United States Patent [19]

Tinker

[11] **3,738,773**

[45] **June 12, 1973**

[54] **BLADELESS PUMP IMPELLER**

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[73] Assignee: **The Tait Manufacturing Company,** Dayton, Ohio

[22] Filed: **Oct. 20, 1971**

[21] Appl. No.: **190,947**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 91,767, Nov. 23, 1970, abandoned.

[52] **U.S. Cl.** **416/179,** 416/186

[51] **Int. Cl.** **F01d 1/34**

[58] **Field of Search** 416/179, 184, 186

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Primary Examiner—Everette A. Powell, Jr.
Attorney—Lawrence B. Biebel, Nathaniel R. French, Dailey L. Bugg et al.

[57] **ABSTRACT**

A bladeless pump impeller has a hollow, generally tubular body with an inlet end and an outlet end communicating with the hollow interior. The inlet to the impeller is of generally circular cross-section and the outlet is of generally oblong cross-section, the interior wall of the impeller providing a smooth transition from the inlet to the outlet.

10 Claims, 25 Drawing Figures

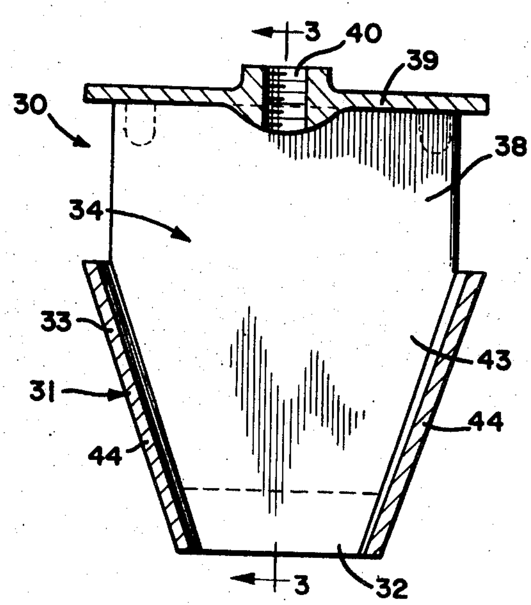
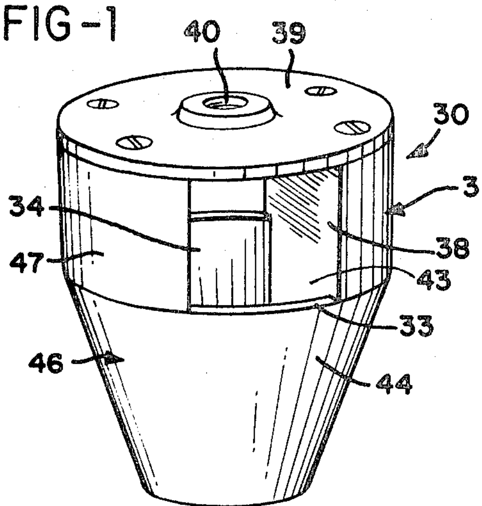


FIG-1



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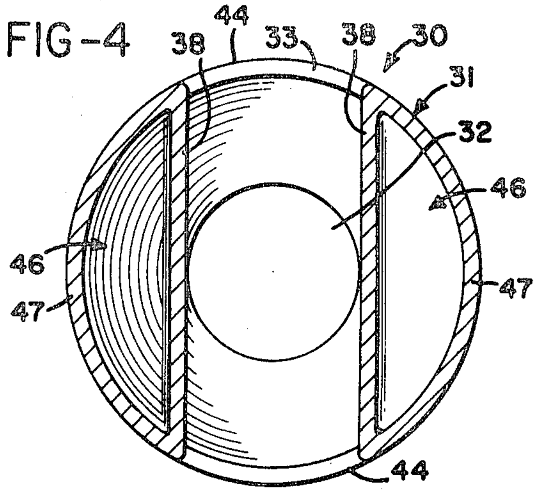
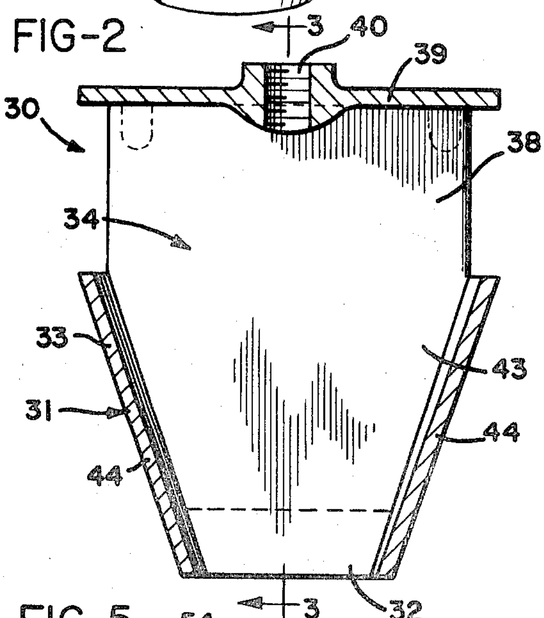


FIG-2



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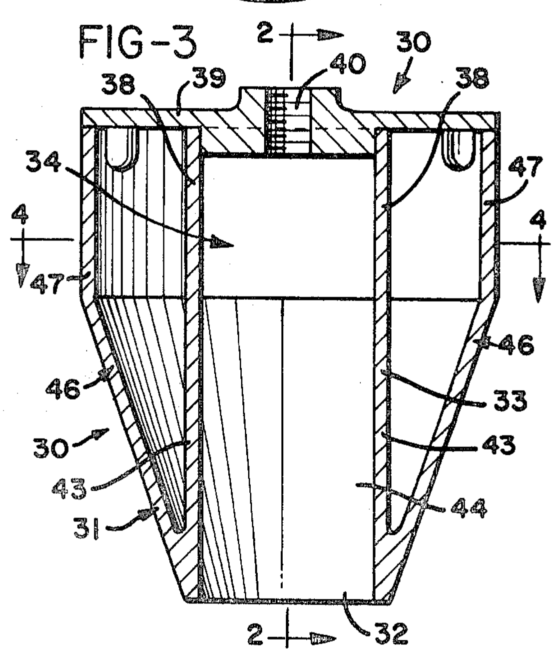

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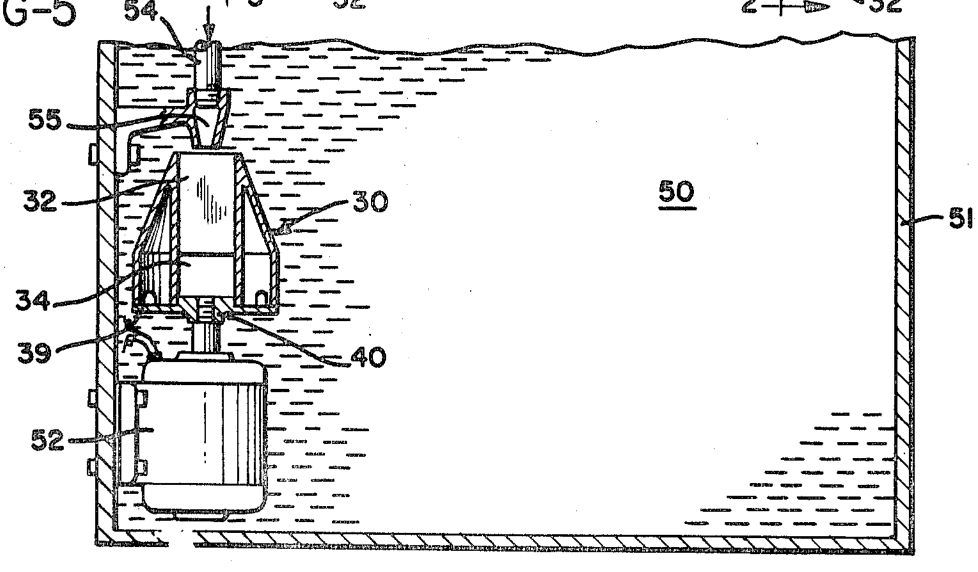
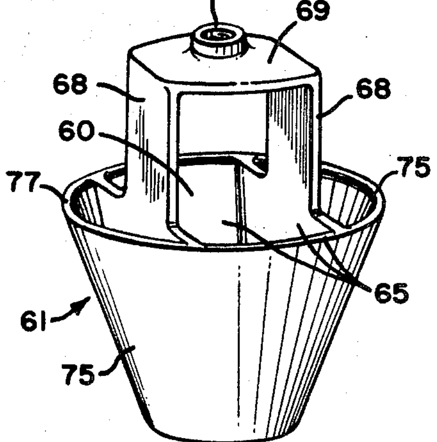


FIG-6



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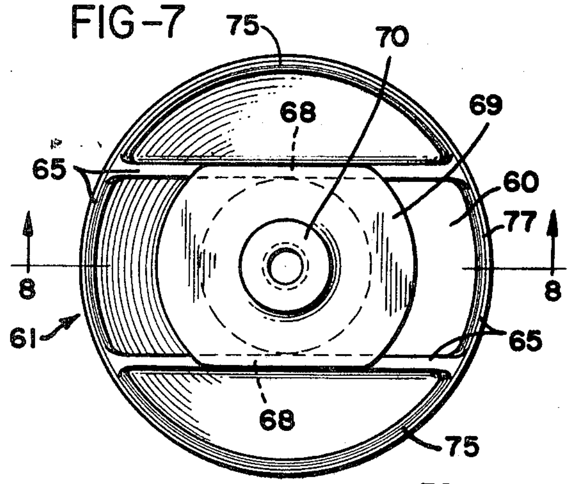

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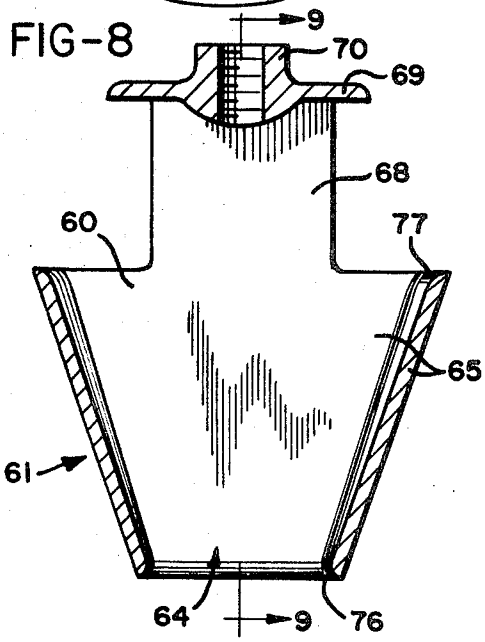

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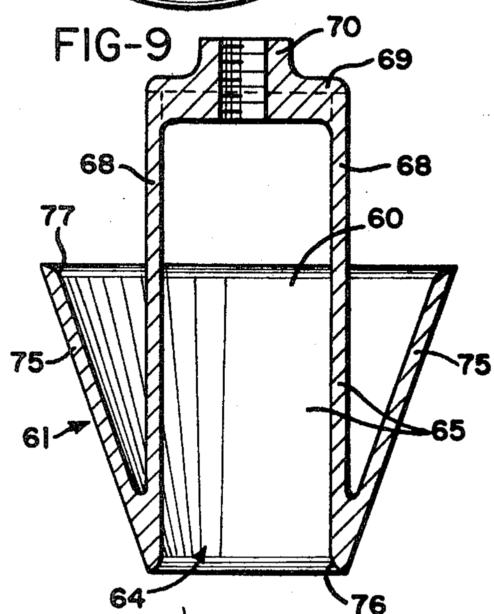

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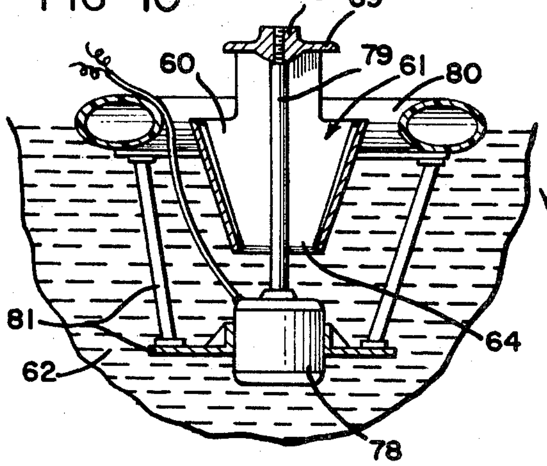

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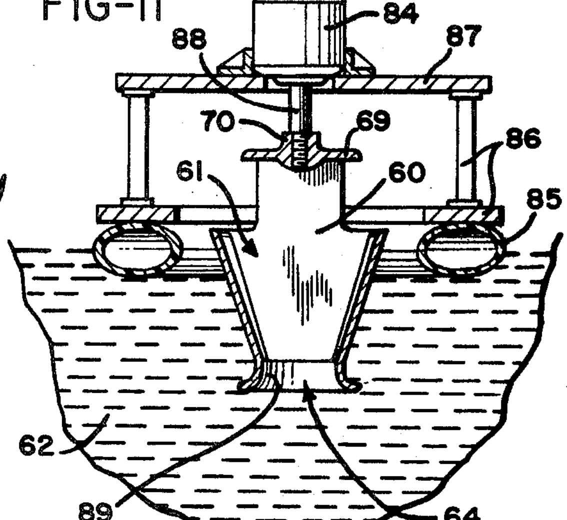

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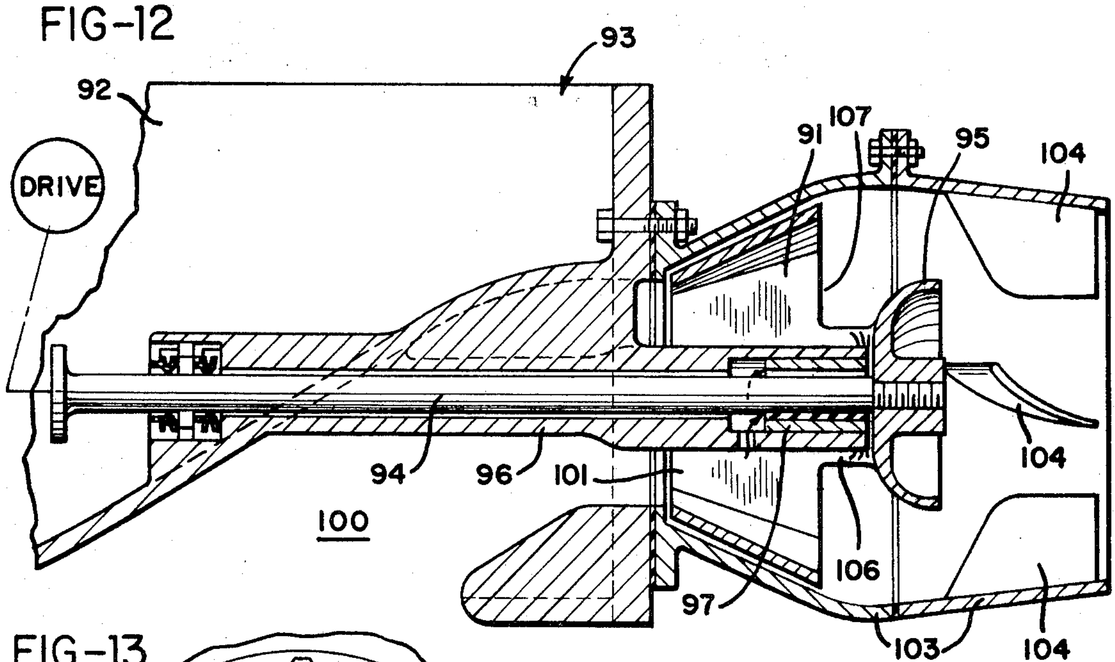

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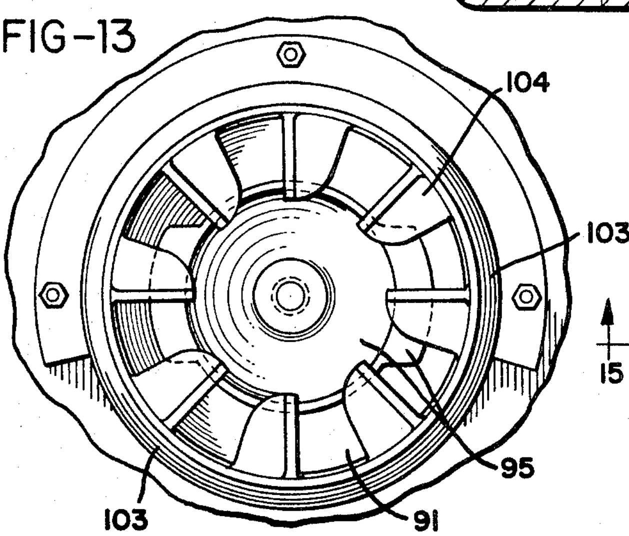

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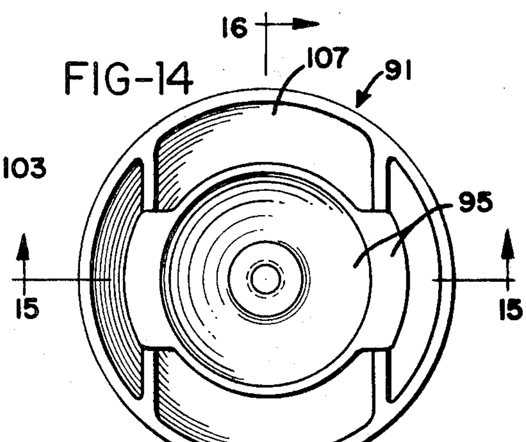

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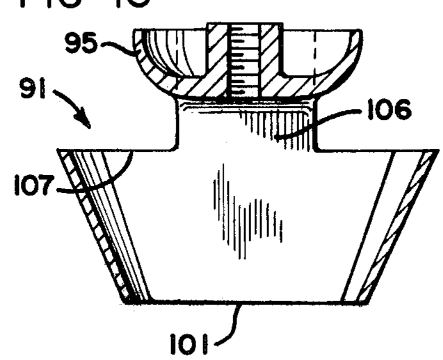

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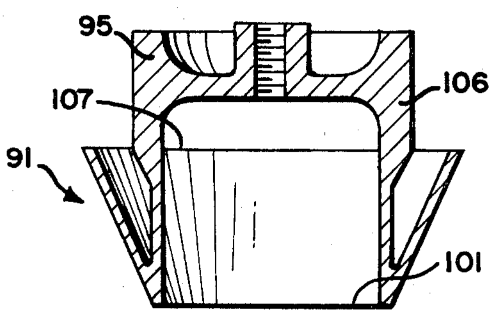

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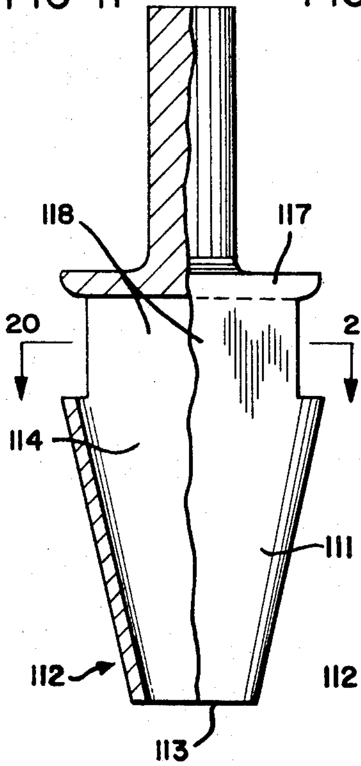

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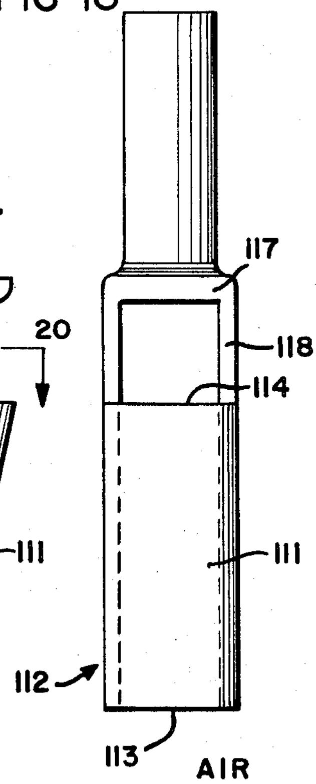
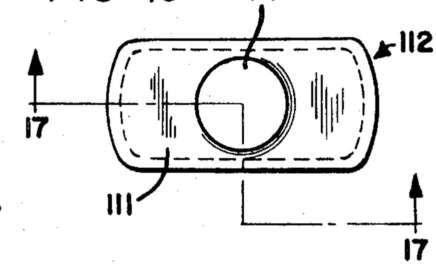


FIG-19



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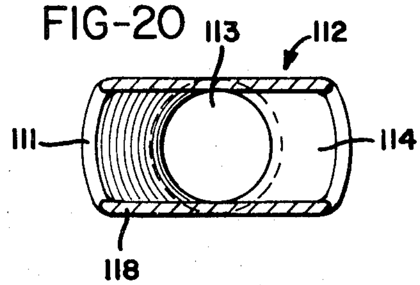

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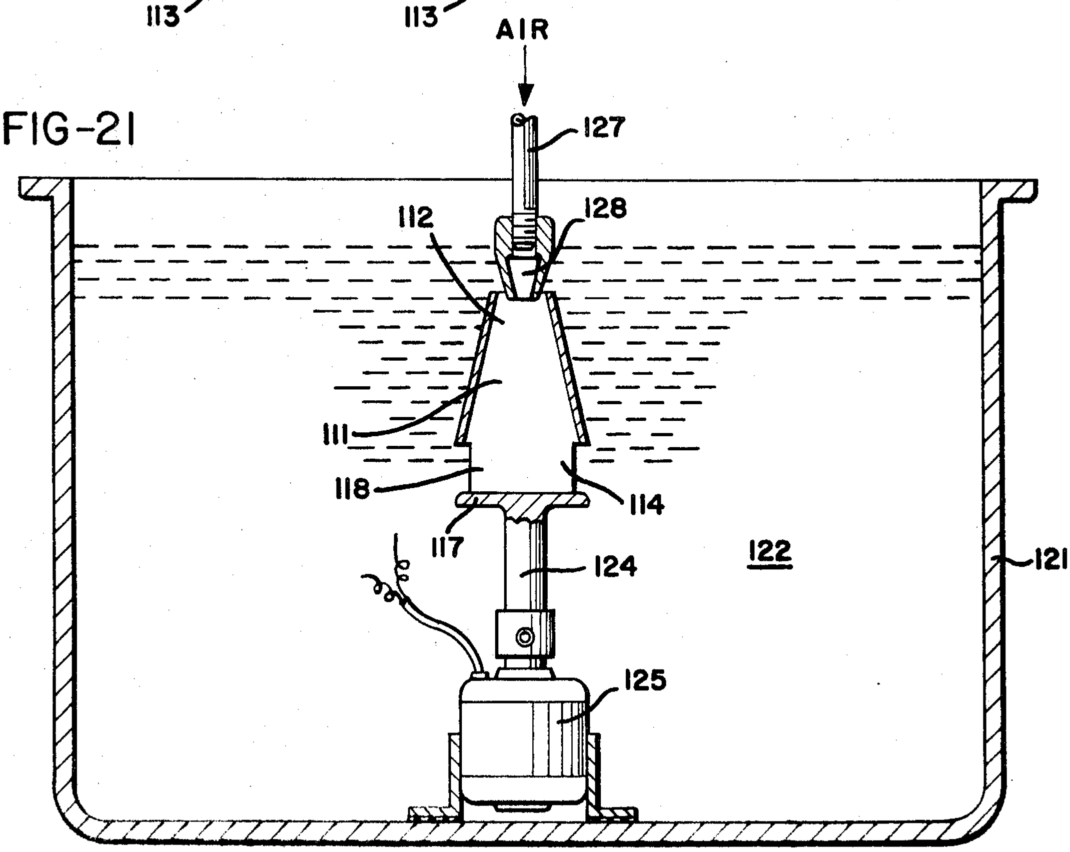

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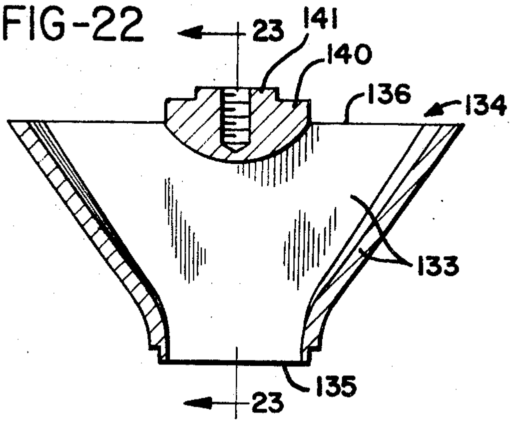

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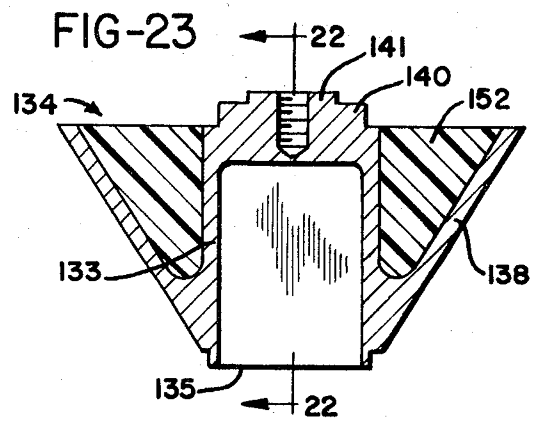

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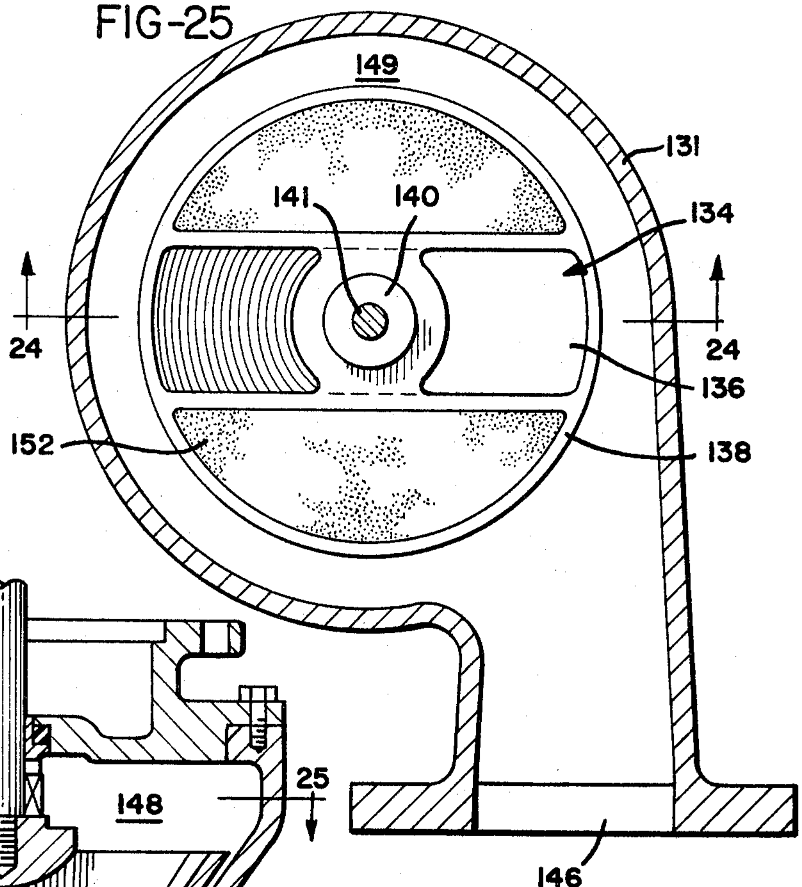

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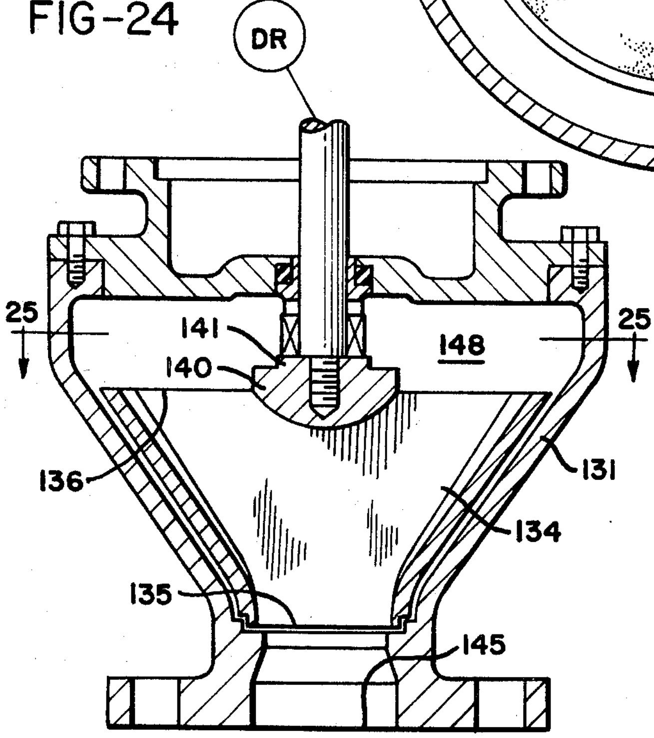

BLADELESS PUMP IMPELLER

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part application of my copending application, now abandoned, entitled BLADELESS PUMP IMPELLERS, Ser. No. 91,767, filed Nov. 23, 1970.

BACKGROUND OF THE INVENTION

This invention relates to pumps, and more particularly to impellers for use in pumping fluids which may have a considerable amount of solid and/or stringy material suspended therein.

Prior art pumps have generally been of either the reciprocating or continuous type, the latter including both bladed and bladeless pumps. The bladed type of continuous pump is quite familiar in the art, and examples thereof may be found in such references as U.S. Pat. No, 2,366,964 (G.P.E. Howard, issued Jan. 9, 1945), and U.S. Pat. No. 3,504,990 (D.B. Sugden, issued Apr. 7, 1970).

The Howard patent is an example of a centrifugal bladed pump. Such pumps use blades to force the fluid to rotate and to generate a centrifugal head, and are well known in the art.

The Sugden patent presents examples of a bladed pushing pump which relies primarily on axially pushing surfaces to move the fluid. Propellers and screws are common examples, and the various impellers disclosed in Sugden present blades and blade-like sections which are shaped to provide a continuously changing pitch in order to push the fluid along. Sugden also provides examples of a combined-function type of bladed design wherein pushing surfaces are also combined with lifting surfaces formed by carefully modulating and altering the shape and pitch of the impeller blade on both surfaces. The Sugden impeller combines the pushing upon the fluid with a cyclical and undulating action performed upon the fluid in order also to obtain a lifting effect with the fluid for enhanced performance.

Examples of bladeless pumps may be found in such patents as German Patent No. 714,289 of **1941**, U.S. Pat. No. 1,074,043 (M.W. Breuer, issued Sept. 23, 1913), and U.S. Pat. No. 1,007,266 (D.V. Burrell, issued Oct. 31, 1911). These impellers achieve their pumping effects by rotating tubular sections such that the fluid is carried around in these tubular sections in circular paths. The Volbracht and Breuer devices wind the pipes in screw-like fashion of ever increasing diameter so that the increasing centrifugal forces upon the fluid tend to carry it ever farther and farther along the pipes. The Burrell device rotates several pipe branches at the bottom of a column of water causing the entire column to rotate. The rotation causes centrifugal forces at the top of the column to carry water over the top edges thereof, resulting in the pumping effect.

The difficulty with the bladed and bladeless pumps thus far discussed is that their capacity for handling fluids containing suspended solid material, such as sewage, is generally quite limited. In the bladed pumps, the edges of the blades may come into contact with and/or become entangled in the suspended material, as may also internal and external edges and modulations which may have been incorporated to provide lifting surfaces. Similarly, the tubular portions of the bladeless pumps may become fouled with the solid and/or stringy material suspended in the fluid.

Another type of bladeless pump using an effect similar to the Burrell pump is disclosed in U.S. Pat. No. 2,301,722 (C.S. Vaughn, issued Nov. 10, 1942). Vaughn discloses a pump wherein a paddle wheel flush with the walls of the container is used to rotate the fluid within the container. The resulting centrifugal vortex then expels the fluid over the rim of the container.

Bladeless centrifugal pumps are also known which rely entirely upon shear forces for rotating the fluid. Such pumps would also be capable of handling fluids containing suspended solids such as are encountered in some types of sewage systems. Examples of such pumps may be found in U.S. Pat. No. 2,835,202 (F.W. Lauck, issued May 20, 1958), and pages 49–50 of Product Engineering, May 6, 1968. These references disclose pumps wherein the container is caused to rotate and the smooth walls thereof induce a sympathic rotation of the fluid due to the shear forces between the fluid and the walls. The rotating fluid forms a vortex and overflows at the rim of the container.

The limitations of the bladeless or shear vortex pumps as well as the Vaughn paddle pump should be readily apparent. These pumps have only a very limited pumping capacity and develop relatively low pumping pressure. Thus although valuable in certain applications, these pumps would not be practical in the typical sewage handling situation.

It may therefore be seen that the bladed type of prior art pump has not been practical for handling fluid containing large amounts of suspended solids because of the risk of fouling. Similarly, prior art bladeless pumps have suffered either from the risk of fouling or from a limited pumping capacity.

SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide an improved bladeless pump impeller having the capacity to pump fluids containing substantial quantities of suspended solids and stringy material while remaining free from fouling or clogging due to the suspended material.

It is another object of this invention to provide such a bladeless pump impeller which can pump large quantities of such fluids while developing a substantial pressure head.

A further object of this invention is to provide such an improved bladeless pump impeller which is uncomplicated, reliable, durable, and economical in construction.

Briefly, one embodiment of this invention includes a hollow tubular body having an inlet at one end and an outlet at the opposite end. The inlet is of circular shape; the outlet is of a generally oblong shape. The smaller dimension of the outlet is generally as large as the inlet, and the larger dimension of the outlet is greater.

The interior walls of the impeller connect the inlet to the outlet smoothly. There are no sharp edges nor curved lifting or bladed surfaces. In the preferred embodiment, a line traced from a point on the outlet directly along an interior wall to its corresponding point at the inlet will be a straight line, such as is found on a straight edge. As the fluid passes through the impeller, its configuration is therefore gradually altered from that of a circular column to that of an oblong column.

The impeller is rotated about an axis which passes symmetrically through the centers of both the inlet and outlet. As the fluid passes through the body into the increasingly oblong portions, it changes its shape accordingly. The fluid is therefore increasingly forced to rotate with this oblong portion, almost as if it were a solid body. Since there is no internal blading, the rotational acceleration of the fluid is caused solely by the tangential sidewall action within the impeller.

At the outlet end of the impeller, the rotating, oblong-shaped fluid has developed a significant centrifugal head. This centrifugal head causes the fluid to be thrown off as it passes the outlet of the impeller.

Succinctly stated, the pumping action of the impeller might be described as follows. A sort of "prior displacement" effect is utilized wherein the removal of fluid at the outlet of the impeller causes more fluid to be drawn into the inlet. The fluid which is drawn into the inlet is then forced to undergo a change of shape. The change of shape into an oblong configuration enables the impeller to force the fluid to rotate. Once the fluid is rotating, the centrifugal pressures of the rotating fluid expel the fluid from the outlet of the impeller. The displacement of the rotating fluid from the outlet of the impeller then causes additional fluid to be drawn into the inlet, and the cycle is continuously repeated.

It is also noteworthy that the impeller may be rotated in either direction with equal pumping efficiencies. This reversibility is a result of the absence of conventional blading within the impeller as well as the lifting and pushing surfaces associated therewith.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an embodiment of this invention adapted for submerged applications;

FIG. **2** is a cross-sectional view of the impeller of FIGS. **1–5** taken along line **2—2** of FIG. **3**;

FIG. **3** is a cross-sectionsl view of the impeller taken along line **3—3** of FIG. **2**;

FIG. **4** is a cross-sectional view of the impeller of FIGS. **1–5** taken along line **4—4** of FIG. **3**;

FIG. **5** is a side view, partially in section, of a mixing and aeration device utilizing the impeller of FIG. **1**;

FIG. **6** is a perspective view of an embodiment of this invention for use in surface aeration;

FIG. **7** is a top view of the impeller of FIG. **6**.

FIG. **8** is a cross-sectional view of the FIG. **7** device taken along line **8—8** of FIG. **7**;

FIG. **9** is a cross-sectional view of the impeller of FIG. **8** taken along line **9—9** of FIG. **8**;

FIG. **10** is a side view, partially in section, of an aeration device utilizing the embodiment of FIG. **6** of this invention;

FIG. **11** shows a device similar to the FIG. **10** device, with the impeller having a rounded inlet and with the motor mounted above the liquid;

FIG. **12** is a cross-sectional view of a stern of a boat showing an embodiment of this invention in combination with straightening vanes to promote an axial discharge for developing thrust;

FIG. **13** is an end view, looking from the right, showing the straightening vanes therein;

FIG. **14** is a view of the outlet end of the impeller of the FIG. **12** device;

FIG. **15** is a cross-sectional view of the impeller of FIGS. **12–16** taken along line **15—15** of FIG. **14**;

FIG. **16** is a cross-sectional view of the impeller taken along line **16—16** of FIG. **14**;

FIG. **17** is a side view, partially in section, of the impeller of FIGS. **18–21** taken along line **17—17** in FIG. **19**, and showing an embodiment of this invention adapted for submerged agitation of fluid as well as the pumping thereof;

FIG. **18** is a side view of the impeller of FIG. **17**;

FIG. **19** is a bottom view of the impeller of FIG. **17**;

FIG. **20** is a cross-sectional view of the impeller of FIG. **17** taken along line **20—20** of FIG. **17**;

FIG. **21** is a side view, partially in section, of an embodiment of this invention according to FIG. **17** employed in an aeration and mixing device;

FIG. **22** is a cross-sectional view of the impeller of FIGS. **23–25**, taken along line **22—22** of FIG. **23**, and showing an impeller adapted for use in a constricted environment such as a pump housing;

FIG. **23** is a cross-sectional view of the impeller of FIG. **22** taken along the line **23—23** of FIG. **22**;

FIG. **24** is a cross-sectional view of the FIG. **25** device taken along line **24—24** of FIG. **25** and showing an impeller according to FIG. **22** utilized in a modified volute centrifugal pump; and

FIG. **25** is a cross-sectional view of the device of FIG. **24** taken along line **25—25** of FIG. **24**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIGS. **1–5** show an embodiment of this invention suitable for submerged application in pumping fluids containing substantial quantities of suspended solids, such as sewage. The impeller **30** has a generally hollow, tubular body **31**. The inlet **32** to impeller **30** is defined by a portion of impeller wall **33** of generally cylindrical section, defining thereby a circuit inlet **32**. The outlet **34** of impeller **30** is defined by a portion of wall **33** of generally oblong section which is located on the end of impeller **30** opposite the inlet end.

The outlet end of the impeller has extensions **38** attached thereto with a hub portion **39** extending between the extensions **38**. Hub portion **39** has a boss **40** or other means which may be attached to a drive means (not shown) to rotate impeller **30** about its principal axis. The principal axis passes symmetrically through inlet **32** and outlet **34**. Extensions **38** support the hub portion **39** at a distance from the outlet end in order to reduce the obstructing effect of hub means **39** opposite outlet **34** of the impeller. It should be noted in this connection that the outlet opening of the impeller extends completely across the outlet end of the impeller, and removal of hub **39** to a distance therefrom is therefore advantageous to the impeller action.

The maximum diameter of the oblong outlet **34** of impeller **30**, defined by wall portions **33**, is greater than the minimum diameter thereof and is also greater than the diameter of the inlet **32** of the impeller. The minimum diameter of the oblong wall portion of outlet **34** of impeller **30** is generally as large as or larger than the diameter of the inlet **32** of impeller **30**. The last condition is not necessary but is preferable in order to avoid constrictions in the impeller which might lead to clogging of suspended solids.

In the preferred embodiment, the wall portions **33** of the interior of impeller **30** define a smooth and continuous transition from the circular inlet **32** to the oblong outlet **34**. The interior is therefore a single channel which changes gradually along the axial direction from a substantially round passage at the inlet end to an essentially oblong passage, in cross section, at the outlet end. The oblong or out of round configuration at the outlet 34 is therefore able to rotate the fluid within the impeller substantially as a solid body. As shown in FIGS. 1–5, the longer wall portions 43 on two sides are generally flat and parallel while the other two shorter sides 44 are curved with increasing radii. The radii of the curved walls 44, as measured on the plane of rotation of the impeller, increase gradually as one passes along the axis of rotation from the inlet 32 to the outlet 34.

That the interior walls of the impeller connect the inlet 32 to the outlet 34 smoothly and with no internal blading may be seen by tracing a line from any point on outlet 34 directly along an interior wall to its corresponding point on the inlet 32. Such a line will be straight, such as is commonly found on a straight edge.

In order to present a smooth exterior to the fluid in which impeller 30 is immersed, skirt portions 46 are provided along the exterior of impeller 30. Skirt portions 46 cooperate with the wall portions 43 and 44 of impeller 30 to give impeller 30 a generally circular or conical external outline. That is, the skirt portions cooperate with a wall portion of the impeller to yield a circular external outline at any radial section taken along the axis of the impeller. Impeller 30 is then shaped somewhat similarly to a frustum attached to a cylindrical section.

The extensions 38 which support hub portion 39 are shown in this embodiment as also comprising extensions 47 of skirt 46 in order to complete the smooth exterior of impeller 30. Hub portion 39 then fully covers these extensions in order to complete the smooth exterior.

In operation, the impeller is caused to rotate about its principal axis by means of a drive means (not shown) attached to boss 40 on hub portion 39. As impeller 30 rotates about this axis, fluid which is contained in the oblong portion of the impeller is forced to rotate due to the oblong configuration. As it rotates, it experiences centrifugal forces and tends to move toward the outlet end 34 of the impeller. As the fluid passes beyond the outlet end of the impeller, extensions 38 maintain the fluid in full rotation and also assist in accelerating portions of the fluid moving radially outwardly. The fluid leaving the impeller draws additional fluid into and along the interior of the impeller, the impeller changing the shape of the fluid from columnar to oblong as it passes through.

The fluid in the oblong portions of the impeller is caused to rotate solely by the tangential sidewall action of the walls 33 of the oblong portion of the impeller. There are no blades or blade-like surfaces in the interior fluid channel of the impeller. The impeller functions by changing the shape of the fluid from circular to oblong whereby it becomes possible to force the fluid to rotate. Further, as the oblong shape of the fluid becomes increasingly pronounced, the fluid may be found more and more to rotate similarly as a solid body.

It is significant in this regard that this impeller is equally effective regardless of the direction in which it is rotated. This complete reversibility results in part from the absence of any blading or blade-like surfaces on the interior or the exterior of the impeller. The insensitivity of this invention to the direction of rotation is in sharp contrast to bladed impellers and makes this impeller particularly useful in those applications where it may be desired to drive the impeller from a drive means subject to reversals in directions. Whatever may be the need to make the drive reversible, the impeller of this invention would then require no compensating gear shift.

The reversibility of this impeller may also be appreciated in certain difficult applications where fluids containing substantial suspended stringy or solid material may be encountered. As discussed above, the contour of the impeller presents a smooth exterior and no sharp contour changes on the interior in order to prevent any of the suspended material from clogging the impeller or becoming entangled on the drive shaft. Should clogging occur in any part of the pump, however, this material may be disloged simply by reversing the impeller with no change in the impeller functioning.

In operation, therefore, the pump utilizes an effect similar to that of "prior displacement." The removal of the fluid at the outlet 34 of the impeller causes the fluid within the channel to be drawn along toward the outlet and additional fluid to be drawn into the inlet 32. As the fluid passes along through the interior of the impeller, the shape of the fluid is changed, as discussed above, allowing it to be forced to rotate. The rotation, in turn, causes the fluid to be expelled from the outlet of the impeller, and this "prior displacement" cycle is repeated.

The extensions 38 of the wall portions 33 are provided to remove the hub means 39 some distance from the outlet portion of the impeller in order to allow the hub means 39 to be larger and stronger without materially affecting the flow of fluid as it leaves the impeller. This feature may be more fully appreciated by comparing FIGS. 6 and 22 (which will be discussed in greater detail below). The extensions 68, or webs, of the wall portion 65 may be clearly seen in FIG. 6, with hub means 69 attached across the ends thereof. The embodiment of FIG. 22 does not include such webs and hub means 140 is attached directly across the outlet 136 of impeller 134.

FIG. 5 illustrates an application of the impeller of FIG. 1 for submerged circulation and aeration of a fluid 50 which may or may not contain suspended solid material. Fluid 50 is shown as being contained generally in a container 51. Impeller 30 is driven by a suitable drive means, illustrated here as a submerged motor 52 adjacent impeller 30. A hollow air pipe 54 extends above the surface of the fluid and has a supporting nozzle 55 attached thereto adjacent the inlet 32 to impeller 30. In operation, impeller 30 will draw fluid in from the regions surrounding inlet 32 and will draw air through air pipe 54 at the same time. The fluid and air will then be mixed within impeller 30 and expelled through outlet 34 of impeller 30. The pumping action of impeller 30 will simultaneously circulate the fluid 50 within the container 51.

The embodiments disclosed in the remaining figures are similar in construction to that shown in FIGS. 1–5, and all operate on the same principles. The modifications shown in these additional embodiments illustrate ways in which the impeller of this invention may be adapted to make it particularly well suited to certain applications.

Thus in FIGS. 6–11, an embodiment of the impeller of this invention is shown which is particularly well suited for applications involving surface spray aeration or decorative fountains. The outlet 60 of the impeller 61 is located above the surface of the liquid 62 (FIGS.

10 and 11) so that the discharge from impeller **61** expels the fluid **62** into the air above the surface of the fluid. The liquid spray thereby presents a very large surface area to the surrounding air, effectively aerating it before it returns.

Thus FIGS. **6–9** show the circular inlet **64** and oblong outlet **60** of the impeller **61** as defined by the wall portions **65** thereof. The dimensions of the inlet and outlet portions are similar to those of the embodiment shown in FIGS. **1–4.**

The embodiment of FIGS. **6–9** also includes extensions **68** which connect the hub means **69** with the impeller **61.** Hub means **69** has a boss **70** thereon for connection with a drive means (not shown) to rotate impeller **61** about its central axis. Web extensions **68** serve to support hub means **69** at a distance from the outlet **60** of impeller **61** in order to minimize the effect of the hub portion **69** upon the exiting fluid.

This embodiment also includes skirt portions **75** which serve to present a smooth exterior to the fluid **62** when this portion is immersed therein. The skirts **75** cooperate with the wall portions **65** of impeller **61** giving it a generally circular or conical exterior outline. The smooth exterior of the impeller serves to minimize agitation of the fluid and to minimize fluid drag on the impeller, in order to improve the efficiency thereof.

Similarly, the edges **76** and **77** of inlet **64** and outlet **60** have been rounded in order to provide a smoother flow pattern for fluid **62** as it enters and leaves impeller **61.**

FIGS. **10** and **11** illustrate aeration or fountain applications utilizing the impeller of FIGS. **6–9.** In FIG. **10** the impeller **61** is driven by a submerged motor **78** with the drive shaft **79** passing along the axis of rotation of the impeller and connected to the boss **70** on hub means **69.** Motor **78** and impeller **61** are suspended in fluid **62** by a flotation device **80** with appropriate bracket means **81** connecting to the motor **78.**

FIG. **11** illustrates an embodiment similar to FIG. **6–9** wherein the motor **84** is not submerged as in FIG. **10.** Instead, drive motor **84** is suspended above a float **85** by means of brackets **86** and cross bar **87.** One advantage of the FIG. **11** application is that the drive shaft **88** is external to fluid **62** and debris will therefore not wind around shaft **88.** The inlet **64** to the impeller in FIG. **11** is also shown as being modified by the addition of a wide scooping mouth **89** in order to develop a smoother flow pattern at the inlet **64.** FIG. **11** therefore illustrates one of many configurations which may be adopted without departing from the scope of the invention.

FIGS. **12–16** illustrate an embodiment of the invention adapted to provide an axial discharge to develop thrust. The impeller **91** is shown as being adapted for propelling a boat **92** or other marine craft. Impeller **91** is mounted on the stern **93** and is driven by a drive shaft **94** connected to the hub means **95.** Drive shaft **94** and impeller **91** are supported by a stationary shroud **96,** drive shaft **94** turning in a water lubricated rubber bearing **97.**

The boat is provided with a conventional water inlet **100** connecting directly to the impeller inlet **101.** An outer casing **103** provided with straightening vanes **104** on the rear portion thereof surrounds impeller **91.** The casing **103** and straightening vanes **104** work cooperatively to convert the generally radial and spiral discharge from impeller **91** into an axial flow, thus providing the desired thrust from the impeller. Straightening vanes **104** are of smooth configuration with a taper which retreats in the direction of the fluid flow in order to prevent debris from snagging thereon. Similarly, hub means **95** has been modified to provide a generally smooth exterior, to direct the fluid into the vanes **104,** and otherwise to improve the flow characteristics within casing **103.** The junction of the hub means **95** with the extensions **106** has been rounded for the same reason and the dimensions of the hub means **95** itself have been kept to a minimum in order to reduce interference with the flow from the outlet **107** of the impeller **91.**

FIG. **13** illustrates the thrust embodiment of FIG. **12** as seen when looking in the direction from right to left into the right end of the FIG. **12** embodiment. Similarly, FIG. **14** presents an end view of impeller **91** itself.

The utility of this impeller for certain propulsion applications becomes readily apparent where fluids containing substantial amounts of suspended solids and stringy material, such as plants and debris, are encountered. Such debris can cause considerable difficulty for conventional bladed propulsion means, and may even be hazardous. The embodiment of FIGS. **12–16,** however, provides propulsion in such debris-laden environments with a minimum of difficulty.

The initial starting thrust produced by the embodiment of FIGS. **12–16** is also likely to be greater than that of conventional bladed impellers. At zero vehicle velocity bladed impellers tend to suffer from cavitation when high thrust is desired. The impeller of this invention, however, is much more resistant to cavitation and the initial thrust produced thereby should be enhanced accordingly.

It should also be noted that unlike bladed impellers, the impeller of this invention is also relatively insensitive to off-axis inlet flow. Conventional bladed impellers suffer from inlet flows which are not axial, thus making the impeller of this invention useful in those applications where an on-axis inlet flow is difficult to maintain. In applications such as shown in FIGS. **12–16** it becomes possible for example to develop maximum efficiency while simultaneously optimizing the fluid-flow configuration.

FIGS. **17–21** illustrate an application of this invention for agitation as well as aeration of the fluid suspension. In this embodiment, wall portion **111** of the impeller **112,** which defines the inlet **113,** outlet **114,** and interior of impeller **112,** also defines the exterior of the impeller. The hub portion **117** is attached to the impeller by means of extensions **118.** By presenting an irregular circumferential exterior to the medium in which it is immersed, impeller **112** will both pump and agitate the fluid as it rotates about its central axis.

Thus in FIG. **21,** the impeller **112** is shown mounted in a container **121** and submerged in a fluid **122** which is to be aerated and agitated. The hub portion **117** of impeller **112** is attached to a shaft **124** which is driven by a motor **125.** An aeration tube **127** is provided and is connected to a source of air such as the surface of the container **121.** The aeration tube **127** delivers the air to an air nozzle **128** adjacent the inlet **113** to impeller **112.** In operation, fluid and air are drawn through impeller **112,** mixed, and caused to circulate within tank **121.** Simultaneously impeller **112** agitates the fluid **122** in its immediate vicinity. This process may be performed satisfactorily even when fluid **122** contains considerable suspended solid material. In fact, this impeller is well adapted for emulsifying certain types of suspensions.

FIGS. 22–25 illustrate still another embodiment of this invention adapted for use, for example, in a volute-like pump housing **131**. In this embodiment, the walls **133** of the impeller **134** again define a circular inlet **135** and an oblong outlet **136** with dimensions similarly related as the other impellers. Skirt portions **138** are provided in order to give the impeller a smooth exterior. As with the other embodiments, therefore, the impeller takes on a shape similar to that of a frustum.

This embodiment illustrates one modification of the impeller which may be made where space limitations are significant. The dimensions of impeller **134** have been reduced by the elimination of the extensions of the other embodiments. Instead, the hub means **140** in this embodiment is attached directly to the walls **133** of the impeller **134** at the outlet end. In this case hub means **140** has been especially contoured with smooth, curved surfaces in order to minimize the interference thereof with the fluid exiting from the impeller. As in the other embodiments hub means **140** is provided with a boss **141** for attachment of the impeller **134** to a drive means for rotation of the impeller about its central axis.

FIGS. **24** and **25** show the impeller within a volute-like pump housing **131** having an inlet **145** and an outlet **146**. The pump housing **131** is not shown as being a true volute because this application is intended for use where the fluid may contain considerable quantities of suspended solids which might be sizeable. The region **148** above the outlet end of the impeller **134** is accordingly shown as being large in relation to the size of the pump housing inlet **145** and to the impeller inlet **134**. Likewise, as may be seen in FIGS. **24** and **25**, the circumference of the discharge portion **149** of the pump housing **131** is larger than the maximum diameter of the oblong portion of the outlet end of impeller **134**. These larger dimensions are provided in order to maintain a clearance for the suspended materials.

It will be recalled that in the typical volute pump housing, the diameter of the discharge end of the housing increases in the direction of rotation of the impeller as the outlet of the pump housing is approached. Where sizeable suspended solids are present, however, the restrictions which are presented by the usual volute pump housing are likely to provide impediments to the solid material. Thus sizeable clearances are maintained in this embodiment in order to allow the solid material freely to pass.

It is also clear that impeller **134** would be equally effective in a standard volute-type centrifugal pump housing when no solids were present or the solids were already highly emulsified.

Impeller **134** produces a varying pressure head at varying radii which terminates as an average pressure head at the outlet **146** of pump housing **131**.

FIGS. **23** and **25** show the region **152** between the impeller walls **133** and the exterior skirt portions **138** as being filled with a suitable filler material **152**. Filler material **152** is selected for compatability with the surrounding fluid medium. Of course the analogous regions in other embodiments may likewise be similarly filled where it is considered appropriate.

The embodiment of FIGS. **1–4** may also be used in applications such as volute pumps, and experiments therewith have proven highly successful. FIGS. **22–25** therefore present but one example of the adaptation of the impeller of this invention to virtually any application where existing bladed impellers would prove unsatisfactory due to the presence of solid or stringy material within the liquid.

While the preferred embodiments of this invention have been shown in the drawings as having generally flat impeller wall portions along the longer dimension, it should be clear that these walls could also have a curved configuration, such as an oval shape. If the walls were selected so that the plane tangential to any point on the wall would be coincident with a plane tangential to a point on the wall of a cylinder or frustum having its axis coincident with the axis of rotation of the impeller, then no internal blade-like effects would obtain even though the walls of the impeller were not flat. The propulsion of the fluid would be strictly due to centrifugal forces. And, of course, such an impeller would still be completely reversible. It will be observed in this regard that the shorter walls of the impeller, as described in the various embodiments above, are in fact curved as just set forth. However, experimental evidence at this time indicates that where the longer dimension is concerned, substantially flat or planar walls are superior.

It should also be noted that where the exterior outline of the impeller is circular or frustoconical, the body of the impeller could equally well be considered as being the frustoconical exterior. In that case the internal wall portions would comprise a pair of internal partition means which generate the oblong internal cross-section.

While the forms of apparatus herein described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise forms of apparatus, and that changes may be made therein without departing from the scope of this invention.

What is claimed is:

1. An impeller especially adapted to pump liquids containing substantial quantities of suspended solids, comprising:

a. a tubular body open at both ends and throughout the interior thereof and having a central axis;
b. said body having adjacent one end thereof a wall portion of cylindrical section defining a circular inlet;
c. said body having at the opposite end thereof a wall portion of generally oblong section defining the outlet of the impeller;
d. the maximum diameter of said oblong wall portion being substantially greater than the minimum diameter thereof and the diameter of said inlet;
e. the interior of said body defining a continuous axially extending pumping channel having a continuous, gradual, and smooth transition, free of internal blading, from said circular inlet wall portion to said oblong outlet wall portion, said pumping channel having a substantially uniformly increasing oblong cross section in the plane of rotation from said inlet toward said outlet;
f. and hub means on said body for mounting said body on a shaft for rotation on said axis to subject liquid in the interior of said body to increasingly positive rotation normal to said central axis, as the shape of the fluid column gradually becomes increasingly oblong in said pumping channel, said ro-

tation causing such liquid to flow from said inlet to said outlet.

2. An impeller as defined in claim 1 wherein the minimum diameter of said oblong portion is substantially the same as the diameter of said inlet.

3. An impeller as defined in claim 1 wherein said hub means comprise extensions on one end of said body.

4. An impeller as defined in claim 1 wherein said hub means comprise extensions on said oblong wall portion, and a hub portion connected between the outer ends of said extensions externally of said body.

5. An impeller as defined in claim 1 comprising skirt portions forming external continuations of said oblong portion and cooperating therewith to impart a circular external outline to said body at all radial section lines along said axis.

6. An impeller as defined in claim 5 comprising means closing the interiors of said skirt portions substantially flush with the outlet end of said body.

7. An impeller as defined in claim 1 wherein the external outline of said body in radial section varies progressively from circular at said inlet to said oblong section at the outlet end of said body.

8. An impeller especially adapted to pump liquids containing substantial quantities of suspended solids, comprising:

a. a tubular body open at both ends and throughout the interior thereof and having a central axis;

b. the outer wall of said body having a substantially symmetrical frustoconical shape;

c. the smaller end of said body defining a circular inlet to the impeller;

d. a pair of partition means extending within said body in symmetrically opposed relation from a location adjacent said inlet to the opposite end of said body;

e. said partition means cooperating with portions of said outer wall to define a generally oblong outlet from said body having a maximum diameter substantially greater than the diameter of said inlet;

f. the interior of said body defining a continuous axially extending pumping channel having a continuous, gradual, and smooth transition, free of internal blading, from said circular inlet to said oblong outlet, said pumping channel having a substantially uniformly increasing oblong cross section in the plane of rotation from said inlet toward said outlet;

g. and hub means on said body for mounting said body on a shaft for rotation on said axis to subject liquid in the interior of said body to increasingly positive rotation normal to said central axis, as the shape of the fluid column gradually becomes increasingly oblong in said pumping channel, said rotation causing such liquid to flow from said inlet to said outlet.

9. An impeller as defined in claim 8 wherein said hub means comprise extensions on said partition means, and a hub portion connected between the outer ends of said extensions and cooperating therewith to define a pair of radially directed discharge ports from said outlet.

10. An impeller as defined in claim 9 comprising cylindrically curved skirt portions extending axially beyond said body from the larger end thereof substantially coextensive with said extensions on said partition means, said skirt portions cooperating with said extensions and with said hub portion to enclose the spaces between said partition means and the surrounding wall portions of said body.

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