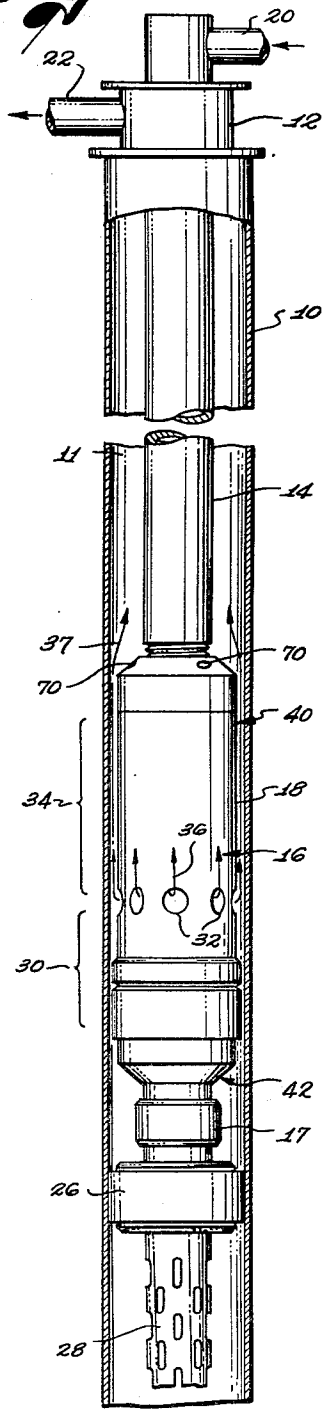
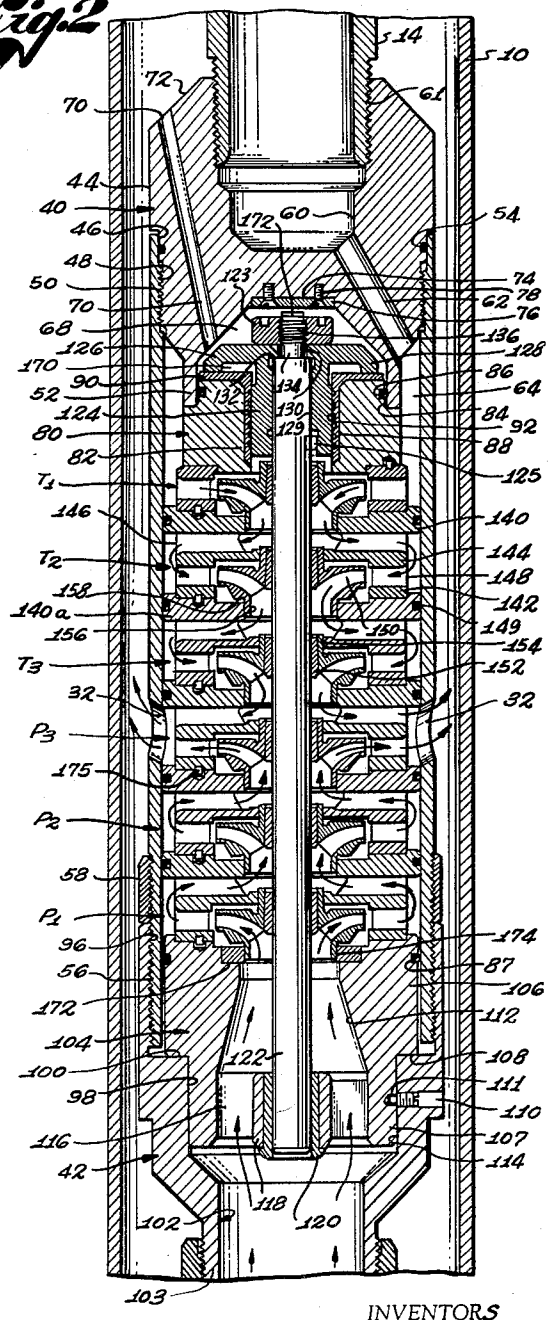


Fig. 2



INVENTORS
JACOB W. HARRIS
RICHARD C. FARNHAM
BY Fulwider, Patton, Rieber Lee, and Utecht
ATTORNEYS

United States Patent Office

3,171,355
Patented Mar. 2, 1965

1

3,171,355

WELL PUMP

Jacob W. Harris, Anaheim, and Richard C. Farnham, Whittier, Calif., assignors to Dresser Industries, Inc., Dallas, Tex., a corporation of Delaware

Filed Mar. 14, 1963, Ser. No. 265,085
8 Claims. (Cl. 103—87)

This invention relates generally to fluid driven pumps, and more particularly to fluid turbine-driven centrifugal type pump units for submerged, so-called bottom hole pumping operations within deep wells.

Such fluid driven turbo-pump units, to which this invention relates, employ a fluid reaction turbine and a fluid reaction or centrifugal type pump means coaxial coupled together to form a single compact, minimum diametered unit with the runners of the turbine and the impellers of the pump mounted coaxially on a common shaft. In the installation of such a pumping unit in an earth bore, such as an oil or water well, it is common practice, if not a practical necessity, to suspend the unit coaxially of the well bore such that the impellers and shaft of the turbine and pump rotate about a substantially vertical axis.

Heretofore, numerous difficulties have been encountered in constructing such turbo-pump units, particularly for vertical operation as before mentioned, which would operate with satisfactory efficiency and durability under all varying pumping load requirements and conditions, particularly those encountered within deep wells. Among such difficulties has been that of providing suitable bearing means for rotatably supporting the axial forces resulting from the weight and from the unbalanced axial fluid reaction forces upon the common, rotatably mounted turbine runners and pump impellers, under varying operating conditions.

It is therefore a principal object of this invention to provide a turbo-pump unit having improved means for rotatably supporting the resultant axial thrust forces of its runners, impellers, and shaft.

It is another object of this invention to provide a means for automatically balancing out the axial thrust forces acting upon the turbine and pump impellers.

It is still another object of this invention to provide improved means for rotatably supporting the weight of a vertically positioned turbine and pump impeller assembly unit.

It is still another object of this invention to provide improved means for effecting improved automatic balancing out of the variable unbalanced axial thrust of the rotating members of a turbine driven centrifugal pump unit, resulting from variations in pump loading conditions.

It is a further object of this invention to provide improved means for preventing wear and damage to the several impellers of the turbine and pump, which may result from variations in axial position thereof under varying load and during pump starting and stopping intervals.

It is a still further object of this invention to provide a fluid turbine-driven centrifugal pump unit having reduced running friction and bearing wear.

These and other objects, advantages, and features of novelty will be evident hereinafter.

In the drawings, which illustrate a preferred embodiment and mode of operation of the invention and in which like reference characters designate the same or similar parts throughout the several views:

FIGURE 1 is a view, partly in elevation and partly in longitudinal section, of a turbine driven pump unit assembly embodying the present invention and illustrating a manner of installation thereof in a typical oil well casing; and

FIGURE 2 is an enlarged, longitudinal sectional view of the turbine driven pump unit shown in FIGURE 1.

2

Referring first principally to FIGURE 1, a typical well casing is illustrated at 10, having installed on the upper end thereof a typical casing head 12. Within the casing 10 and suspended from the casing head 12 upon suitable pipe or tubing 14, as indicated generally at 16, is a turbo-pump unit embodying the features of the present invention. The turbo-pump unit 16 is of smaller outside diameter than the inside diameter of the casing 10 enabling it to be lowered into the casing upon the pipe or tubing 14 in conventional manner to the depth in the well from which the production fluid entering the well is to be lifted. The upper end of the pipe or tubing 14 makes connection through the casing head 12, in conventional manner, to an inlet pipe 20, which is in turn connected to a source of power fluid, such as oil, water, gas or the like, which may be supplied under suitable pressure through a fluid circulating pump, not shown.

The annulus 11 between the casing 10 and pipe 14 is connected at its upper end through the casing head 12, in conventional manner, to a fluid outlet pipe 22, which is in turn connected to a suitable receiver or storage means which may include means for separating and cleaning the thus received fluid and for returning a part thereof to the before-mentioned circulating pump for re-introduction under pressure through connection 20 to serve as the before-mentioned power fluid.

The lower suction inlet end of the turbo-pump unit 16 is coupled at 17 through a wall packer, which is more or less schematically illustrated at 26, to the upper end of a downwardly extending section of conventional strainer or perforated pipe 28. Packer 26 which may be of any conventional design, but preferably capable of being set and released in the well casing by manipulation of the suspending pipe or tubing 14, such as for example a conventional slip actuated hook wall production packer, serves to separate the annular space 11*a* in the lower portion of the well casing into which the strainer or perforated pipe 28 extends, from the annular space 11 in the upper portion containing the turbo-pump unit 16 and suspending pipe 14.

The lower portion of the turbo-pump unit housing 18, indicated generally at 30, contains the centrifugal pump section which receives production fluid from the lower portion of the well below the packer 26 through the strainer or perforated pipe 28 and discharges the same therefrom to the exterior of the housing 18 above the packer 26 through a plurality of intermediately located, circumferentially spaced-apart discharge ports 32. The upper portion of the turbo-pump unit housing 18, indicated generally at 34, contains the turbine drive section which receives pressure fluid at its upper end through pipe 14 and discharges the same, together with the before-mentioned production fluid from the centrifugal pump section, through the same discharge ports 32. The thus commingled fluid discharged through the ports 32 from both the pump section 30 and turbine section 34 flows upwardly, as indicated by the arrows 36 and 37, through the annular space 11 within the casing to the casing head 12 and thence through the outlet pipe 22 to the storage and separating means, as hereinbefore-mentioned.

Referring now primarily to FIGURE 2, the turbo-pump unit assembly 16 comprises an elongated cylindrical housing 18, which is closed at its upper end by a turbine inlet head 40 and is closed at its lower end by a pump inlet head 42.

The turbine inlet head 40 is formed with an exterior upper, cylindrical section 44 having an outside diameter substantially equal to that of the housing 18, an intremdiate section 46 of reduced outside diameter having external threads as shown at 48, which make screwed connection with corresponding internal threads 50 in the upper end of the housing 18, and a lower, downwardly extending, skirted section 52 of still further reduced outside

diameter. Suitable sealing means, such as an O-ring and groove as shown at 54 is provided between the inside wall surface of the housing 18 and the adjacent outside surface of the intermediate section 46 of the inlet head 40. The turbine inlet head 40 is also provided with a coaxial bore 60 extending partway therethrough from its upper end, the upper end portion of which makes screwed connection at 61 with the lower end of pipe 14. A plurality of downwardly, divergingly directed inlet passages, as shown at 62, extending through the turbine inlet head 40, interconnect the lower end of the bore 60 with the upper end of an annular space 64 formed between the outer cylindrical surface of the downwardly projecting annular skirted section 52 of the inlet head 40 and the adjacent inside surface of the housing 18.

The underneath end of the turbine inlet head 40 is formed with a coaxial, downwardly facing, generally frusto-conical shaped cavity 68, the lowermost internal cylindrical portion of which is bounded by the inner wall of the before-mentioned annular skirted section 52. A plurality of obliquely directed outlet ducts, as shown at 70, circumferentially interspaced between the before-mentioned passages 62, as shown in FIGURES 1 and 2 extending through the turbine inlet head 40, serve to interconnect the cavity 68 with the exterior of the turbine inlet head 40 at the upper exterior beveled end portion 72 thereof. The uppermost end portion of the frusto-conical recess 68 is formed with a downwardly facing, flat bottomed circular recess 74 in which is flushly seated a metal thrust disk 76, secured in place therein by means of two or more countersunk head machine screws, as shown at 78, the purpose of which will be more fully described hereinafter.

Seated coaxially upwardly within the lower portion of the skirted section 52 of the turbine inlet head 40 is an annular upper retainer body 80 having a coaxial bore 82, and formed with an outer upper end portion 84 of reduced outside diameter, which extends into said seating engagement with the skirted section 52. An O-ring seal and groove, as shown at 86, is provided between the contiguous surfaces of the skirted portion 52 and the upper end portion 84. The bore 82 of the annular upper retainer body 80 has fixed therein a sleeve shaped bearing liner 88, said liner 88 having integrally formed at its upper end a radially outwardly extending flange 90 which seats upon the annular, upper end surface of the upper retainer body 80. The inner cylindrical surface of the bearing liner 88 is formed with a plurality of axially spaced-apart, semi-circular sectioned, inwardly facing annular grooves, as shown at 92.

The pump inlet head 42 at the lower end of the housing 18, is formed with a coaxial bore therethrough having an upper internally threaded bore portion 96 with an inside diameter slightly less than the outside diameter of the housing 18, an intermediate bore portion 98 of reduced inside diameter, forming an upwardly facing annular shoulder 100, and a lower bore portion 102 of still further reduced inside diameter terminating in an externally threaded connection 103. The upper bore portion 96 of the pump inlet head is provided with internal threads 56, with which corresponding external threads on the lower end of the housing 18 makes screwed coupling connection. An annular lock ring 58 carried on the said external threads on the lower end of the housing 18 is adapted to be screwed into jamming engagement with the top end of the threaded portion 96 of the inlet head and thereby serves to lock the screwed connection between the pump inlet head 42 and the lower threaded end of the housing 18 in a longitudinally adjustable position relative to one another, as required to clamp the several turbine and pump assemblies axially together within the housing 18, as hereinafter more fully described.

Positioned within the lower end portion of the housing 18 and seated within the intermediate bore portion 98 of the bore of the pump inlet head 42 is a generally annular, lower retainer body 104 formed with an upper annular portion 106 having an outside diameter slightly less than the inside diameter of the adjacent portion of the housing 18 and with a lower annular end portion 107 of reduced outside diameter, thereby forming at the juncture of the upper portion 106 and the lower portion 107 a downwardly facing annular shoulder 108. The lower end portion 107 makes coupling engagement within the intermediate bore section 98 of the pump inlet head 42, with the downwardly facing annular shoulder 108 thereof seated upon the before-mentioned upwardly facing annular shoulder 100 of the pump inlet head 42. An O-ring seal and groove, as shown at 87 is provided between contiguous surfaces of the outside of the upper annular portion 106 of the retainer body 104 and the inside surface of the housing 18. A set screw 110 threaded through the wall of the pump inlet head 42 into engagement at its inner end with a drilled recess 111 in the lower retainer body 104 serves to lock the said retainer body firmly seated and free of axial and rotational movement within the pump inlet head 42.

The annular lower retainer body 104 is provided with a coaxial bore extending therethrough, said bore having an upper, upwardly converging, frusto-conical portion 112, and a lower cylindrical portion 114. Supported within the lower cylindrical bore portion 114 of the lower retainer body 104, by means of a spider structure comprising a plurality of radially extending, integrally formed web members as shown at 116, is a central, coaxially located, cylindrical shaped bearing housing 118. Press fitted within the bearing housing 118 is a sleeve bushing 120, which constitutes a bearing for the lower end of the turbine and pump drive shaft 122.

Rotatably and longitudinally slidably contained within the hereinbefore described sleeve shaped bearing liner 88 contained within the upper retainer body 80 is an annular shaped, combined shaft bearing and plunger member 124 having integrally formed at its upper end a coaxial, radially outwardly extending flange member or balancing disk 126, the outside diameter of which is greater than that of the annular plunger member 124, but less than the inside diameter of the adjacent walls of the cavity 68. The peripheral, marginal portion of the balancing disk 126 is formed with a downwardly depending annular rim 128 which normally, under non-operating conditions, rests upon and is suported by the upper surface of the radial flange portion 90 of the bearing liner 88.

The annular plunger member 124 is provided with a coaxial bore therethrough, the major section 129 of which has an inside diameter substantially greater than that of an upper end section 130, located centrally of the balancing disk 126, thereby forming at the juncture of such upper and lower bore sections a downwardly facing, annular shoulder 132 located coaxially of the before-mentioned balancing disk 126. The upper end of the shaft 122 is formed with an upwardly extending attachment portion 134 of reduced outside diameter and carrying external threads 136 adjacent its upper end. The upper end portion of the shaft 122 extends into and is fixed within the bore 128 in abutment with the before-mentioned downwardly facing shoulder 132 and with the upwardly extending attachment portion 134 of reduced diameter extending through the bore 130 in the balancing disk 126. An annular nut 123 threaded on the shaft threads 136 serves to retain the integral plunger member and balancing disks 124, 126 firmly attached to the upper end of the shaft 122. The plunger member 124 is keyed to the shaft 122, as shown at 125.

Contained coaxially within the housing 18 between the upper annular retainer body 80 and the lower annular retainer body 104, is a plurality of coaxial turbine drive stages and centrifugal pump stages, which generally occupy the upper and lower portions of the turbo-pump unit indicated at 34 and 30, respectively. For convenience of illustration, three turbine stages, located

and indicated generally at T_1, T_2, and T_3, and three centrifugal pump stages, located and indicated generally at P_1, P_2, and P_3 have been shown and described herein. However, a greater or lesser number of such stages in either or both the turbine section and pump section may be employed, the choice being dependent upon various factors of a particular installation such as, for example, the available differential pressure, quantity and kind of driving fluid, and the pumping head, volume and kind of fluid required to be handled by the pumping unit.

Each of the turbine drive stages, except for stage T_1 in which a separate diffuser section is coupled to the lower end of the annular upper retainer body 80, comprises in brief, with reference mainly to turbine stage T_2 as being typical, a turbine stater or cover body comprising an upper annular cover plate 140, a lower annular base plate 142, and an intermediate annular separator member 144, all preferably integrally formed in a single casting. Between the outer marginal portion of the intermediate annular separator member 144 and the annular base plate 142 is a vaned diffuser section 148 for directing flow of the power fluid laterally inwardly into the runner, as indicated by the arrow therein. Between the annular cover plate 140 and the intermediate separator member 144 is formed a radially vaned, annular passage 146 for flow of fluid discharged from the preceding stage to the diffuser section 148, as indicated by the arrow therein. An O-ring seal and groove as shown at 149 is provided around the outer periphery of each cover plate of each turbine cover body, making sealing engagement with the inside surface of the housing 18.

Rotatably contained within a generally cylindrical cavity formed within the diffuser section of the turbine cover body is an internally vaned, turbine runner 150 of the mixed flow type, adapted to receive power fluid radially and to discharge same axially. The runner 150 is secured to the shaft 122 by means of a tapered locking sleeve 152, which is press fitted between the bore of the hub 154 of the runner 150 and the cylindrical surface of the shaft 122. The runner hub 154 extends upwardly into and makes a relatively free rotatable fit within the circular opening in the center of the beforementioned intermediate annular separator member 144 of the cover body.

The turbine runner 150 is formed with a coaxial, downwardly extending, axial discharge sleeve 156 which, like the hub, makes a relatively free rotatable fit within a central, circular opening in the annular cover plate 140*a* of the next adjacent lower turbine stater cover body. Each of the runners is formed with an exterior, radially extending, downwardly facing, annular bearing surface as shown at 153, adapted under certain operating conditions, as hereinafter described, to make supporting engagement with the adjacent upper surface of the beforementioned cover member 140*a* of the next adjacent lower turbine cover body.

Each of the centrifugal pump stages has a construction which is similar to that of the hereinbefore described turbine drive stages, except that the vanes of the impeller and the diffuser sections in general may be shaped slightly differently, as is well known in the art, to provide for the proper direction of flow of pumped fluid therethrough which is in a direction opposite to that of the flow of fluid in the turbine drive stages, such flow in the pump stages and turbine drive stages being indicated by the several arrows therein. Also the first pump stage P_1 has a slightly modified form of cover body in which the base plate is formed in effect in two pieces, a separate replaceable ring member 172 being seated in an annular groove in the upper portion of the bore 112 of the retainer body 104. The ring member 172 serves to receive rotatably the downwardly extending sleeve 174 of the first pump stage impeller.

As hereinafter mentioned, the fluid discharged from the final stage of the turbine drive, which is that leaving the discharge of the runner of the turbine stage T_3, and the fluid discharged from the final pump section, which is that discharged from the impeller at the pump stage P_3 through the corresponding diffuser section, commingle within the adjacent portion of the housing 18 and are discharged directly therefrom through the ports 32 into the annular space intermediate the housing 18 and the casing 10, and thence flows up through said annular space and through annular space 11 to the casing head 12 and out through the outlet pipe 22, as hereinbefore mentioned.

The several turbine drive and centrifugal pump stater cage units or cover bodies are coaxially nested together, one upon another, and pin connected together as shown at 175, against relative rotation thereof, and such cover body units are clamped together axially by means and between the upper annular retainer body 80 and the lower annular retainer body 104. These retainer bodies are, in turn, clamped together by adjustment of the coupling of the threaded connection 56 between the lower end of the housing 18 and the pump inlet head 42. The hereinbefore described lock ring 58 serves to maintain such clamping adjustment.

In operation of the apparatus of the invention, power fluid is forced under suitable pressure down the tubing or pipe 14 to the upper end of the turbine pump unit 16 where it passes through the inlet passages 62 into the annular space 64 within the housing 18. From the annular space 64, the power fluid flows under pressure through the diffuser section radially inwardly into the passages in the runner of the first turbine drive stage T_1 from which it is discharged axially downwardly into the passage 146 of the cover body of the second turbine drive stage T_2. From the passage 146, fluid under pressure flows around the edge of the separator member 144 and radially inwardly through the diffuser section 148 into the vaned passages of the runner of the second stage turbine drive T_2. The pressure fluid discharged axially downwardly from the runner of the second stage turbine drive flows outwardly through the adjacent passage, through the diffuser section and radially inwardly into the runner of the third turbine drive stage T_3 in the same manner as that hereinbefore described. The power fluid finally discharged from the runner of the third turbine drive stage T_3 flows outwardly through the discharge ports 32, as hereinbefore mentioned.

Production fluid which has entered the bottom of the casing 10, flows in through the openings in the strainer pipe 24 and fills the passages within the centrifugal pump section of the housing 18. Rotation of the pump impellers by the turbine drive then causes the production fluid to be drawn in through the strainer pipe 24 and up into the central inlet of the impeller of the first pump stage P_1 from which it is discharged into the passages of the vaned cover body thereof and thence flows into the central inlet of the impeller of the second pump stage P_2 and so on until it is discharged from the third centrifugal pump stage P_3 and out through the before mentioned discharge passages 32.

The power fluid discharged from the last stage T_3 of the turbine drive and the production fluid from the last stage P_3 of the pump section commingles as they are discharged through the openings 32 in the housing 18 into the annular space in the casing and from there the commingled power fluid and pumped production fluid flows upwardly through the annular space 11 in the casing to the casing head 12 and thence is discharged through the outlet pipe 22 to the storage and separating means, as hereinbefore mentioned.

Because of the axial forces acting upon the several runners of the turbine drive stages and the impellers of the centrifugal pump stages resulting from the pressure differentials and dynamic forces of the fluids flowing therethrough which are seldom, if ever, in exact balance with each other, the whole rotating system including the shaft

122 is usually subjected to a resultant axial force, which tends to displace it and the rotors and impellers carried thereby axially relative to the turbine and pump cover bodies and housing. This axial force must be resisted by some means which is relatively free from friction and wear and which will automatically compensate for changes in the axial forces which must be resisted resulting from changes and variations in pumping conditions. Such means must also automatically maintain the proper axial position of the shaft 122 and the impellers and runners relative to the structural members of their surrounding cover bodies, otherwise inefficient running conditions will occur and even in extreme cases possible damage or destruction of the runners and impellers may result.

Usually, under normal operating conditions, the resultant axial force in the shaft 122 is downward relative to the stationary portions of the apparatus, and relatively friction free, automatic compensation for this downward force is accomplished as follows.

Sufficient clearance is provided at the outer edge and along the upper portion of the runner of the first stage turbine drive T_1 to permit pressure fluid from its diffuser to flow under pressure between the top of the runner and the bottom end of the annular retainer body 80, and thence into the space surrounding the drive shaft 122 at the lower end of the annular plunger member 124. The clearance between the outside diameter of the plunger member 124 and the inside diameter of the bearing sleeve 88, which may be approximately 0.006", while insufficient to prevent the plunger member 124 from serving as a shaft supporting bearing member, is sufficient to permit flow of a relatively small quantity of pressure fluid therethrough into the annular space 170 formed under the balancing disk 126 within the rim 128. The differential pressure thus established across the annular plunger 124 and the balancing disk 126 tends to lift the drive shaft 122 axially upwardly sufficient to balance the otherwise unbalanced downward axial forces therein. As the balancing disk 126 is thus lifted, the lower edge of the rim 128 is raised out of sealing contact with the upper surface of the bearing flange 90, thereby permitting escape of a small quantity of pressure fluid from space 170 into the cavity 68, thereby causing a small drop in pressure under the balancing disk 126. This action continues until equilibrium is reached between the fluid pressure acting upwardly on the plunger 124 and the balancing disk 126 and the downward force transmitted thereto by the shaft 122, and under such conditions of equilibrium, the lower edge of the rim 128 of the balancing disk 126 will float a short distance above and out of contact with the upper surface of the bearing flange 90.

The pressure fluid which thus escapes into the cavity 68 is exhausted through the passages 70 into the annular space between the casing 10 and pipe 14 at the upper beveled surface 72 of the turbine inlet head 40. It has been discovered that the provision for the discharge of pressure fluid from the cavity 68 to this particular low pressure location at the upper end of the turbine inlet head is an important factor not only in the proper functioning of the hereinbefore described balancing action, but also results in an important practical simplification of the structure of the upper end portion of the turbine pump unit. A particular advantageous feature of this arrangement is that it requires only a simple, single seal between the upper end of the housing 18 and the turbine inlet head 40, as shown at 54. Structural simplification and reduction in undesirable by-pass leakages is thus eliminated.

Under some conditions, where driving fluid pressure, and the character and head of the fluid being pumped rapidly vary causing surges, the resultant axial forces in the drive shaft 122 may be intermittently reversed to an upward direction relative to the unit and in such cases, the upper end portion 172 of the reduced diameter portion 134 of the shaft 122 is brought into rotating abutment with the lower surface of the thrust disk 74. The thrust disk thus acts temporarily as a thrust bearing.

Another important feature of this invention resides in forming each of the runners and impellers with an exterior, radially extending, downwardly facing annular bearing surface 158, as hereinbefore described. Such bearing surface 158 acts as a seat or thrust bearing means under certain operating conditions occasionally encountered, particularly in the event excessive wear has occurred at the lower edge of rim 128 of the balancing disk 126, which would permit such runners and impellers to lower into rotating contact with the upper surfaces and edges of the central passages through the cover plates of the several cover bodies. Such wear on the rim 128 apparently occurs mainly at the times when the pump is just starting or being shut down and the initial or final rotation of the runners, impellers, and shaft occur with the weight thereof being supported by the rim 128 of the balancing disk rim 126 in metal-to-metal rotating contact with the bearing flange 90. The turbine runners and pump impellers, as heretofore conventionally designed, had no provision such as that hereinbefore described for limiting the axial displacement thereof relative to their respective surrounding structure and therefore at a certain stage in the life and wear of the unit, sudden destruction of the runners and impellers occasionally resulted.

Since the power fluid as it enters the top of the turbo-pump unit is substantially free of foreign material, such as would have an abrasive effect on the various parts of the mechanism, abrasion of the turbine drive runners, bearings, and particularly the hereinbefore described axial thrust balancing mechanism will be maintained at a minimum.

It is to be understood that the foregoing is illustrative only and that the invention is not limited thereby, but may include various modifications and changes made by those skilled in the art within the scope of the invention as defined in the appended claims.

We claim:

1. In a turbo-pump for installation in wells, apparatus comprising:
- a housing adapted to be lowered into a well;
- a turbine in said housing having runners adapted to be driven by power fluid introduced thereinto;
- inlet means for introducing such power fluid into said housing and drivingly to said runners;
- a centrifugal pump in said housing having impellers adapted to pump fluid from such well;
- shaft means upon which said runners and impellers are fixed for support and rotation about a common axis;
- and means for balancing axial thrust in said shaft including:
  - a cylindrical outer bearing body,
  - a cylindrical inner bearing body rotatable and axially slidable in said outer bearing body,
  - means fixing one of said bearing bodies in said housing and the other bearing body to said shaft,
  - duct means in said housing interconnecting said inlet means and said bearing bodies to apply a differential fluid pressure across said inner bearing body in said outer bearing body, whereby to apply an axial balancing force to said shaft,
  - and means, actuatable by axial displacement of said inner and outer bearing bodies from a predetermined position relative to one another to vary the said differential pressure.

2. In a turbo-drive for installation in wells, apparatus comprising:
- a housing adapted to be lowered into a well;
- a turbine in said housing having runners adapted to be driven by power fluid supplied thereto;
- inlet means for introducing such power fluid into said housing and drivingly to said runners;
- shaft means upon which said runners are fixed for support and rotation therewith about a common axis;

and means for balancing axial thrust in said shaft including:

a cylinder fixed in said housing adjacent one end of said shaft,

plunger means fixed to said shaft and rotatable and axially slidable in said cylinder,

duct means in said housing interconnecting said inlet means and one end of said cylinder to apply differential fluid pressure across said plunger in said cylinder, whereby to apply an axial balancing force to said shaft, the clearance space between said cylinder and plunger being such as to permit a relatively low volume of fluid flow therethrough from said one end to the other end,

and control means, actuatable by axial displacement of said shaft from a predetermined position to vary the said differential pressure and thereby said force such as to tend to restore said shaft to said predetermined position, said control means including:

means fixed to said shaft adjacent the other end of said cylinder to vary the resistance to escape of fluid from the other end of said cylinder in accordance with said axial displacement of said shaft.

3. In a turbo-drive unit for installation in wells, having a housing adapted to be lowered into a well, a turbine in said housing having runners adapted to be driven by power fluid introduced thereinto, inlet means for introducing such power fluid into said housing and drivingly to said runners, and shaft means in said housing upon which said runners are fixed for support and rotation therewith about a common axis, means for balancing axial thrust in said shaft comprising:

a cylinder bearing means fixed in said housing adjacent one end of said shaft and having an annular outer end surface;

plunger bearing means fixed to said one end of said shaft and rotatable and axially slidable in said cylinder bearing means;

an annular flange fixed to the outer end of said plunger bearing means and extending laterally over an adjacent portion of the said annular outer end surface of said cylinder bearing means, the clearance between said flange and said outer end surface thereby being variable in accordance with axial displacement of said shaft means;

and duct means in said housing interconnecting said inlet means and the inner end of said cylinder bearing means to apply fluid pressure to the inner end of said plunger bearing means in said cylinder bearing means, whereby to apply an axial balancing force to said shaft.

4. In a turbo-drive unit for installation in wells having a housing adapted to be lowered into a well bore, a turbine in said housing having runners adapted to be driven by power fluid introduced thereinto, inlet means for introducing such power fluid into said housing and drivingly to said runners, shaft means in said housing upon which said runners are fixed for support and rotation about a common axis, means for balancing axial thrust in said shaft comprising:

a cylindrical bearing support means fixed in said housing adjacent one end of said shaft and having a coaxial bearing bore therethrough terminating in an annular outer end surface;

shaft bearing means fixed to said shaft and rotatable and axially slidable in the said bearing bore of said bearing support means;

duct means in said housing interconnecting said inlet means and the inner end of said bearing support means to apply a differential fluid pressure across said shaft bearing means in said bearing support means, whereby to apply an axial balancing force to said shaft, there being provision for a relatively low rate of leakage of such fluid between the bore of said bearing support means and said shaft bearing means from the inner to the outer end thereof;

and control means, actuatable by axial displacement of said shaft and said shaft bearing means from a predetermined position relative to said bearing support means to vary the said differential pressure, said control means including an annular flange fixed to the outer end of said shaft bearing means and extending laterally over an adjacent portion of the said annular outer end surface of said bearing support means, the clearance between said flange and the said annular outer end surface being variable in accordance with said axial displacement, thereby to vary said rate of leakage.

5. In a turbo-drive unit for installation in wells, apparatus comprising:

a cylindrical housing adapted to be lowered into a well, said housing including an upper inlet head coaxially joined to the upper end portion of a cylindrical housing shell;

a turbine in said housing having runners adapted to be driven by power fluid supplied thereto;

inlet pipe connection means extending coaxially of of the top of said upper inlet head for introducing such power fluid into said inlet head, the outside diameter of said inlet pipe connection means being substantially less than the outside diameter of said upper inlet head, thereby forming a surrounding, upwardly facing shoulder on the exterior of said upper inlet head;

a coaxial, downwardly facing, generally cylindrical recess formed in the lower end of said upper inlet head;

an annular retainer body having a coaxial bore therethrough and an annular upper end surface in said retainer body making coaxial coupling engagement with the lower end portion of said cylindrical recess, thereby forming therebetween a generally cylindrical cavity;

a fluid duct in said upper inlet head directly interconnecting said cavity with said upwardly facing shoulder of said inlet head;

annular bearing means rotatably and axially slidably journaled in said bore of said retainer body, said bearing means including an annular flange at the upper end thereof extending laterally within said cavity adjacent the said annular upper end surface of said retainer body;

shaft means upon which said runners are fixed for support and rotation about a common axis coaxial with said housing, one end of said shaft means being fixed within the said bore of said annular bearing means;

and duct means in said housing interconnecting said inlet pipe connection means and the lower end of said annular bearing means, thereby to apply a differential fluid pressure between the said lower end of said annular bearing means and said cavity, whereby to apply an axial force to said annular bearing means and said annular flange and thence to said shaft.

6. In a turbo-drive unit for installation in wells, apparatus comprising:

a cylindrical housing adapted to be lowered into a well, said housing including an upper inlet head coaxially joined to a lower head by an intermediate cylindrical housing shell;

a turbine in said housing having runners adapted to be driven by power fluid supplied thereto;

inlet pipe connection means extending coaxially of the top of said upper inlet head for introducing

such power fluid into said inlet head, the outside diameter of said inlet pipe connection means being substantially less than the outside diameter of said upper inlet head, thereby forming a surrounding upwardly facing exterior shoulder on said upper inlet head;

a coaxial, downwardly facing, generally cylindrical recess formed in the lower end of said upper inlet head separate from said inlet pipe connection;

an annular retainer body having a coaxial bore therethrough and an outside diameter less than the adjacent inside diameter of said housing shell, said annular retainer body making coaxial coupling engagement at its upper end with the lower end portion of said inlet head, thereby closing said cylindrical recess to form between said inlet head and said annular retainer body a generally cylindrical cavity, and forming around said annular retainer body within said housing shell an annular space;

a fluid duct in said upper inlet head directly interconnecting said inlet pipe connection means with said annular space;

a fluid duct in said upper inlet head directly interconnecting said cavity with said upwardly facing exterior shoulder of said inlet head;

annular bearing means rotatably and axially slidably journaled in the said coaxial bore of said retainer body;

shaft means upon which said runners are fixed for support and rotation about a common axis, coaxial with said housing, one end of said shaft means being fixed within the said bore of said annular bearing means;

and passage means interconnecting said annular space, the inlet to said runners and the lower end of said annular bearing means, thereby to apply a differential fluid pressure between the said lower end of said annular bearing means and said cavity, whereby to apply an axial force to said annular bearing means and thence to said shaft.

7. In a turbo-drive unit for installation in wells, apparatus comprising:

a cylindrical housing adapted to be lowered into a well, said housing including an upper inlet head coaxially joined to the upper end portion of a cylindrical housing shell;

a turbine in said housing having runners adapted to be driven by power fluid supplied thereto;

inlet pipe connection means extending coaxially of the top of said upper inlet head for introducing such power fluid into said inlet head, the outside diameter of said inlet pipe connection means being substantially less than the outside diameter of said upper inlet head, thereby forming a surrounding, upwardly facing exterior shoulder on said upper inlet head;

a coaxial, downwardly facing, generally cylindrical recess formed in the lower end of said upper inlet head separate from said inlet pipe connection;

an annular retainer body having a coaxial bore therethrough and an outside diameter less than the adjacent inside diameter of said housing shell, said annular retainer body making coaxial coupling engagement at its upper end with the lower end portion of said inlet head, thereby closing said cylindrical recess to form between said inlet head and said annular retainer body a generally cylindrical cavity and forming around said annular retainer body within said housing shell an annular space;

a fluid duct in said upper inlet head directly interconnecting said inlet pipe connection means with said annular space;

a fluid duct in said upper inlet head directly interconnecting said cavity with said upwardly facing exterior shoulder of said inlet head;

annular bearing means rotatably and axially slidably journaled in the said coaxial bore of said retainer body;

shaft means upon which said runners are fixed for support and rotation about a common axis, coaxial with said housing, one end of said shaft means being fixed within the said bore of said annular bearing means;

passage means interconnecting said annular space and the lower end of said annular bearing means, thereby to apply a differential fluid pressure between the said lower end of said annular bearing means and said cavity, whereby to apply an axial force to said annular bearing means and thence to said shaft;

a thrust bearing body coaxially fixed in the upper, downwardly facing end of said cavity;

and a thrust member coaxially extending from the upper end of said shaft means, the upper end of said thrust member being normally positioned adjacent the lower surface of said thrust bearing body to limit axial movement of said shaft which may be induced by said axial force.

8. In a turbo-drive unit for installation in wells, apparatus comprising:

a cylindrical housing adapted to be lowered into a well, said housing including an upper inlet head coaxially joined to a lower head by an intermediate cylindrical housing shell said lower head having a bore formed therein;

a turbine in said housing having runners adapted to be driven by power fluid supplied thereto;

inlet pipe connection means extending coaxially of the top of said upper inlet head for introducing such power fluid into said inlet head;

a coaxial, downwardly facing, generally cylindrical recess formed in the lower end of said upper inlet head separate from said inlet pipe connection;

an upper annular retainer body having a coaxial bore therethrough and an outside diameter less than the adjacent inside diameter of said housing shell, said annular retainer body making coaxial coupling engagement at its upper end with the lower end portion of said upper inlet head, thereby closing said cylindrical recess to form between said inlet head and said annular retainer body a generally cylindrical cavity, and forming around said annular retainer body within said housing shell an annular space;

a fluid duct in said upper inlet head directly interconnecting said inlet pipe connection means with said annular space;

a fluid duct in said upper inlet head directly interconnecting said cavity with the exterior of said inlet head;

annular bearing means rotatably and axially slidably journaled in the said coaxial bore of said upper retainer body;

a lower annular retainer body having a coaxial bore therethrough, and formed with an outside diameter less than the adjacent inside diameter of said housing shell, said lower annular retainer being coaxially seated within the said bore of said lower head;

a lower bearing means fixed coaxially within the bore of said lower annular retainer body;

shaft means upon which said runners are fixed for support and rotation about a common axis, coaxial with said housing, the upper end of said shaft means being fixed within the said bore of said upper annular bearing means and the lower end of said shaft being rotatably journaled within said lower bearing means;

and passage means interconnecting said annular space, the inlet to said runners and the lower end of said annular bearing means, whereby a differential fluid pressure may be applied between the said lower end of said annular bearing means and said cavity, whereby to apply an axial force to said annular bearing means and thence to said shaft.

References Cited in the file of this patent

UNITED STATES PATENTS

899,559	Pfau	Sept. 29, 1908
1,045,019	Griessmann et al.	Nov. 19, 1912
1,105,808	Macneill	Aug. 4, 1914
1,609,306	Peterson	Dec. 7, 1926
1,610,454	Lawaczeck	Dec. 14, 1926