United States Patent

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[54] **MULTISTAGE CENTRIFUGAL PUMP**
13 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** **415/140,** 415/199, 415/501
[51] **Int. Cl.** **F04d 1/00,** F04d 1/06
[50] **Field of Search** .... 415/199, 501, 198, 110, 111, 112, 113, 116, 170 A, 169, 171, 172, 173, 174, 104, 105, 106, 140, 141

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ABSTRACT: Several embodiments of pumps are shown which are advantageous in pumping liquids containing abrasives. FIGS. 1–4 show a centrifugal pump with floating stages. Each stage has a rubber journal and a stainless steel bushing which provide a radial bearing as well as a seal between the impeller chamber and diffuser passages. The other embodiments show other forms of the bearing and journal members applied to a stacked (nonfloating) impeller type of centrifugal pump. In FIGS. 7 and 8, one of the members is tapered to allow the motor to operate more easily in liquids containing abrasives.

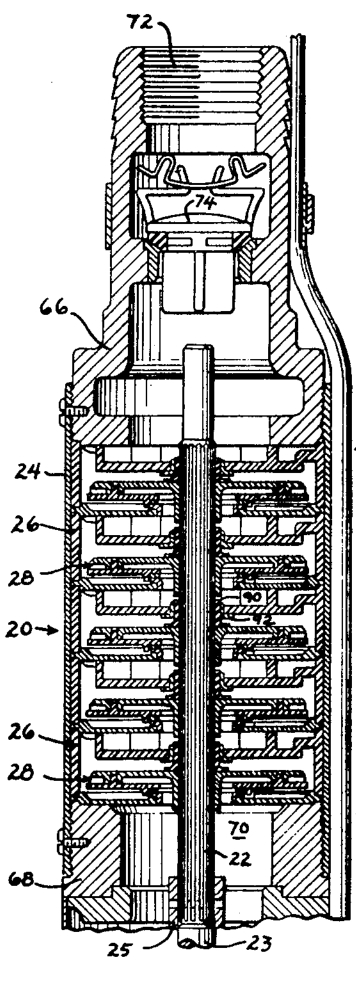
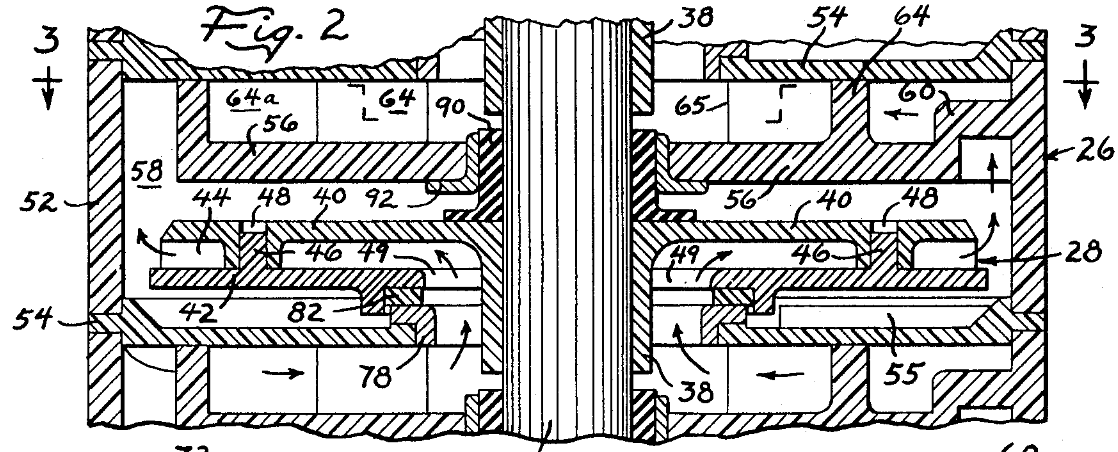


Fig. 2



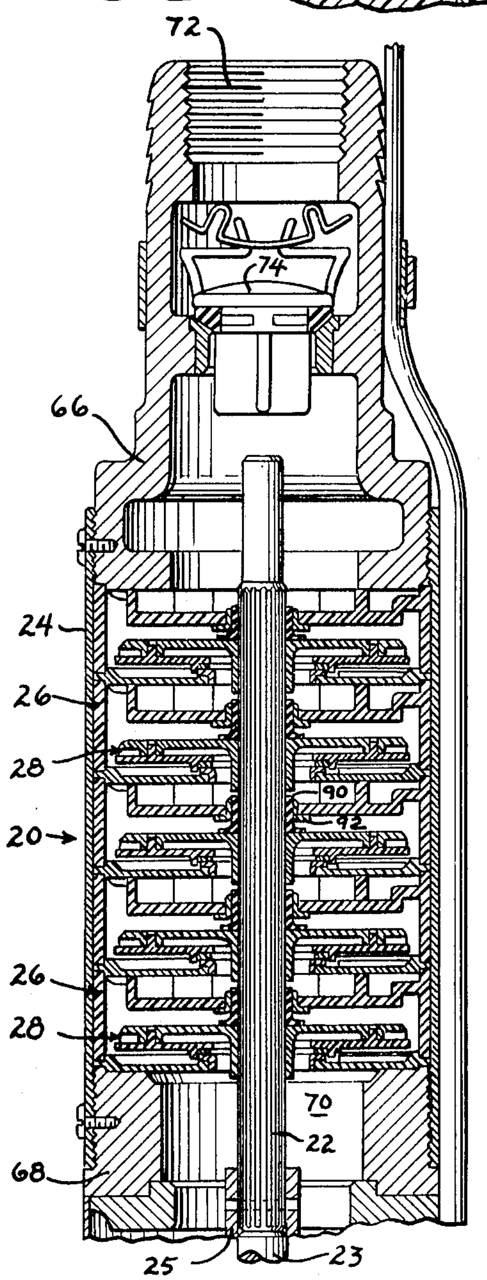


Fig. 1

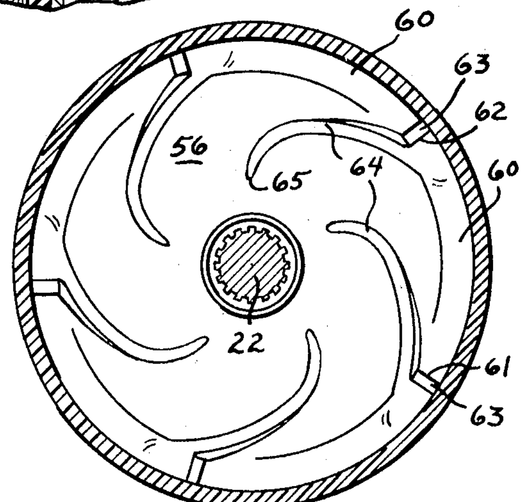


Fig. 3

Fig. 4.

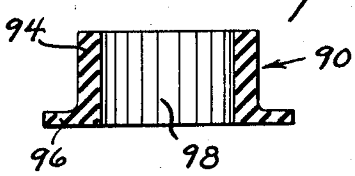


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Fig. 5

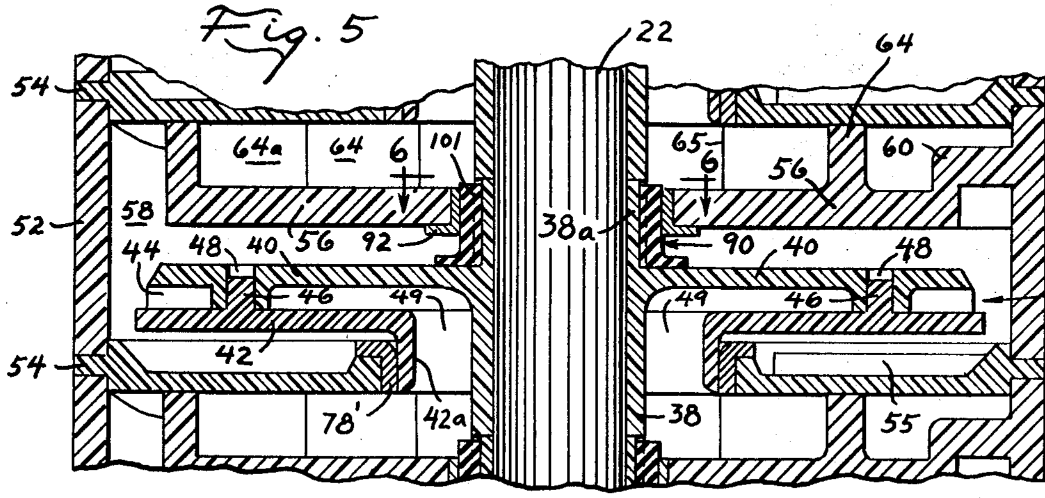


Fig. 7

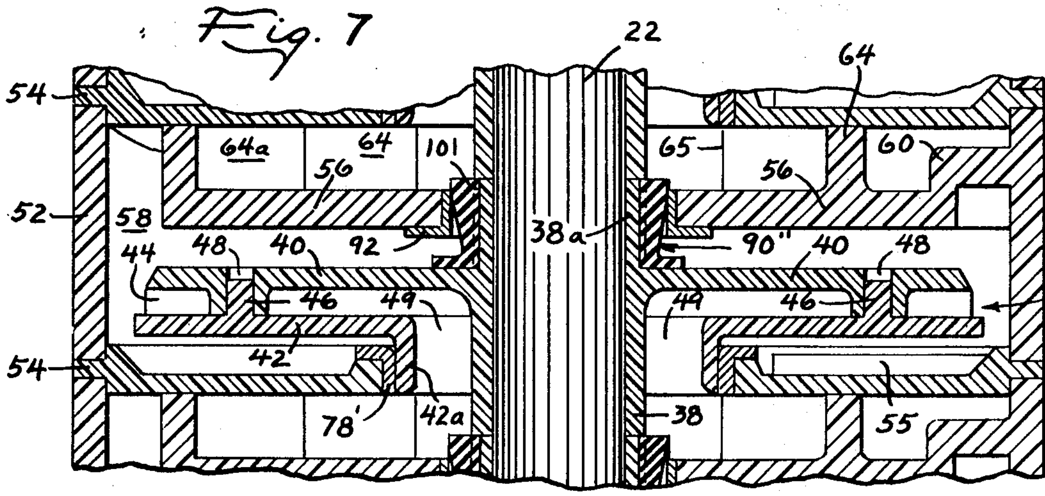
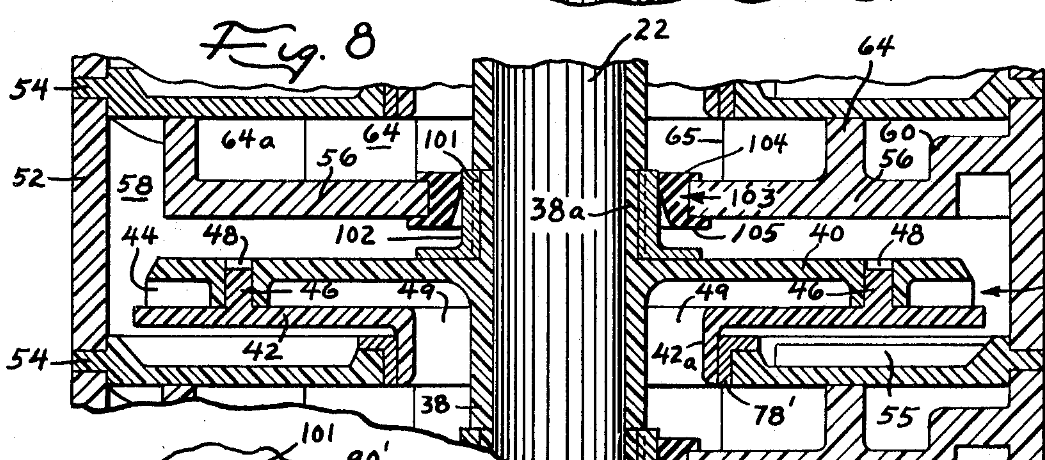


Fig. 8



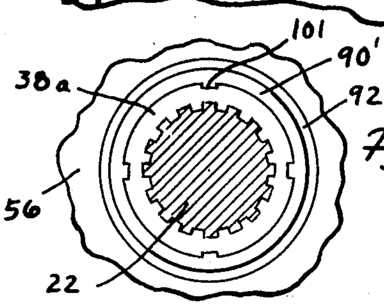


Fig. 6

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MULTISTAGE CENTRIFUGAL PUMP

BACKGROUND

The invention pertains generally to the field of pumps and more particularly to a centrifugal pump having multiple stages and diffusers.

Some wells tend to continually supply sand or other abrasives with the water. The same condition exists, for a period of time, in newly drilled wells that have not been properly cleaned. Increased wear, caused by such abrasives, can greatly reduce the efficiency of a centrifugal pump. In addition, increased clearances may allow the shaft to whip during operation and this increases the rate of wear. When there are heavy abrasives in the liquid, there is a tendency for the pump to lockup and prevent the motor from starting, or even stall the motor. This occurs when the abrasives lodge in the seal between the hub and the diffuser.

SUMMARY

The present invention relates to new and improved construction for centrifugal pumps having multiple stages and diffusers.

It is a general object of the present invention to provide a centrifugal pump with improved performance and life when utilized to pump liquids containing abrasives.

Another object is to provide a centrifugal pump which is constructed and arranged to provide reduced wear.

Still another object is to provide a multistage centrifugal pump with an improved radial bearing arrangement at each stage.

It is another object to provide a centrifugal pump with improved seal construction between the impeller chamber and the diffuser passages.

Yet another object of the present invention is to provide a centrifugal pump constructed to reduce the tendency for the pump to lockup when handling liquids containing abrasives.

It is another object of the present invention to provide a centrifugal pump with a self-cleaning seal construction.

These and other objects and advantages of the present invention, will become apparent as the same becomes better understood from the following detailed description when taken in conjunction with the accompanying drawings.

DRAWINGS

FIG. 1 is a vertical sectional view through a centrifugal pump unit of one embodiment of the present invention;

FIG. 2 is an enlarged fragmentary sectional view of the embodiment of FIG. 1;

FIG. 3 is a cross-sectional view taken generally along broken line 3—3 of FIG. 2 and on a smaller scale;

FIG. 4 is a sectional view through the rubber bushing utilized in the embodiment of FIGS. 1–3; FIG. 5 is a fragmentary sectional view similar to FIG. 2 but of a second embodiment of the invention;

FIG. 6 is a partial cross-sectional view taken along line 6—6 of FIG. 5; and

FIGS. 7 and 8 are fragmentary sectional views similar to FIG. 2 but of other embodiments of the invention.

DESCRIPTION

Reference is now made more particularly to the drawings which illustrate the best presently known mode of carrying out the invention and wherein similar reference characters indicate similar parts throughout the several views.

Referring to FIG. 1, pump 20 has a drive shaft 22 driven by a motor (not shown) mounted on the lower end of the pump and having a motor shaft 23 connected to the shaft 22 through a coupling 25. The pump has an outer sleeve 24 which contains a plurality of impeller casings 26 and a plurality of impellers 28 arranged in the respective casings. In this embodiment, the impellers 28 are arranged to float relatively freely on the drive shaft 22 within preselected limits.

The impellers 28 have hubs 38 slidably and nonrotatably mounted on the drive shaft 22. The hubs 38 are internally splined to fit on the splined drive shaft 22. A rear wall 40 extends radially from hub 38 and a front wall 42 is spaced axially from the rear wall 40 as best shown in FIG. 2. The outer periphery of the rear wall is advantageously spaced radially inwardly from the periphery of the front wall to direct fluid upwardly to a succeeding pump stage. Impeller vanes 44 separate the front and rear walls and define a plurality of impeller passages for transferring fluid from the inlet of the impeller to the outer periphery thereof when the impellers are rotated. Vanes 44 are conveniently formed integral with rear wall 40 on the front side thereof, and a plurality of openings 48 are located in these vanes. Pins 46, extending from the rear side of front wall 42, extend into openings 48 for assembly of the completed impeller. The impellers may be economically fabricated from a suitable plastic such as "Delrin." Front wall 42 is provided with a central impeller inlet 49 which leads to the impeller passageways defined by the walls 40 and 42 and the vanes 44.

Each impeller 28 is contained in the casing 26. Each casing includes an outer peripheral wall 52, a diffuser wall 56, and an inlet or thrust wall 54. Walls 52, 54 and 56 define an impeller chamber 58 for transferring fluid from the periphery of one impeller to the inlet of the adjacent impeller of the next succeeding pump stage. For this purpose, diffuser wall 56 is provided with ramps 60 which extend upwardly from a lower edge 61 to an upper edge 62 (see FIG. 3). Diffuser vanes 64 spiral inwardly on the rear side of diffuser wall 56 and terminate at an innner end 65. Thus fluid leaving the periphery of the impeller 28 travels upwardly along ramps 60, through an opening 63 and inwardly along diffuser passages 64*a* between diffuser vanes 64 to the impeller inlet 49 of the next adjacent impeller of the succeeding pump stage. The ramps 60 and impeller vanes 64 are herein shown as five in number although any convenient number may be utilized.

Each of the aforedescribed impellers 28 and casings 26 for the several stages of the pump are generally identical in construction and like numerals are utilized to designate corresponding parts of the several stage. The casings 26, each containing an impeller 28, are advantageously stacked one on top of the other and held together by outer sleeve 24 which surrounds the casings. Outer sleeve 24 is secured to an upper discharge member 66 and a lower motor mount 68. Motor mount 68 contains a main pump inlet 70 and the impellers, all facing in the same direction, will transfer the fluid from the main pump inlet 70 to a main pump outlet 72 in the upper discharge member 66. Upper discharge member 66 also contains a valve member 74 of any convenient construction.

During pumping, the liquid is transferred though the successive impeller chambers as described above. The pressure of the fluid is increased in step fashion in the successive pump stages and the difference between the fluid pressures in each impeller chamber 58 and at the inlet of the respective impellers produces an axial hydraulic thrust on the impellers in a direction toward the pump inlet under certain operating conditions.

Each thrust wall 54 has a central opening adjacent the impeller inlet. Seal means is provided at the impeller inlet 49 to limit recirculation of fluid from the impeller chambers 58 back to the respective inlet. In the embodiment shown, the seal means includes an annular insert 78 disposed in the thrust wall central opening and a washer 82 mounted at the front side of the impeller front wall 42. Insert 78 is preferably formed of stainless steel and is of L-shaped cross section. Washer 82 may be formed of various different materials which provide good wear characteristics when in rubbing contact with insert 78. The washer 82 cooperates with inlet 78 to provide a seal at the impeller inlet 49 as well as a bearing when the impeller 28 is urged toward the inlet or front side.

As indicated previously, the hydraulic pressures are continually increased through the successive pump stages. As one example, the relative pressures of a middle pump stage may be about 12 p.s.i. at the central inlet 49, about 20 p.s.i. at the outlet of the impeller, and 24 p.s.i. in the diffuser passage 64a. At the same time, the pressure at the center of the impeller chambers 58 may be about 18 p.s.i. Thus there can be about a 6 pound differential between the impeller passageway 64 leading to the inlet of the succeeding pump stage and the central portion of the impeller chamber 58. Backflow between these areas will reduce the efficiency of the pump. Thus it is desirable to provide a seal between the diffuser passages 64a and the impeller chamber 58. For this purpose, an annular rubber member 90 is mounted on the drive shaft 22 and a stainless steel member 92 is mounted on the diffuser wall 56. As best seen in FIG. 4, rubber member 90 is generally L-shaped in cross section having legs 94 and 96 and is internally splined as at 98 to have a driving connection to the spline drive shaft 22. In this embodiment, the rubber member 90 provides a journal and the stainless steel member 92 is a bussing L-shaped in cross section, engaged with the journal. Bushing 92 is preferably formed of stainless steel and has a press fit in the nonrotatable diffuser wall 56. As can be seen, journal 90 is mounted rearwardly of the rear wall 40 of the impeller for rotation with the drive shaft and impeller while the bushing 92 is nonrotatably mounted and in engagement with the journal 90. These two members have a relatively close fit to provide a seal between the impeller chamber 58 and the diffuser passage 64a to reduce backflow of liquid therebetween. Further, these members provide a radial bearing for the drive shaft 22 at each pump stage thereby eliminating the necessity for a bearing in the pump head. Also, since the rubber journal 90 is a separate part, it can be replaced without necessitating the replacement of the whole impeller 28.

Since there is a differential in pressure between the impeller chamber 58 and the diffuser passage 64a, there will be some flow between members 90 and 92. When the fluid contains an abrasive, such as sand, this flow can cause serious wear between the members. Thus, the member 90 is preferably made of rubber so that it can be deformed, pass any such abrasives, and return to its original seal position without undue wear.

From the foregoing it is thought that the construction and operation of the embodiment of FIGS. 1–4 will be readily understood. Vanes 55 on the thrust plate 54 retard rotation of the fluid at the front side of the impellers 28 to increase the pressure thereat. The impellers are free to axially float in the impeller chambers and move away from the vanes a distance such that the axial hydraulic thrust of the impellers will be balanced. This provides a self-regulating type of hydraulic balance for the impellers. Since the impellers do not exert a large axial thrust on the shaft 22, it is unnecessary to provide a large thrust bearing for the pump drive shaft. The front and rear walls of the impellers are moulded in separate pieces for ease of moulding and are held together by the pressure conditions in the impeller chambers so as to eliminate the necessity of a separate assembly step to rigidly secure the sections together. The rubber journal 90 at the rear side of the impeller 28 permits limited axial floating of the impellers on the drive shaft, cooperates with the stainless steel bushing 92 to provide a seal between the diffuser passages and the impeller chamber, and yet is resilient to pass any abrasives that may be contained in the fluid and which might otherwise tend to lodge in the seal. Rubber member 90 and stainless steel bushing 92 provide a radial bearing at each pump stage thereby eliminating the necessity of a bearing in the pump head.

In the embodiment of FIGS. 5 and 6, the majority of the parts are identical to those described above and are identified by the same numerals. There are some minor differences which will now be described. The wall 54 has a larger central opening and a bushing 78', is mounted in that opening. The front wall 42 of the impeller has a skirt 42a at its central opening 49 and in engagement with the bushing 78'. The skirt and the bushing provide a radially seal around the inlet opening 49.

The major differences in construction of this embodiment relate to the impeller hub and the rubber journal. The impeller hub 38 has an extension 38a at the rear side of the rear wall. The extremity of extension 38a engages the front edge of a succeeding hub 38 thereby providing a stacked (nonfloating) impeller. With this construction, a bearing (not shown) is provided for receiving the axial thrust from the impellers. The hub extension 38a has a plurality of keyways 101 as best shown in FIG. 6. A rubber journal 90' is mounted outwardly of the extension 38a at the rear side of the rear wall 40 of the impeller. The rubber journal 90' is shaped to extend into the keyways 101 and is thus keyed to the hub extension 38a for rotation with the drive shaft 22. The rubber journal 90' cooperates with the stainless steel bushing 92 in the manner described above and for the same purposes.

In the embodiment of FIG. 7, all parts are identical with the embodiment of FIG. 5 with the exception of the rubber journal. In this embodiment, a rubber journal 90'' is tapered inwardly away from the stainless steel bushing 92 in the direction from the diffuser wall 56 toward the rear wall 40 of the impeller. This provides a channel which diverges from the higher pressure diffuser passageway 64a toward the lower pressure impeller chamber 58. This allows any abrasives or grit that may be lodged in the seal between the rubber journal 90'' and the stainless steel bushing 92 to be more easily passed into the lower pressure impeller chamber 58. It has been found that this type of construction greatly reduces the tendency for the pump to lockup and stall the motor, or prevent the motor from starting when there is sand or other abrasives in the water being pumped. The seal between the rubber journal 90'' and the stainless steel bushing 92 still prevents excessive bypassing of fluid between the diffuser passageway and impeller chamber.

In the embodiment of FIG. 8, the tapered clearance arrangement is provided on the bushing instead of the journal. In this embodiment, a journal 102 is formed of stainless steel and is keyed to the hub extension 38a. The journal 102 could be directly mounted on the shaft 22, if desired. A bushing 103 is advantageously formed of rubber and has legs 104 and 105 extending on opposite sides of the diffuser wall 56. Leg 104 is advantageously shorter than leg 105 for ease in assembly. As shown, bushing 103 is tapered away from journal 102 and in the same direction as described above. If desired, the tapered clearance arrangement could be provided integrally with a plastic hub or could be provided by a tapered central opening in the diffuser wall 56.

From the foregoing it is believed that the construction and function of the various embodiments will be readily understood. Each embodiment provides a centrifugal pump with improved life when utilized for pumping liquids containing abrasives. Each embodiment provides an improved radial bearing arrangement at each stage of the pump and an improved self-cleaning seal construction between the impeller chamber and the diffuser passages. The embodiments of FIGS. 7 and 8 provide a construction which reduces the tendency for the pump to lockup when handling liquids containing abrasives.

While preferred embodiments of the invention has herein been illustrated and described, this has been done by way of illustration and not limitation, and the invention should not be limited except as required by the scope of the appended claims.

I claim:

1. In a multistage diffuser-type centrifugal pump for pumping liquid from a main pump inlet to a main pump outlet and including: a rotatable drive shaft; a plurality of pump impellers each having a hub engaged with the drive shaft for rotation therewith, a rear wall extending outwardly from the hub, a central opening, a front wall extending outwardly from the central opening, and impeller passages extending between the front and rear walls toward the outer periphery of the impeller; and a nonrotatable pump casing surrounding said impellers and including a plurality of walls each spaced axially

forwardly of the front wall of a respective impeller, a plurality of nonrotatable diffuser walls each spaced axially rearwardly of the rear wall of a respective impeller to define a plurality of impeller chambers, and means defining a plurality of diffuser passages for transferring liquid from the periphery of each impeller chamber to the rear side of the respective diffuser wall and to the inlet opening of the impeller of a succeeding pump stage; the improvement comprising: each pump stage having an annular rubber member and an annular stainless steel member engaged with each other; means for mounting one of the members rearwardly of the rear wall of the impeller for rotation with the drive shaft and impeller; means for mounting the other member on the nonrotatable diffuser wall and in sealing engagement with the one member to provide a seal between the impeller chamber and the diffuser passages, to reduce backflow of liquid and to provide a radial bearing for the drive shaft at each pump stage.

2. A multistage diffuser-type centrifugal pump as set forth in claim 1 wherein the rubber member is mounted on the rotatable drive shaft, and the stainless steel member is mounted on the nonrotatable diffuser wall.

3. A multistage diffuser-type centrifugal pump as set forth in claim 2 wherein the drive shaft is externally splined; the rubber member is internally splined, mounted directly on the drive shaft and spaced from at least one adjacent impeller hub; and the impellers are dimensioned in relation to the impeller chambers to permit limited independent float of the impellers axially within their respective chambers.

4. A multistage diffuser-type centrifugal pump as set forth in claim 1 wherein the rubber member is a sleeve circumjacent the impeller hub and secured thereto for rotation with the drive shaft, and the stainless steel member is a bushing mounted on the nonrotatable diffuser wall.

5. A multistage diffuser-type centrifugal pump as set forth in claim 4 wherein the hubs of adjacent impellers are contiguous and provide a stacked, nonfloating impeller construction, and including bearing means for receiving the axial thrust from the impellers.

6. A multistage diffuser-type centrifugal pump as set forth in claim 1 wherein at least one of the members is tapered away from the other member in the direction from the diffuser wall toward the rear wall of the impeller.

7. A multistage diffuser-type centrifugal pump as set forth in claim 6 wherein the tapered member has an annular surface adjacent the taper and engaged with the periphery of the other member.

8. A multistage diffuser-type centrifugal pump as set forth in claim 1 wherein the stainless steel member is mounted on the impeller hub for rotation therewith, and the rubber member is a bushing mounted on the diffuser wall, the bushing being shaped to receive the end of the diffuser wall and having legs extending along opposite sides of the diffuser wall to mount the bushing thereon.

9. A multistage, diffuser-type centrifugal pump for pumping liquid from a main pump inlet to a main pump outlet and including:

a rotatable drive shaft;

a plurality of pump impellers each having a central inlet opening, a front wall extending outwardly from the central inlet opening, a hub, a rear wall extending outwardly from the hub, impeller passages extending between the front and rear walls from the central inlet opening to the outer periphery of the impeller, means slidably mounting the hub on the drive shaft for rotation therewith but permitting limited axial movement of the impeller relative to the shaft, and the impellers being disposed on the drive shaft with their inlet openings facing in the same direction;

a pump casing surrounding the impellers and including a plurality of walls each spaced axially forwardly of the front wall of a respective impeller, a plurality of nonrotatable diffuser walls each spaced axially rearwardly of the rear wall of a respective impeller to define a plurality of impeller chambers, each diffuser wall having a central opening spaced from the drive shaft, means defining a plurality of diffuser passages for transferring liquid from the periphery of each impeller chamber to the rear side of the respective diffuser wall and to the inlet opening of the impeller of a succeeding pump stage;

the difference between the liquid pressure acting on the rear wall of each impeller and the liquid pressure at the inlet opening of the impeller producing an axial hydraulic thrust on each impeller in a direction toward the inlet opening, the impellers being dimensioned in relation to the impeller chambers to permit independent axial float within the respective chamber and along the shaft whereby the impellers can shift as the hydraulic thrust changes;

an annular rubber journal mounted on the drive shaft for rotation therewith, the journal being located rearwardly of the rear wall of the impeller and disposed in the central opening of the diffuser wall, and the journal being spaced from at least one adjacent hub to allow the axial float of the impeller; and

a stainless steel bushing mounted in the central opening of each diffuser wall in fixed relation thereto, and the bushing being in sealing engagement with the journal to provide a seal between the impeller chamber and the diffuser passages to reduce backflow of liquid and to provide a radial bearing for the drive shaft at each pump stage.

10. In a multistage, diffuser-type centrifugal pump for pumping liquid from a main pump inlet to a main pump outlet and including: a rotatable drive shaft; a plurality of pump impellers each having a hub engaged with the drive shaft for rotation therewith, a rear wall extending outwardly from the hub, a central opening, a front wall extending outwardly from the central opening, and impeller passages extending between the front and rear walls toward the outer periphery of the impeller; and a nonrotatable pump casing surrounding the impellers and including a plurality of walls each spaced axially forwardly of the front wall of a respective impeller, a plurality of nonrotatable diffuser walls each spaced axially rearwardly of the rear wall of a respective impeller to define a plurality of impeller chambers, each diffuser wall having a central opening spaced from the drive shaft, and means defining a plurality of diffuser passages for transferring liquid from the periphery of each impeller chamber to the rear side of the respective diffuser wall and to the inlet opening of the impeller of a succeeding pump stage; the improvement comprising: first means mounted on the drive shaft for rotation therewith; the first means being located rearwardly of the rear wall of the impeller and disposed in the central opening of the diffuser wall; second means at the central opening of the diffuser wall defining a surface in sealing engagement with the member to provide a seal between the impeller chamber and the diffuser passages to reduce backflow of liquid; one of the first and second means being tapered away from the other in the direction from the diffuser wall toward the rear wall of the impeller to provide a diverging channel for the passage of any foreign matter which becomes lodged at the seal and thereby reduce the friction of the pump.

11. Apparatus according to claim 10 wherein the hub extends through the central opening of the diffuser wall and the means being tapered is a tapered surface on the hub.

12. Apparatus according to claim 10 wherein the means being tapered is a tapered surface at the central opening of the diffuser wall, and including a flat land adjacent the tapered surface, the land being in contact with the other means over substantially its entire area.

13. Apparatus according to claim 10 wherein the means being tapered is made of rubber, and the other means is an annular stainless steel member.