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CENTRIFUGAL PUMP

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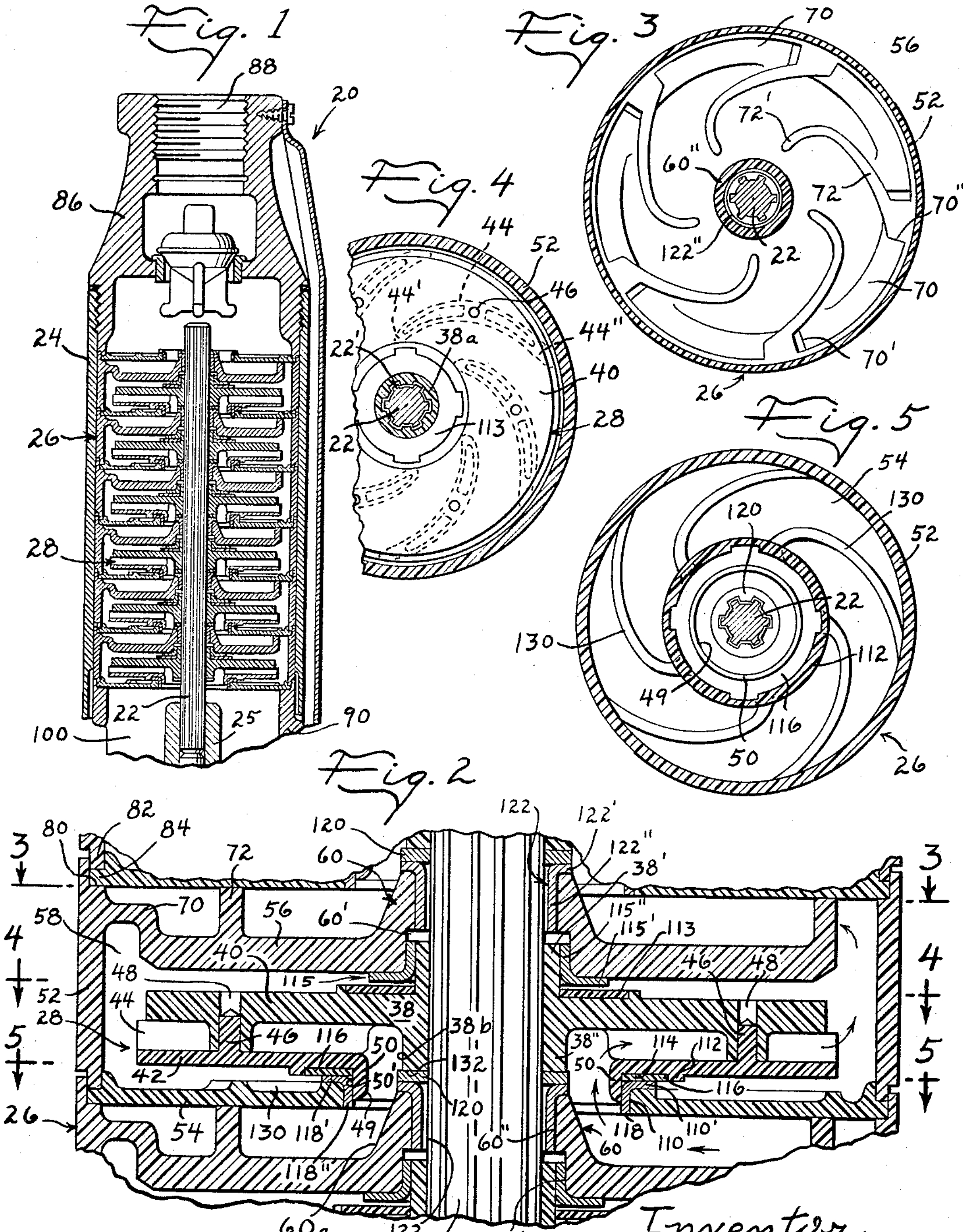

Inventor
Elmer M. Deters

By McCanna, Morsbach & Pillote
Atty's

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CENTRIFUGAL PUMP

Elmer M. Deters, Davenport, Iowa, assignor to Red Jacket Manufacturing Company, Davenport, Iowa, a corporation of Iowa

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This invention relates to improvements in centrifugal pumps and particularly to a multi-stage centrifugal pump.

In a centrifugal pump having single suction impellers, there is a marked pressure difference between the pressure at the inlet of the impeller and the pressure in the impeller chamber which acts on the remaining area at the inlet or front side of the impeller and also on the area at the rear side of the impeller. This difference between the fluid pressure in the impeller chamber and at the impeller inlet produces an axial hydraulic thrust on each impeller necessitating some thrust bearing means to support the impeller. In addition this pressure difference also necessitates some means to form a running seal between the impeller and the impeller casing in the area around the impeller inlet, in order to control recirculation of fluid back to the impeller inlet.

It has heretofore been proposed to slidably mount the individual impeller of a multi-stage pump on a shaft to allow the impellers to float in their respective impeller chambers with the seal face on the impeller supported on an opposing seal face on the casing around the inlet opening to maintain a close fit and limit recirculation of fluid back to the inlet. However, because of the substantial pressure difference between the fluid in the impeller chamber and the fluid at the pump inlet, there is some recirculation back to the impeller inlet and, when the fluid being pumped contains sand or other abrasive material, the sand lodges at the seal faces around the impeller inlet and produces wear. When the seal faces on the impeller and casing are the only means for taking the down thrust on the impellers, the wear on the seal faces can continue until the impellers are effectively destroyed.

It is an object of this invention to provide a centrifugal pump which can be economically manufactured and assembled and which has high pump efficiency under operating conditions and which will withstand the deleterious effects of abrasive particles in the fluid pumped.

It is an object of this invention to provide a multi-stage centrifugal pump having a plurality of impellers mounted on the pump shaft for relatively free axial float on the shaft with improved bearing means.

It is yet another object of this invention to provide the pump as described with impeller eye bearing means radially spaced from the pump shaft to take the hydraulic thrust of the impellers initially, and, to provide auxiliary bearing means operable to take the hydraulic thrust after said impeller eye bearing means has become worn by the abrasive action of sand or other abrasive materials present in the fluid being pumped.

Still another object of the invention is to provide a multi-stage centrifugal pump having impeller thrust bearing means for supporting the impeller so arranged as to minimize wear and abrasion of the bearing means when sand or other abrasive material is present in the fluid being pumped.

Other objects and features pertain to the particular arrangements and structure whereby the foregoing objects are attained. The invention, both as to its structure and manner of use will be better understood by reference to the following specification and drawings forming a part thereof wherein:

FIG. 1 is a longitudinal sectional view through a multi-stage submersible pump embodying the present invention.

FIG. 2 is an enlarged view of part of the portion of FIG. 1.

FIGS. 3, 4, and 5 are transverse sectional views through the pump taken on the plane 3—3, 4—4, 5—5, of FIG. 2, respectively.

The multi-stage centrifugal pump herein described and illustrated comprises a plurality of impellers having impeller hubs slidably and non rotatably mounting the impellers on the pump shaft. Pump casings, defining impeller chambers, surround the impellers, and, the casings are so arranged to allow the impellers to float relatively freely on the pump shaft but within pre-selected limits. Impeller eye seal means are provided between the impellers and the casings around the impeller inlet to take hydraulic thrust, and the impeller eye seal means are radially spaced from the pump shaft. Auxiliary bearing means are provided to limit movement of the impellers toward the inlet to control wear on the impellers when sand or other particles are present in the fluid being pumped. The auxiliary bearing means are preferably arranged closely adjacent the shaft to minimize the peripheral speed at the bearing surfaces, and where there is little pressure differential across the bearing means to minimize flow through the bearings which could carry sand thereto, and at a point where the direction of the fluid flowing past the bearing means will tend to carry sand and the like away from the bearing means, to thereby minimize the abrasive effects of the abrasive materials in the fluid transferred through the pump. In particular, the auxiliary thrust bearing is advantageously located on the impeller hub and in an area adjacent the inlet of a impeller, since the fluid is not changing the direction of flow at this point.

Referring to FIG. 1, pump **20** has a drive shaft **22** and the pump components are enclosed by outer sleeve **24**. The drive shaft is driven by a motor (not shown) mounted on the lower end of the apparatus and connected to the shaft through a coupling **25**. Within outer sleeve **24** are arranged a plurality of impeller casings **26**, and, a plurality of impellers **28** and arranged in the casings. The impellers may economically be fabricated from a suitable plastic such as "Delrin." Each of these impellers and associated impeller casings for the several stages of the pump are identical in construction and like numerals are utilized to designate corresponding parts of the several stages.

The impellers **28** have hubs **38** slidably and non rotatably mounted on the drive shaft **22** by means of hub key way **38a** which fits in spline relationship on shaft keys **22'** (FIG. 4) of drive shaft **22**. Impeller rear wall **40** extends radially from hub **38** and impeller front wall **42** is spaced axially from the rear wall **40** as shown in FIGS. 2 and 4. The outer periphery of the rear wall is preferably spaced radially inwardly from the periphery of the first wall to direct fluid upwardly to the succeeding pump stage. Impeller vanes **44** separate the rear wall from the front wall and spiral outwardly from inner ends **44'** to outer ends **44"** to 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 in the direction indicated by the arrow in FIG. 4. Vanes **44** are conveniently formed integral with rear wall **40** on the front side thereof, and in these vanes are arranged a plurality of openings **48**, and pins **46**, extending from the rear side of front wall **42**, extend into openings **48**. As disclosed, the front wall is fabricated separately from the rear wall, and, vanes **44** are integral with the rear wall although fabrication methods may require that the vanes be fabricated as attached to the front wall, or, that the impeller components be fabricated integral. Furthermore, front wall **42** is provided with a central impeller inlet **49** surrounding shaft **22** and leading to the plurality of passageways between vanes **44**.

As best seen in FIG. 2, each impeller 28 is surrounded by an assembled casing unit, and each casing unit comprises peripheral wall 52, an inlet or thrust wall 54 and diffuser wall 56. 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 70 herein shown, five in number (see FIG. 3), and these ramps extend upwardly from lower edge 70′ to upper edge 70″. Diffuser vanes 72 spiral inwardly on the rear side of diffuser wall 56 from the periphery thereof, adjacent upper edge 70″, and terminate inwardly at inner end 72′. Thus fluid in leaving the periphery of an impeller travels upwardly over ramps 70 and is caused to move inwardly between diffuser vanes 72 to the impeller inlet 49 of the next adjacent impeller of the succeeding pump stage.

The casing units are conveniently stacked one on top of the other and are clamped together by outer sleeve 24 which surrounds the casing units. To facilitate the stacking arrangement of the casing units, peripheral wall 52 is provided with an internal rabbet which defines an upwardly facing shoulder 80 disposed substantially coplanar with the upper edges of the diffuser vanes 72 and the lower end of each peripheral wall is formed with an external rabbet which defines a locating flange 82 whereby the flange 82 extends into the groove of an adjacent lower peripheral wall. Furthermore, the outer periphery of the thrust wall 54 is provided with a peripheral rim 84 for insertion in the internal rabbet between the shoulder 80 and the flange 82. This may be best seen by reference to FIG. 2 where shoulder 80, flange 82, and rim 84 are fittingly arranged together to facilitate stacking of one casing unit upon another. To facilitate securing the casing units in stacked relationship, outer sleeve 24 is threadedly engaged on upper discharge member 86 and lower motor mount member 90, and, such threaded engagement clampingly secures the casing units in the outer sleeve between members 86 and 90. When pump 20 is submerged in a well such as a water well, the water will be transferred from pump inlet 100 in motor mount 90, through the successive impeller chambers, and finally out of pump outlet 88 in upper discharge member 86. The pressure of the fluid is increased in step fashion in the successive pump stages and, as previously described, 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. A means described hereinafter, is provided for controlling recirculation of fluid from the impeller chambers back to the pump inlet and to take up the axial hydraulic thrust on each impeller.

Each thrust wall 54 has a central opening 110 around the impeller inlet and an annular boss is preferably formed around the opening to define an upper radially extending annular face 110′. An impeller eye seal means is provided around impeller inlet to limit recirculation of fluid for the impeller chambers 58 back to the respective inlet and, preferably, the seal means includes both radial and axial seal faces. In the preferred embodiment shown, the impeller casings are formed of a plastic material such as "Delrin" and an annular insert 118 is provided in the central opening 110, which insert is formed of a preferably rigid wear resistant material such as stainless steel to provide radial and axial seal faces 118′ and 118″. The impellers are advantageously formed with an annular skirt 50 around the impeller inlet, which skirt has a generally cylindrical outer wall 50′ defining an axial extension seal face on the impeller that cooperates with a seal face 118″ on the thrust wall to limit recirculation. While the opposed axially extending seal faces 50′ and 118″ are useful in limiting recirculation, very close tolerances would have to be maintained on the skirt 50, and insert 118 to provide high pump efficiency. It is accordingly advantageous to also

employ radial seal faces on the impeller and thrust wall. For this purpose, the impeller is formed with a rim 112 on the underside of the front wall 42 of the impeller and a washer 116 of wear resistant material is disposed in the recess in the rim 112 to form a radial seal face on the impeller around the inlet opening. The washer may be formed of various different materials which provide good wear characteristics when in rubbing contact with the insert 118, with the pumped fluid as a lubricant and may, for example, be a cloth impregnated with phenolic or melamine resins such as sold commercially under the mark "Synthane." The washer 116 cooperates with the thrust plate insert 118 and this structure prevents plastic to plastic rubbing between the impeller front wall and the respective thrust wall. As previously described, the insert includes a radial portion 118′ and an axial portion 118″ and radial portion 118′ is disposed against thrust washer 116. Axial portion 118′ serves as an axial seal for cooperation with skirt axial face 50′, and there is conveniently provided a slight clearance between portions 118′ and 50′ to allow a limited amount of fluid recirculation from the impeller chamber to the impeller outlet. For a 4 inch diameter pump, this clearance may range between .005 and .010 inch.

As aforementioned, impeller hubs 38 are slidably and non-rotatably mounted on shaft 22 and such mount allows the impellers to move axially between pre-selected limits. In order to minimize the downthrust which must be taken by mechanical thrust bearings, thrust wall vanes 130 are preferably provided on the rear side of thrust wall 54 and the vanes extend from the periphery of the thrust wall to boss 110. As fluid leaves the periphery of the respective impeller, some of the fluid returns between impeller front wall 42 and thrust wall 54 through passageways between thrust wall vanes 130 and this return fluid is slowed down by vanes 130 producing a pressure on the front side of impeller front wall 42. This pressure tends to counteract hydraulic thrust by tending to force the impeller to axially float toward outlet 88. As the impeller 28 moves axially away from the thrust plate thrust bearing disk 116 is separated from radial portion 118′ of thrust plate insert 118 allowing increased recirculation to the impeller inlet between skirt axial face 50′ and axial portion 118″. Ideally, the impeller will float in light rubbing contact with the respective casings by provision of the thrust wall vanes 44, when the pump is operating near its rated volume and pressure. However, the hydraulic pressures on each impeller change under different pump operating conditions. Thus, when the pump is operating near shut-off, that is when the flow from the pump is substantially cut-off, the pressure unbalance on the impeller forces the same downwardly against the thrust bearings. Conversely, when the pump outlet is wide open with low back pressure on the line, the momentum force of the fluid forces the impeller in a direction away from the inlet. An upper thrust washer 113 is preferably non-rotatably keyed to the rear wall of the impeller and cooperates with the radial face 115′ on a diffuser wall insert 115. The diffuser wall insert 115 also includes axial portion 115″ which extends into a lower annular recess 60′ in the diffuser sleeve 60. The impeller hub has an upper portion 38′ to radially center and support the impeller on the casing.

As previously noted, there is a substantial pressure differential across the impeller eye seal means and, if there is sand or the like in the pumped fluid, the recirculating fluid carries some of the abrasive particles between the seal faces 116, 118′. This produces an abrasive action which becomes progressively deleterious to the impeller bearing structure as described and to counteract this deterioration a hub thrust bearing 120 is provided for controlling movement of the impeller toward the thrust wall. More particularly, diffuser sleeve 60 has an upper portion 60″ which surrounds but is spaced radially from shaft 22. A sleeve insert 122 is affixed to upper sleeve portion 60″ and includes axial portion 122, spaced from but surrounding shaft 22, and radial portion 122′ forming a radial bearing face for engagement with the hub thrust bearing 120. The hub bearing 120 is mounted for rotating with the impeller and, as best shown in FIG. 5, is preferably internally keyed for splined engagement directly on the shaft. The hub thrust, washer 120 is disposed between the end of the hub portion 38″ and the face 122′ on the diffuser wall insert to limit movement of the impellers toward the inlet. For maximum pump efficiency, it is preferable to provide a close running fit between the impeller eye seal faces 116 and 118′ and the hub thrust bearing is therefore ideally constructed to support the impeller when the impeller eye seal faces just contact. However, in practice, it is difficult to maintain such close tolerances. Accordingly, it is better practice to arrange the hub thrust bearing so that there is a slight initial gap of from .001 to .005 inch between the hub thrust washer 120 and the thrust face 122′, when the seal faces 116 and 118′ are in contact. This provides a good seal around the impeller inlet until some wear occurs on the seal. At that time, the hub thrust bearing becomes effective to limit downward movement of the impeller and thus control further wear on the impeller eye seal faces. Since the hub thrust bearing is located closely adjacent the shaft, the bearing has a lower peripheral speed than the impeller eye bearing and is therefore subjected to less wear. Further, there is little pressure differential across the hub thrust bearing and therefore very little flow of fluid across the bearing face which would carry abrasive material to this area. In addition, it is to be noted that the hub thrust bearing is located at a level adjacent the inlet opening 50 in the impeller. Therefore, the fluid flow through the pump, as indicated by the arrows in FIG. 2, is not changing direction at this point and accordingly tends to carry the abrasive material past the hub seal instead of throwing the sand into the hub seal faces.

I claim:

1. A multi-stage centrifugal pump for pumping fluid from a main pump inlet through successive stages to a main pump outlet, a shaft, a plurality of pump impellers each having an impeller inlet in the front side and impeller passages extending from the impeller inlet to the periphery of the impeller, said impellers each having an impeller hub slidably and non-rotatably mounted on the shaft for free axial float thereon with the hubs on adjacent impellers axially spaced apart along the shaft, a portion of the hub extending axially toward the impeller inlet and having one end disposed at a level adjacent the impeller inlet, a pump casing surrounding the impellers and including a plurality of inlet walls each spaced axially from the front side of a respective impeller and a plurality of diffuser walls each spaced axially from the rear side of a respective impeller, intermediate ones of the diffuser walls having sleeve portions immediately surrounding the shaft between the adjacent ones of the hubs and extending from the diffuser wall toward the hub on the impeller of the next succeeding pump stage, each impeller and the adjacent inlet wall of the pump casing having opposed seal faces around the impeller inlet to limit recirculation of fluid therebetween, and a hub thrust bearing means for each impeller surrounding the shaft and defining opposed axially facing bearing faces between said one end of each hub portion and the end of the adjacent sleeve portion for limiting movement of the impellers in a direction toward the pump inlet to control wear on said impellers and said inlet walls of the pump casing when sand or other abrasive material is present in the water being pumped, the outer surfaces of the hub portions and sleeve portions defining the inner boundary of the flow passage through the impeller inlet and said hub thrust means having its outer periphery adjacent the outer surfaces of the hub portions and sleeve portions and being located at a level adjacent the inlet of the impeller whereby fluid flowing through the impellers tends to carry any foreign matter therein past the hub thrust bearing.

2. A multi-stage centrifugal pump for pumping fluid from a main pump inlet through successive stages to a main pump outlet, a shaft, a plurality of pump impellers each having an impeller inlet in the front side and impeller passages extending from the impeller inlet to the periphery of the impeller, said impellers each having an impeller hub slidably and non-rotatably mounted on the shaft for free axial float thereon with the hubs on adjacent impellers axially spaced apart along the shaft, a portion of the hub extending axially toward the impeller inlet and having one end disposed at a level adjacent the impeller inlet, a pump casing surrounding the impellers and including a plurality of inlet walls each spaced axially from the front side of a respective impeller and a plurality of diffuser walls each spaced axially from the rear side of a respective impeller, intermediate ones of the diffuser walls having sleeve portions immediately surrounding the shaft between adjacent ones of the hubs and extending from the diffuser wall toward the hub on the impeller of the next succeeding pump stage, each impeller and the adjacent inlet wall of the pump casing having opposed seal faces around the impeller inlet to limit recirculation of fluid therebetween, and thrust bearing means including a wear resistant washer surrounding the shaft and defining opposed axially facing bearing faces between said one end of each hub portion and the end of the adjacent sleeve portion for limiting movement of the impellers in a direction toward the pump inlet to control wear on said opposed seal faces around the impeller inlet, said thrust washers being slidably and non-rotatably keyed directly to said shaft the outer surfaces of the hub portions and sleeve portions defining the inner boundary of the flow passage through the impeller inlet and said hub thrust means having its outer periphery adjacent the outer surfaces of the hub portions and sleeve portions and being located at a level adjacent the inlet of the impeller whereby fluid flowing through the impellers tends to carry any foreign matter therein past the hub thrust bearing.

3. A multi-stage centrifugal pump for pumping fluid from a main pump inlet through successive stages to a main pump outlet, a shaft, a plurality of pump impellers each having an impeller inlet in the front side and impeller passages extending from the impeller inlet to the periphery of the impeller, said impellers each having an impeller hub slidably and non-rotatably mounted on the shaft for free axial float thereon with the hubs on adjacent impellers axially spaced apart along the shaft, a portion of the hub extending axially toward the impeller inlet and having one end disposed at a level adjacent the impeller inlet, a pump casing surrounding the impellers and including a plurality of inlet walls each spaced axially from the front side of a respective impeller and a plurality of diffuser walls each spaced axially from the rear side of a respective impeller, intermediate ones of the diffuser walls having sleeve portions immediately surrounding the shaft between adjacent ones of the hubs and extending from the diffuser wall toward the hub on the impeller of the next succeeding pump stage, an impeller eye thrust bearing and seal means for each impeller surrounding the impeller inlet and defining opposed axially facing seal faces on the front side of each impeller and the rear face of the respective inlet wall of the casing for limiting recirculation of fluid therebetween, and an impeller hub thrust bearing means for each impeller surrounding the shaft and defining opposed axially facing bearing faces between said one end of each hub portion and the end of the adjacent sleeve portion for limiting movement of the impellers in a direction toward the pump inlet to control wear on said opposed seal faces when sand or other abrasive material is present in the water being pumped, the outer surfaces of the hub portions and sleeve portions defining the inner

boundary of the flow passage through the impeller inlet and said hub thrust means having its outer periphery adjacent the outer surfaces of the hub portions and sleeve portions and being located at a level adjacent the inlet of the impeller whereby fluid flowing through the impellers tends to carry any foreign matter therein past the hub thrust bearing.

4. The combination of claim 3 wherein the impeller hub thrust bearing means has a slight initial gap between said opposed bearing faces when the pump is first assembled with the opposed seal faces on the eye thrust bearing and seal means in engagement whereby the thrust on the impeller is initially transmitted through said impeller eye thrust bearing to the inlet wall of the casing and, after the seal faces wear, the bearing faces of the hub thrust bearing come into contact to limit movement of the impellers in a direction toward the pump inlet to thereby control wear on said opposed seal faces around the impeller inlet.

5. The combination of claim 4 wherein said hub thrust bearing means includes a flanged metal insert in said sleeve portion on the diffuser wall and a wear resistant washer overlying the end of the hub on the impeller and mounted for rotation with the impeller.

6. The combination of claim 5 wherein said wear resistant washer is slidably and non-rotatably keyed directly to said shaft.

7. A multi-stage centrifugal pump for pumping fluid from a main pump inlet through successive stages to a main pump outlet, a shaft, a plurality of pump impellers each including front and rear walls defining an impeller inlet in the front wall and impeller passages extending from the inlet to the periphery of the impeller, said impellers each having an impeller hub slidably and non-rotatably mounted on the shaft for free axial float thereon with a portion of the hub extending axially from a rear wall of the impeller toward the inlet opening in the impeller, a pump casing surrounding the impellers and including a plurality of inlet walls each spaced axially from the front side of the respective impeller and a plurality of diffuser walls each spaced axially from the rear side of a respective impeller, said pump casing including means defining diffuser passages between the

diffuser wall and the inlet wall of the next succeeding pump stage for transferring fluid from the peripheries of the respective impellers into the impeller inlets of the next succeeding stage, the diffuser walls each having sleeve portions surrounding the shaft and extending from the diffuser wall toward the hub on the impeller of the next succeeding pump stage, an impeller eye thrust bearing and seal means for each impeller surrounding the impeller inlet and defining opposed axially facing seal faces on the front wall of each impeller and the rear side of the respective inlet wall of the casing for limiting recirculation of fluid therebetween, an impeller hub thrust bearing means for each impeller immediately surrounding the shaft and defining opposed axially facing bearing faces between an end of each hub portion and the end of an adjacent sleeve portion for limiting movement of the impeller in a direction toward the pump inlet to control wear on said opposed seal faces when sand or other abrasive material is present in the fluid being pumped, and a plurality of ribs on each inlet wall at the side adjacent the front walls of the impellers for retarding rotation of the fluid at the front walls of the impellers to thereby produce a pressure on the front walls of the impellers which is greater than the pressure at the rear walls of the impellers.

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MARK NEWMAN, *Primary Examiner.*

HENRY F. RADUAZO, *Examiner.*

SAMUEL LEVINE, *Assistant Examiner.*