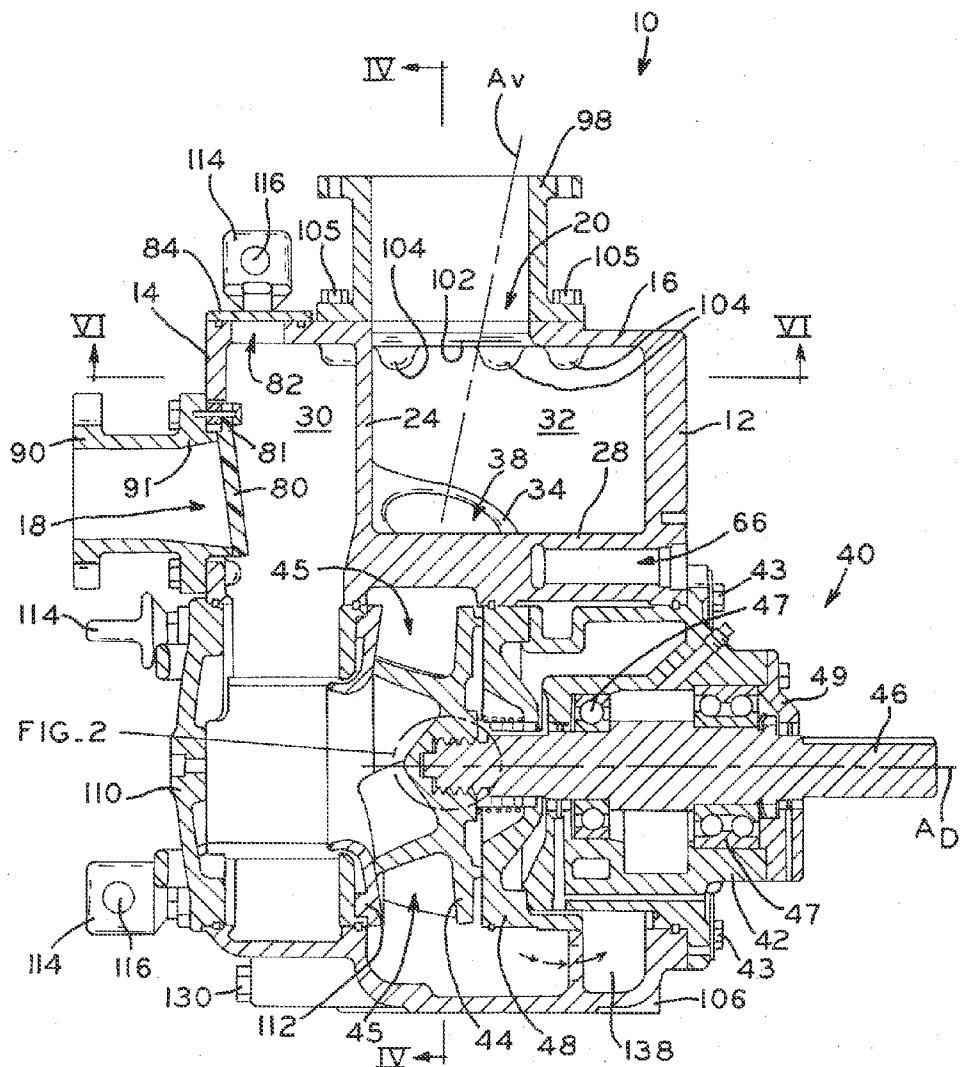




US 20160245291A1

(19) **United States**(12) **Patent Application Publication**
Carnes(10) **Pub. No.: US 2016/0245291 A1**(43) **Pub. Date: Aug. 25, 2016**(54) **SELF-PRIMING CENTRIFUGAL PUMP**(52) **U.S. Cl.**(71) Applicant: **Franklin Electric Co., Inc.**, Fort Wayne,
IN (US)CPC **F04D 17/10** (2013.01); **F04D 25/02**
(2013.01); **F04D 29/4206** (2013.01); **F04D**
29/624 (2013.01)(72) Inventor: **William M. Carnes**, Milwaukie, OR
(US)(57) **ABSTRACT**

A self-priming centrifugal pump has enhanced efficiency and performance characteristics and/or features which facilitate installation, inspection and maintenance of the pump. For efficiency and performance, the pump may include a smooth fluid flow path which enhances pump output for a given input power, including one or more of a specially shaped and directed volute discharge, a lack of internal stiffening ribs on the pump casing walls, a necked inlet and a rounded, flow-channeling outlet aperture. For maintenance and serviceability, the pump may include one or more of a coarse-threaded drive shaft and impeller with a concentricity feature, a combination port for both filling the casing and accessing the inlet flapper valve, and a drive disassembly system which facilitates attachment or removal of the drive system from the pump.

(21) Appl. No.: **14/625,732**(22) Filed: **Feb. 19, 2015****Publication Classification**(51) **Int. Cl.**
F04D 17/10 (2006.01)
F04D 29/42 (2006.01)
F04D 29/62 (2006.01)
F04D 25/02 (2006.01)

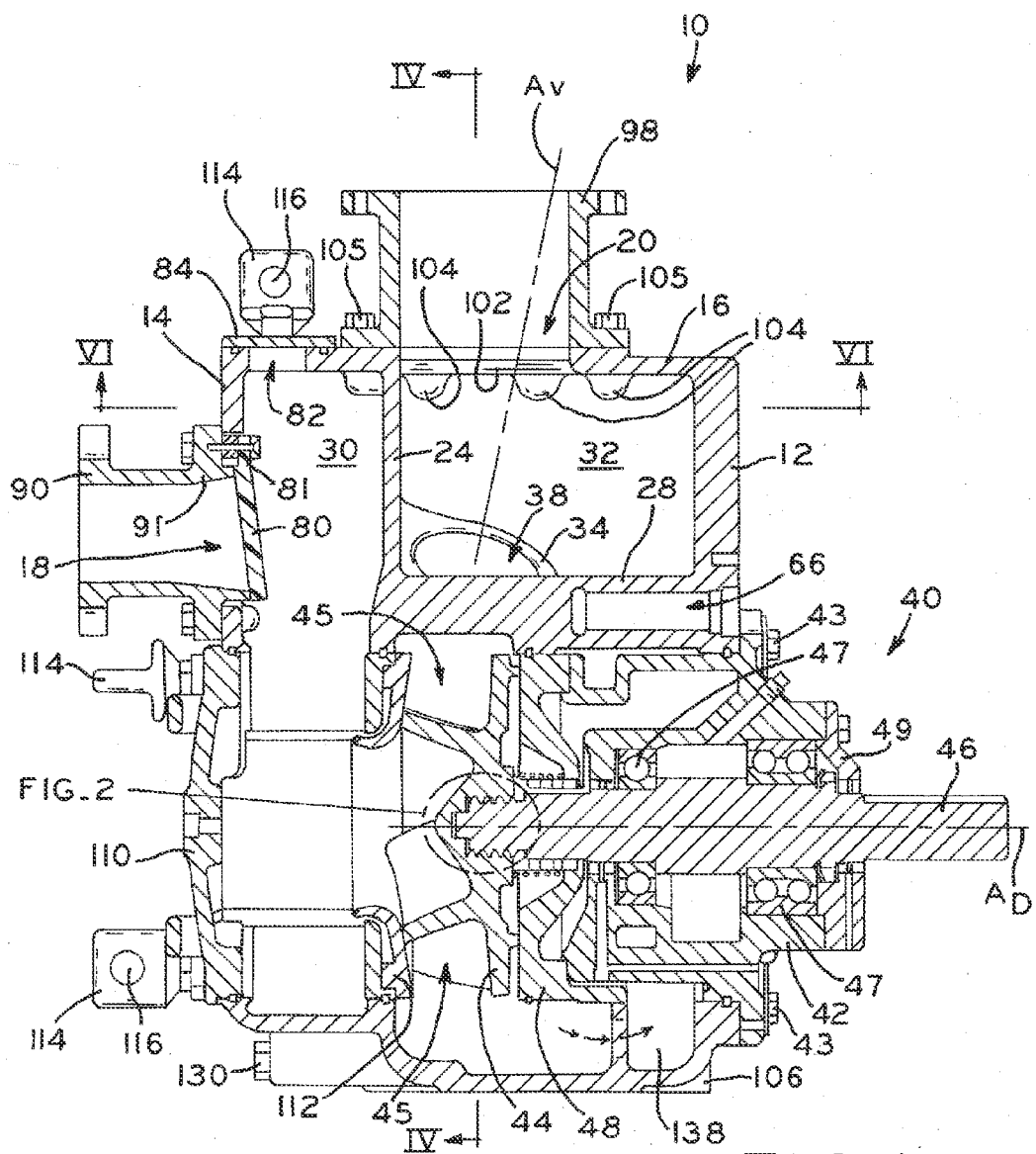


FIG. 1

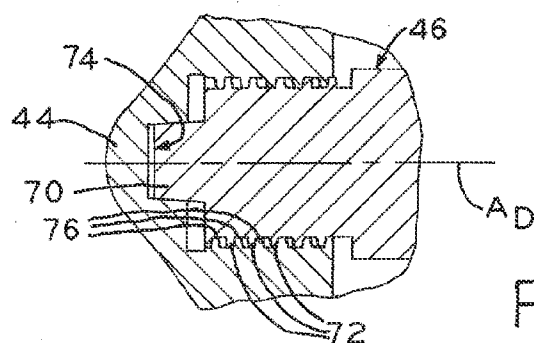


FIG. 2

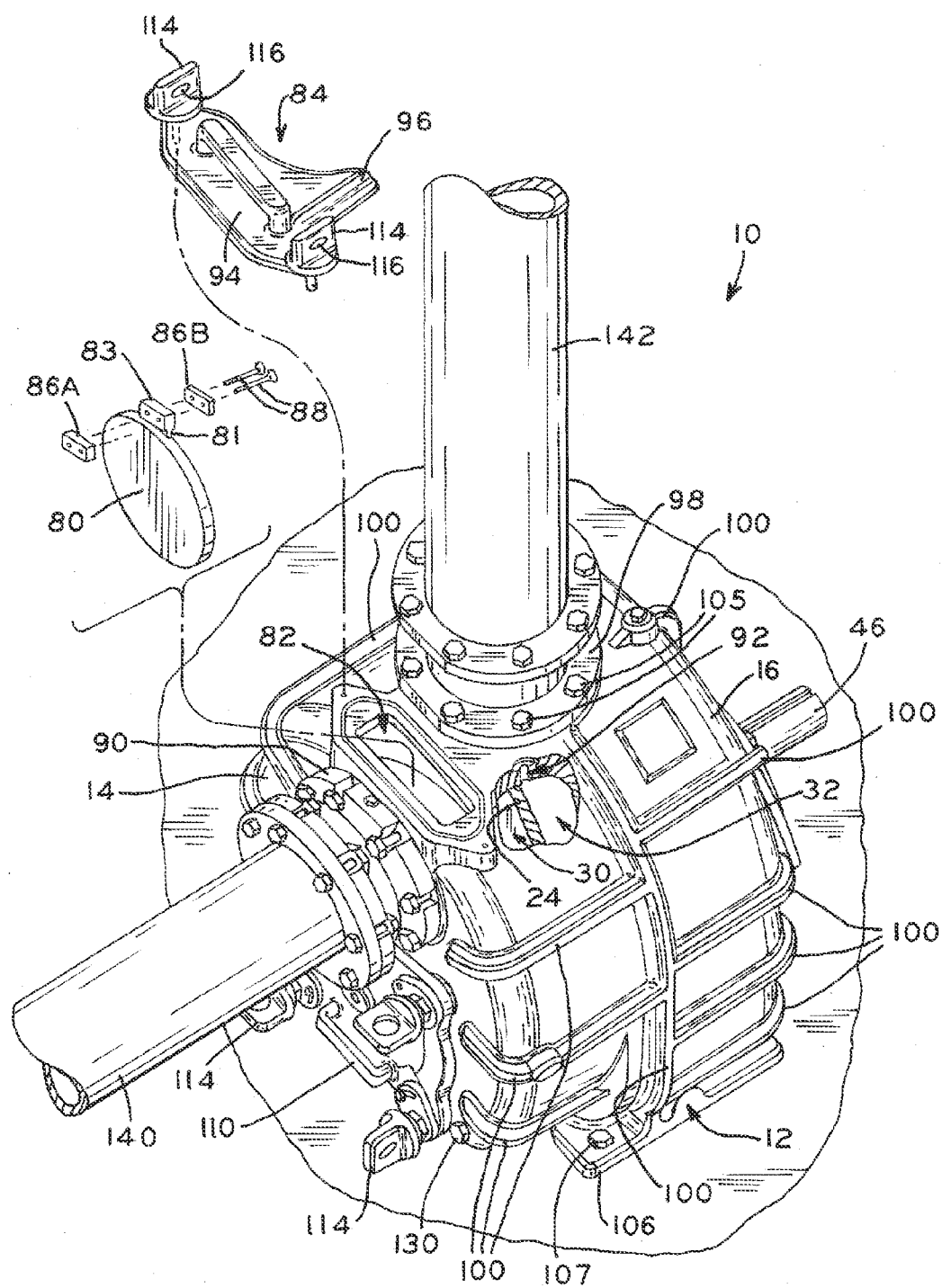


FIG. 3

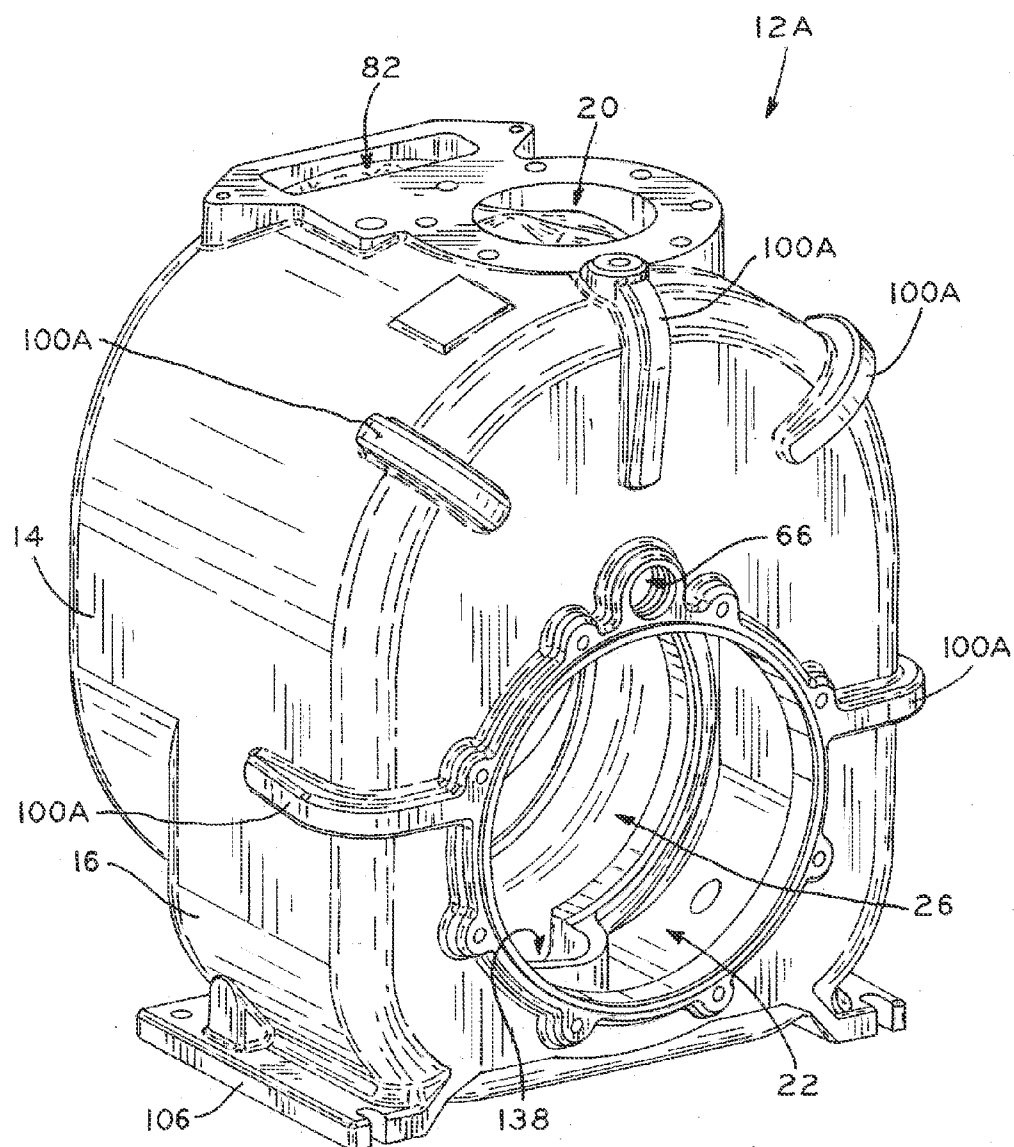


FIG. 3A

FIG. 3B

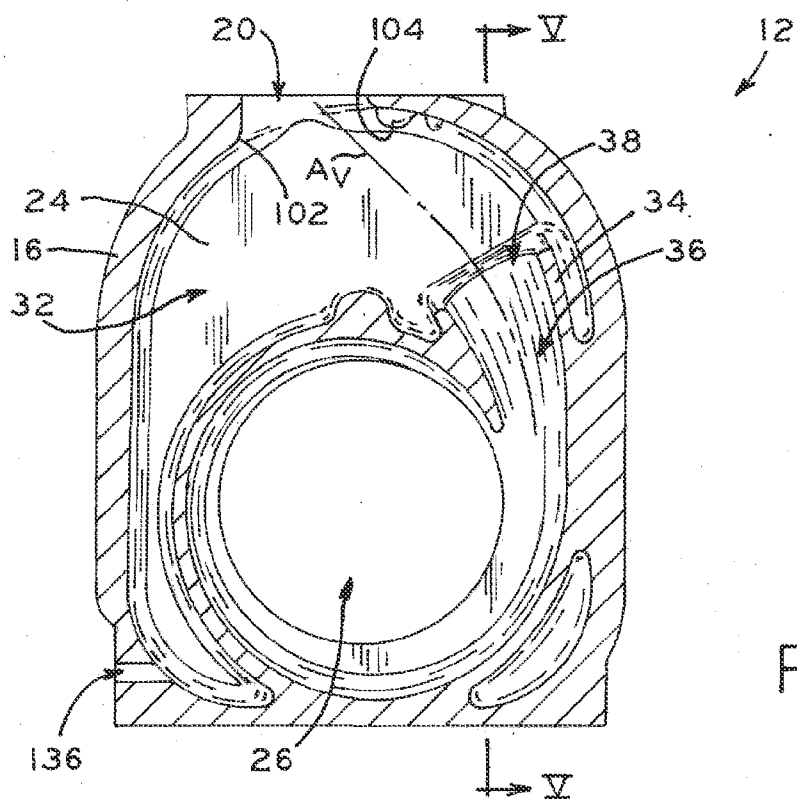


FIG. 4

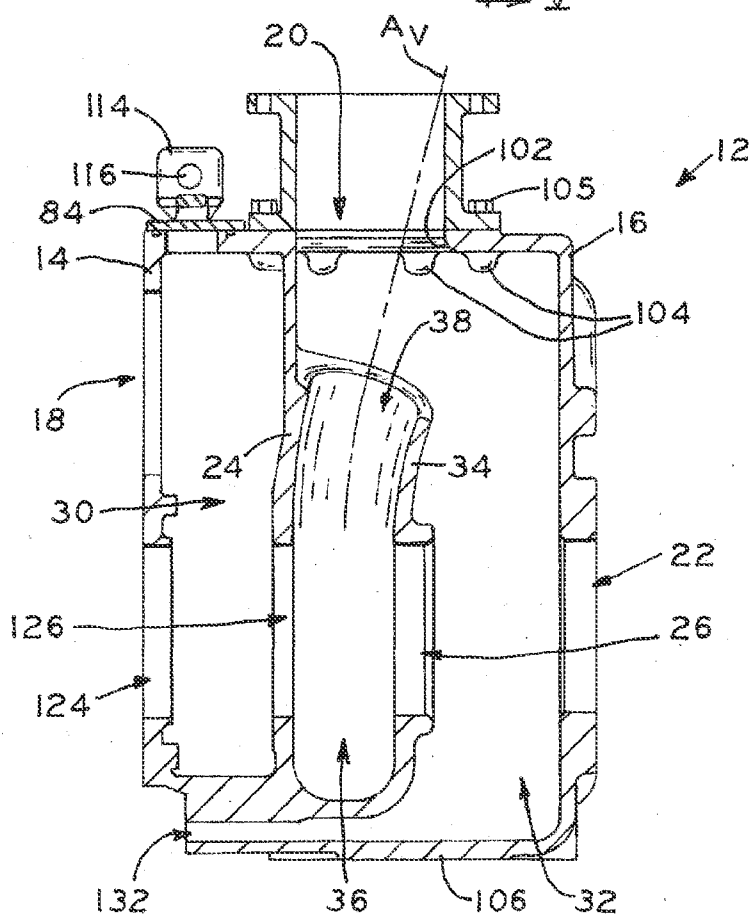


FIG. 5

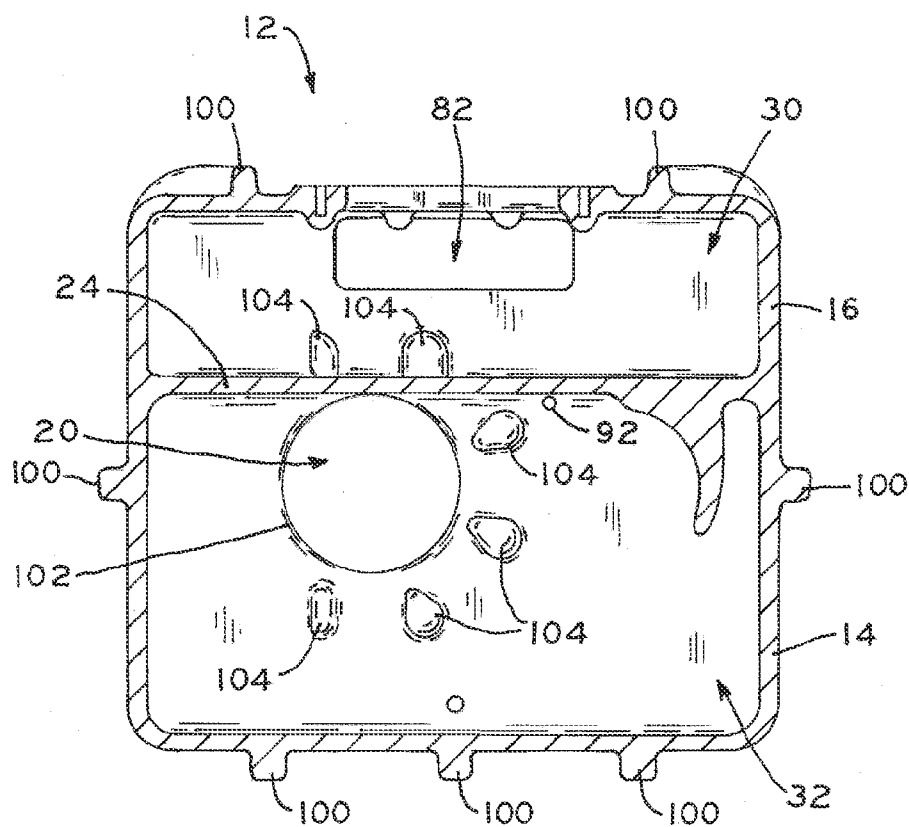


FIG. 6

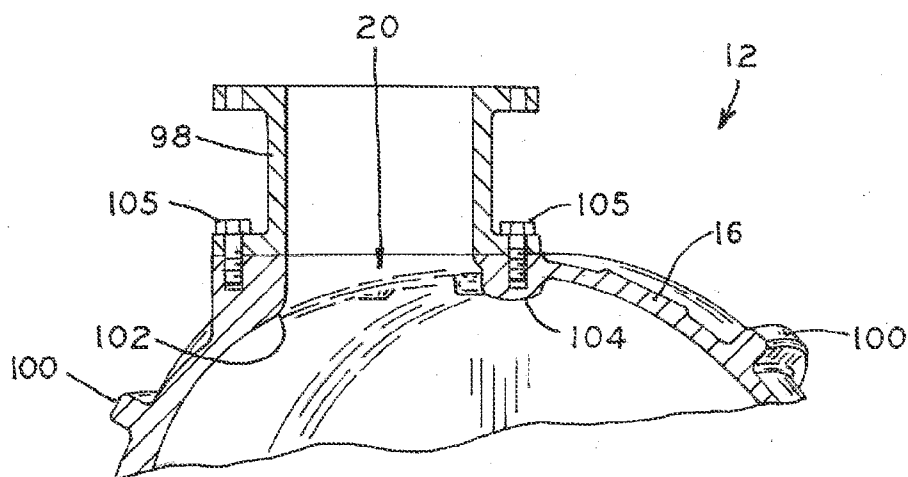


FIG. 7

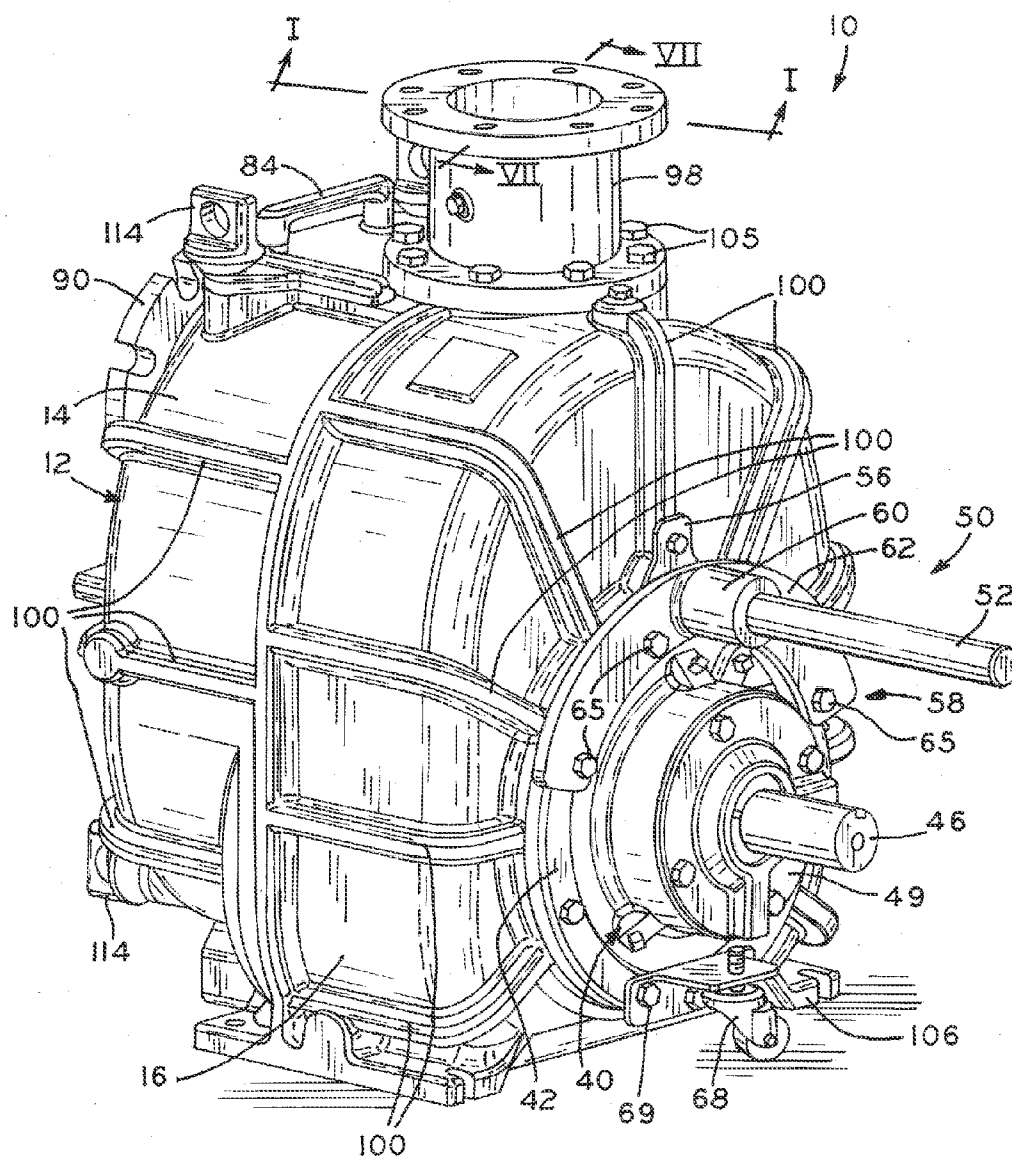


FIG. 8

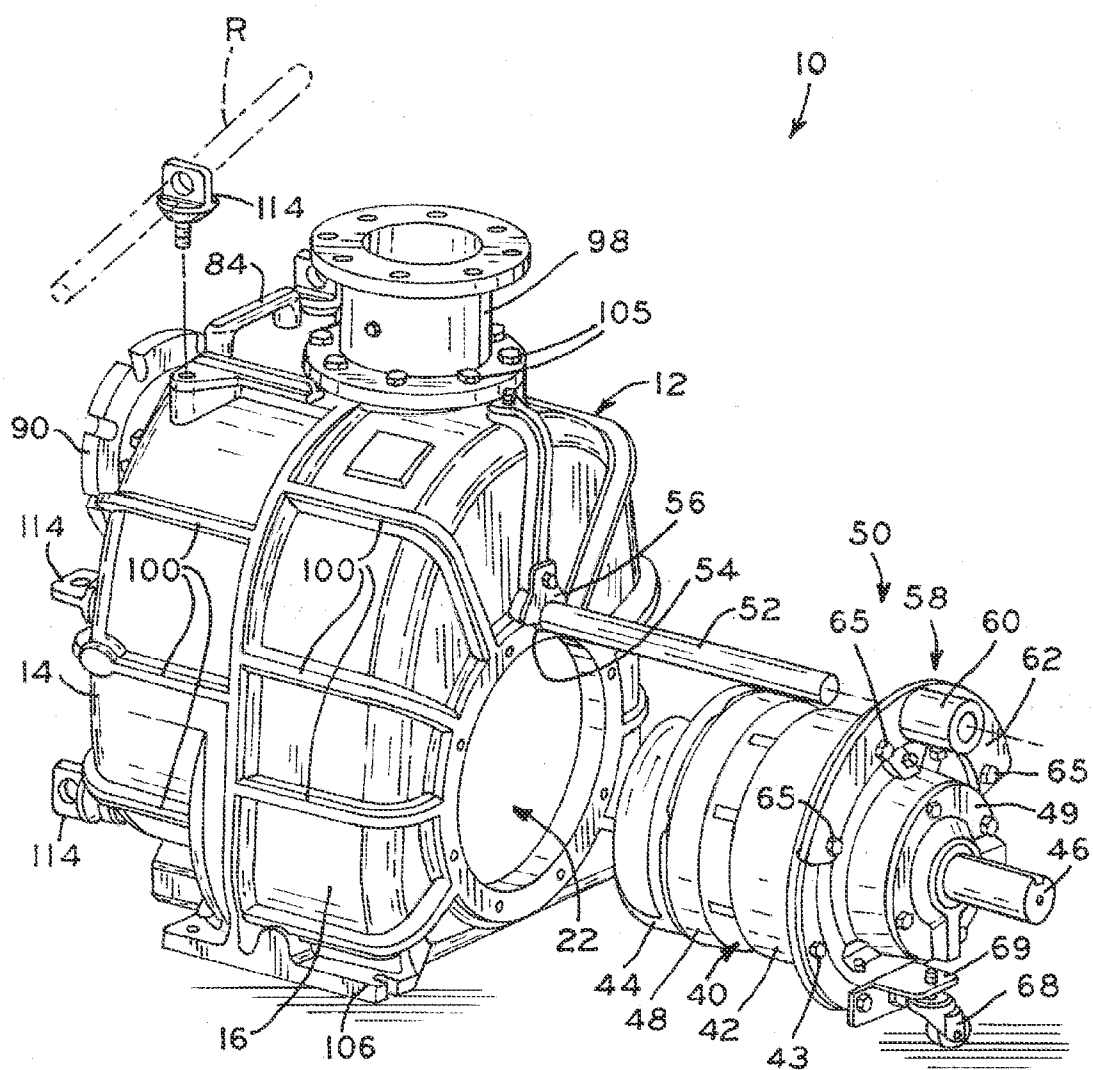


FIG. 9

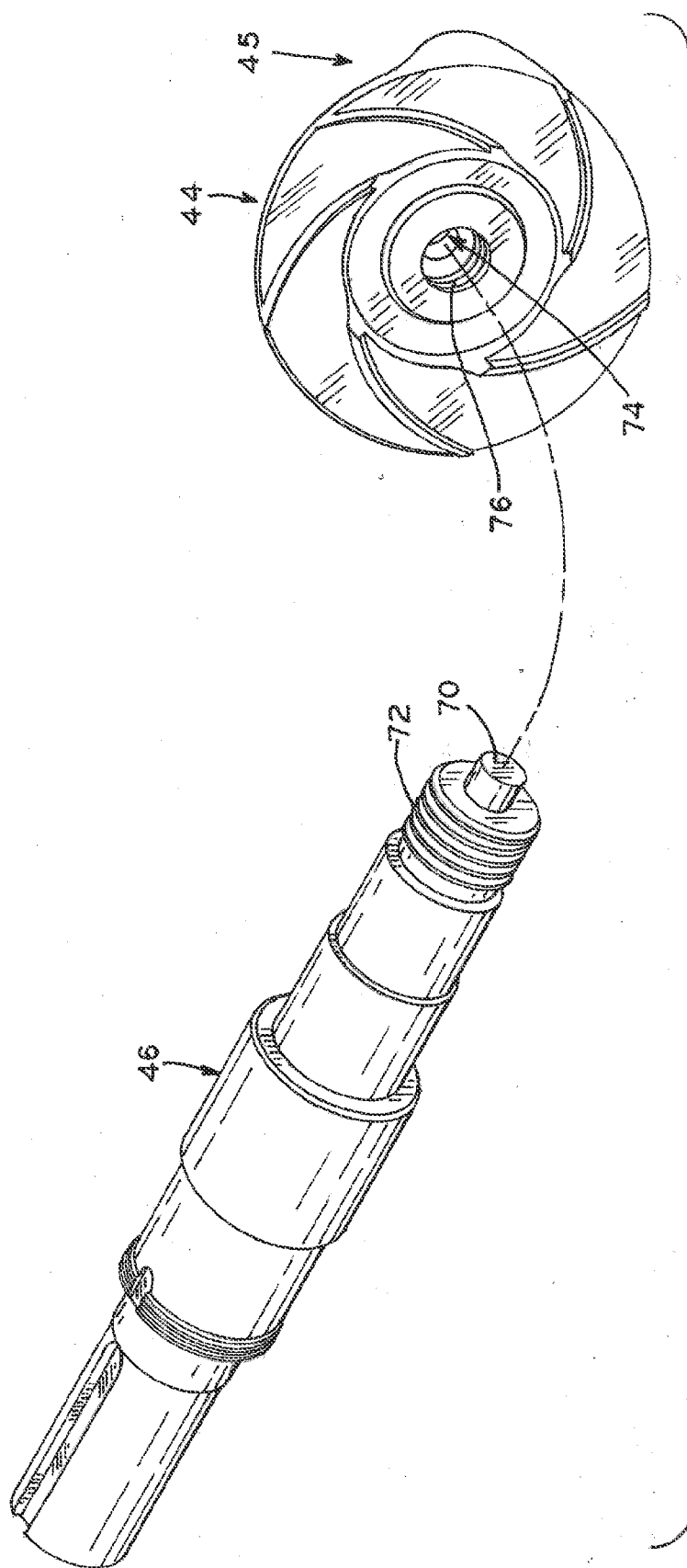


FIG. 10

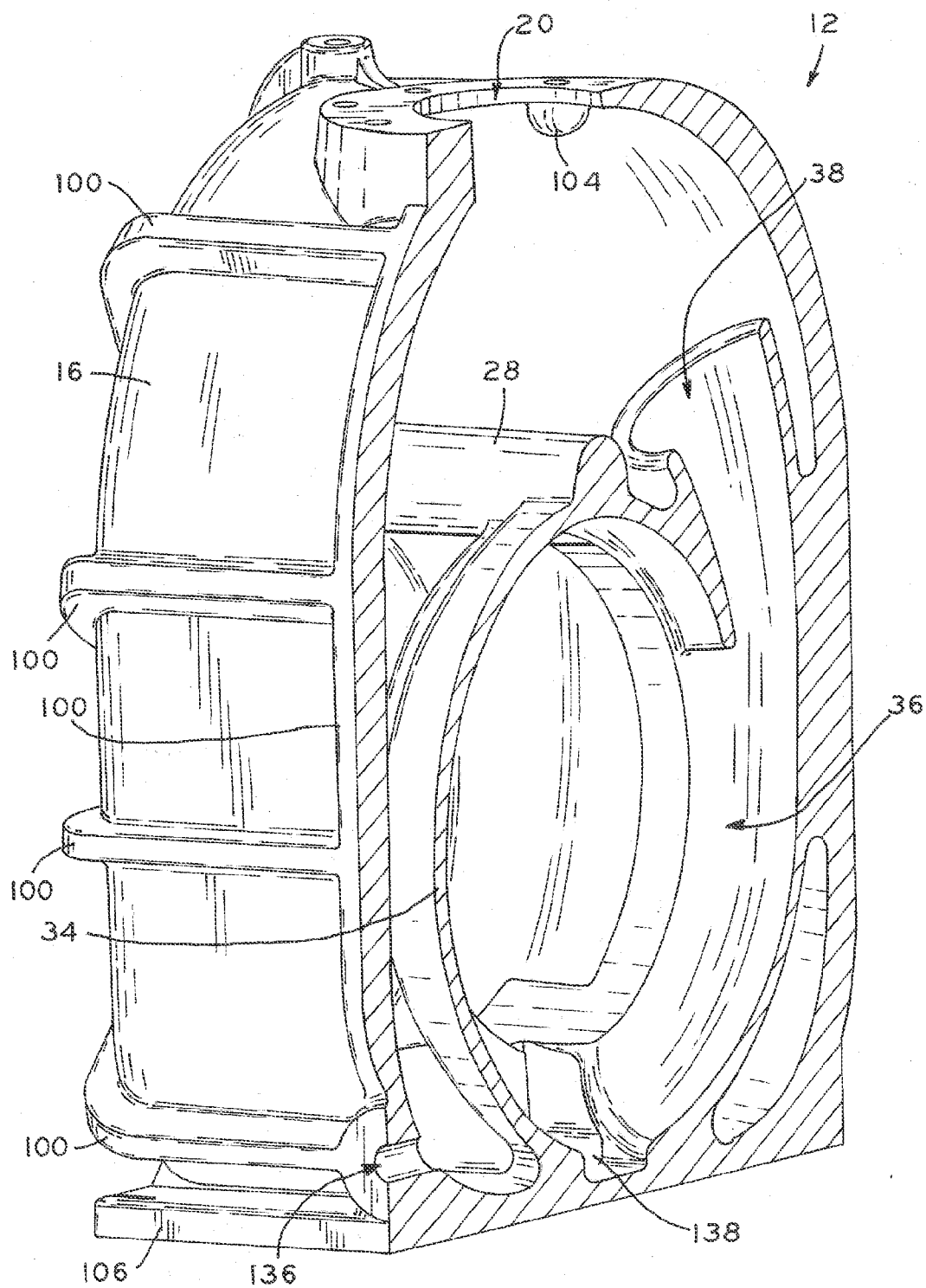


FIG. 12A

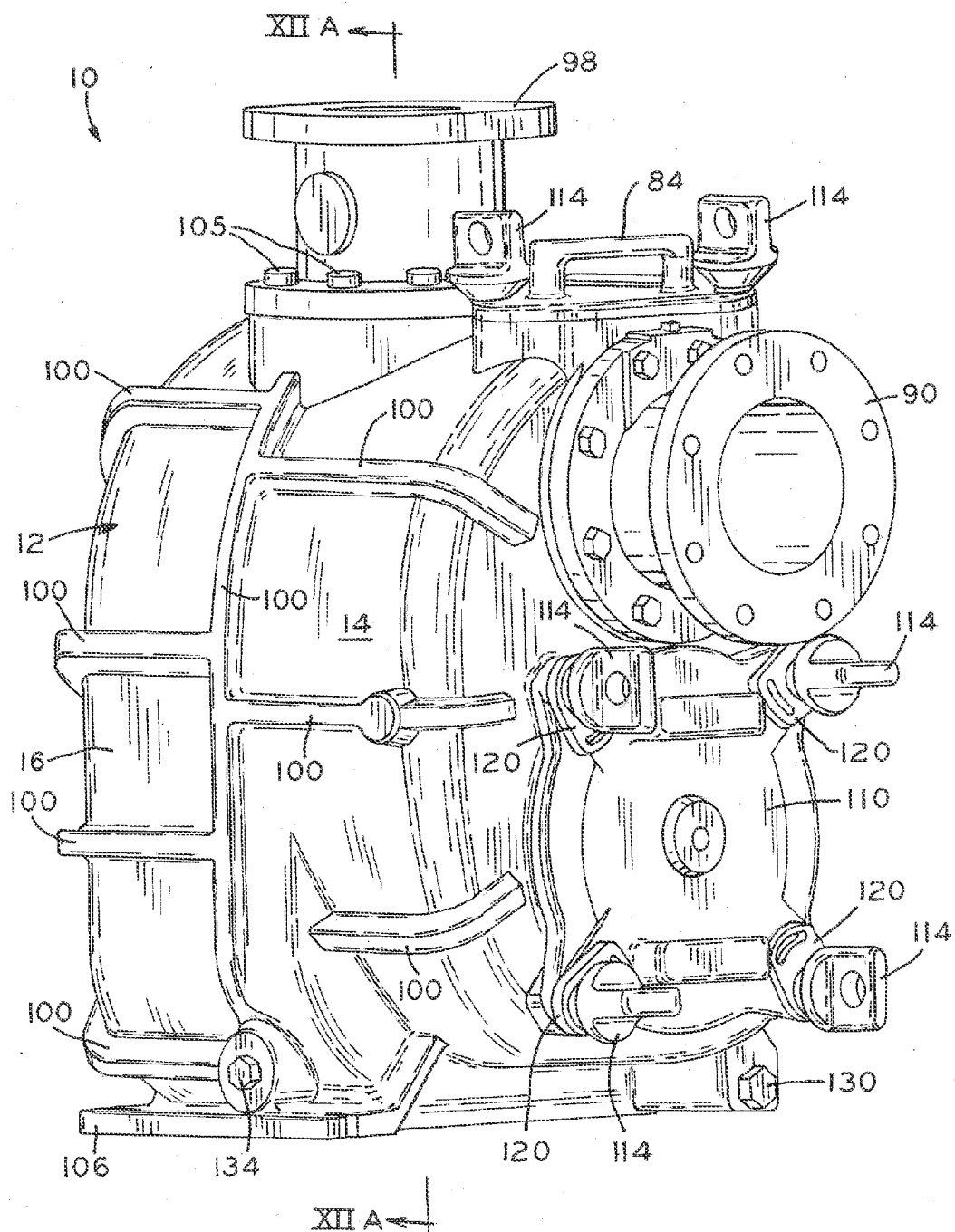
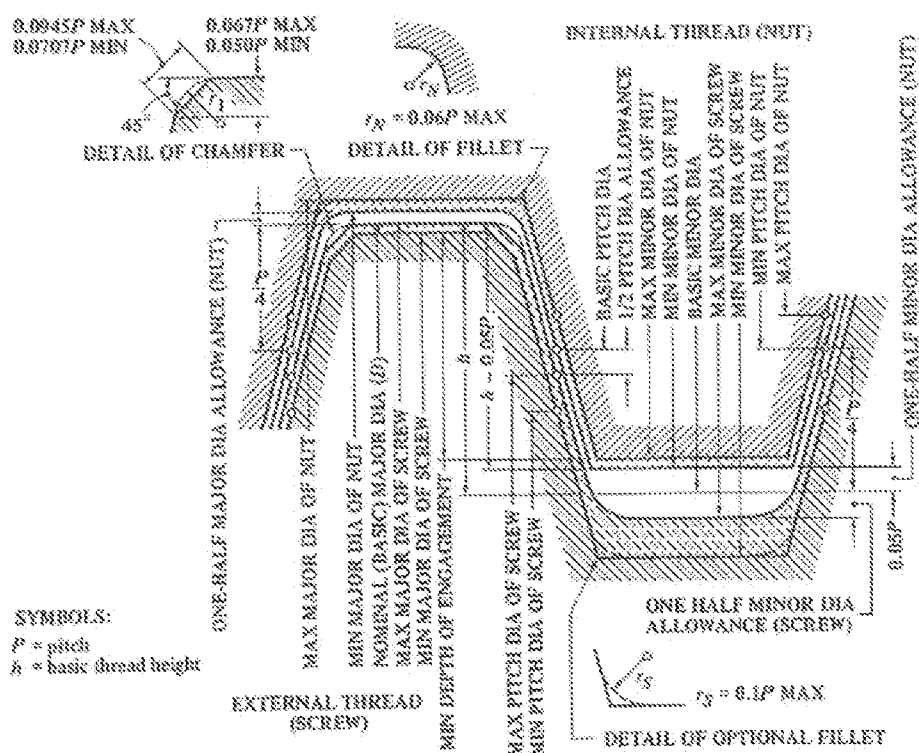


FIG. 12B



Disposition of Allowances, Tolerances, and Crest Clearances for Centralizing Single-Start Acme Threads — Classes 2C, 3C, and 4C

FIG. 13

SELF-PRIMING CENTRIFUGAL PUMP

BACKGROUND

[0001] 1. Technical Field

[0002] The present disclosure relates to pumps and, in particular, to self-priming pumps with enhanced performance, efficiency and/or serviceability.

[0003] 2. Description of the Related Art

[0004] Self-priming centrifugal pumps generally include a spinning impeller positioned inside an annular volute, which in turn is positioned within a pump casing. The volute forms an eye at the center where liquid enters the pump and is directed into the center of the impeller. Rotation of the impeller accelerates the liquid outward to the perimeter of the impeller where it is collected in the volute and discharged from the pump casing at an elevated pressure. As the liquid is driven outward by the centrifugal force of the rotating impeller, a vacuum formed at the eye is used to draw source fluid through the inlet and into the pump.

[0005] In a “wet prime” type pump, a centrifugal pump is arranged in a casing designed to retain water when the pump is not operating. When the pump is started, the impeller in the pump casing starts to mix the retained water with the air in the case. Inside the casing, a “P-trap” is utilized to allow the air to be expelled from of the pump cavity via the pump outlet, while the water remains available to the impeller. This air expulsion continues until enough air has been removed from the piping connected to the pump suction inlet so that the impeller eye becomes substantially flooded. This point, the pump achieves prime.

[0006] In such wet prime pumps, the pump casing may include a partition to separate the suction (i.e., inlet) side from the pressure (i.e., outlet) side so that the air/water mixture discharges exclusively toward the outlet side of the casing. In the outlet-side chamber of the casing during the self-priming operation, air is expelled via the outlet and is prevented from flowing back into the inlet-side chamber by the partition, while liquid water remains available to flow back to the suction side around the submerged or partially submerged pump impeller.

[0007] Self-priming centrifugal pumps are employed in applications where the source liquid may not be uniform. For example, so-called “trash pumps” may be self-priming centrifugal pumps in which solids suspended in the fluid are allowed to be cycled through the pump. Trash pumps are used for, e.g., wastewater treatment, lift stations for municipal sewage, and waste handling for food processing plants.

SUMMARY

[0008] The present disclosure provides a self-priming centrifugal pump with enhanced efficiency and performance characteristics and/or features which facilitate installation, inspection and maintenance of the pump. For efficiency and performance, the pump may include a smooth fluid flow path which enhances pump output for a given input power, including one or more of a specially shaped and directed volute discharge, a lack of internal stiffening ribs on the pump casing walls, a necked inlet and a rounded, flow-channeling outlet aperture. For maintenance and serviceability, the pump may include one or more of a coarse-threaded drive shaft and impeller with a concentricity feature, a combination port for both filling the casing and accessing the inlet flapper valve, and a drive disassembly system which facilitates attachment

or removal of the drive system from the pump. Any combination of the aforementioned features may be utilized in accordance with the present disclosure.

[0009] In one form thereof, the present disclosure provides a centrifugal pump including: a drive mechanism; an impeller drivingly connected to the drive mechanism; a casing having an inlet and an outlet. The casing includes: an inlet-side wall having an inlet aperture formed therein; an outlet-side wall joined to the inlet-side wall to form a cavity within the casing, the outlet-side wall having an outlet aperture; a volute disposed in the casing and in fluid communication with the inlet aperture and the outlet aperture, the volute having a central opening sized to receive the impeller and a spiral-shaped fluid channel such that the fluid channel progresses radially outwardly toward a volute discharge opening, the volute discharge opening defining a longitudinal discharge axis which extends through the outlet aperture. The volute is adapted to receive fluid accelerated outwardly by the impeller, direct the fluid radially outwardly through the spiral-shaped fluid channel, and discharge the fluid along the longitudinal discharge axis toward the outlet aperture.

[0010] In another form thereof, the present disclosure provides a centrifugal pump including: a drive mechanism; an impeller drivingly connected to the drive mechanism; a flapper valve; a casing having an inlet and an outlet. The casing includes: an inlet-side wall having an inlet aperture formed therein, the flapper valve positioned at the inlet aperture to admit a flow of fluid into the casing via the inlet aperture while preventing a flow of fluid out of the casing via the inlet aperture; an outlet-side wall joined to the inlet-side wall to form a cavity within the casing, the outlet-side wall having an outlet aperture; a partition wall interposed between the inlet-side wall and the outlet-side wall to form an inlet pump chamber and an outlet pump chamber, the partition wall having an inner drive aperture positioned to allow fluid communication between the inlet chamber and the outlet chamber via the inner drive aperture; a combination port formed in the casing near the flapper valve, the combination port sized and positioned to allow access to the flapper valve by a maintenance person, and to allow fluid to be added to the inlet pump chamber; and a fill vent formed through the casing on an opposite side of the partition wall as the combination port, such that the fill vent allows fluid communication between the outlet pump chamber and the ambient environment, whereby liquid added to the inlet pump chamber is allowed to flow to the outlet pump chamber via the inner drive aperture while air contained in the outlet pump chamber vents to atmosphere via the fill vent.

[0011] In yet another form thereof, the present disclosure provides a centrifugal pump including: a drive shaft having a first coarse thread and a first centering feature; an impeller drivingly connected to the drive shaft, the impeller having a second coarse thread and a second centering feature, the second coarse thread engageable with the first coarse thread of the drive shaft to selectively rotatably fix the drive shaft to the impeller, and the second centering feature engageable with the first centering feature to concentrically align the impeller with the drive shaft.

[0012] In still another form thereof, the present disclosure provides a centrifugal pump comprising: a drive mechanism; an impeller drivingly connected to the drive mechanism; a casing having an inlet and an outlet, and a drive disassembly system. The casing includes: an inlet-side wall having an inlet aperture formed therein; an outlet-side wall joined to the

inlet-side wall to form a cavity within the casing, the outlet-side wall having an outlet aperture; a bore extending inwardly from the exterior of the outlet-side wall whereby the bore is accessible to a user of the pump. The drive disassembly system includes: a guide rail sized to be snugly received within the bore of the stiffener; and a rail guide having a bearing and a flange fixed to the bearing, the bearing sized to be slidably received on the guide rail while the flange is fixed to the drive mechanism, such that the drive mechanism can be assembled into or removed from the casing while being supported by the guide rail.

[0013] In still another form thereof, the present disclosure provides a method of disassembling a drive mechanism from a centrifugal pump, the method including: inserting a rail into a bore formed in a casing of the pump, such that the rail fits snugly within the bore; sliding a rail guide over the rail and into engagement with the pump; affixing the rail guide to the drive mechanism while maintaining the rail guide in sliding engagement with the rail; and disconnecting the drive mechanism from the casing and sliding the drive mechanism away from the casing using the support of the rail.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The above-mentioned and other features of the disclosure, and the manner of attaining them, will become more apparent and will be better understood by reference to the following description of embodiments of the disclosure taken in conjunction with the accompanying drawings. These above-mentioned and other features of the invention may be used in any combination or permutation.

[0015] FIG. 1 is an elevation, cross-section view of a centrifugal pump made in accordance with the present disclosure, taken along the line I-I of FIG. 8 but with the drive disassembly system of FIG. 8 removed;

[0016] FIG. 2 is an enlarged view of a portion of FIG. 1, illustrating a drive shaft assembly connection to the pump impeller;

[0017] FIG. 3 is a perspective view of the pump shown in FIG. 1, illustrating a flapper access port and fill vent;

[0018] FIG. 3A is a perspective view of an alternative pump casing in accordance with the present disclosure;

[0019] FIG. 3B is another perspective view of the alternative pump casing shown in FIG. 3A;

[0020] FIG. 4 is an elevation, cross-section view of the casing of the pump shown in FIG. 1, taken along the line IV-IV of FIG. 1;

[0021] FIG. 5 is an elevation, cross-section view of the casing of the pump shown in FIG. 1, taken along the line V-V of FIG. 4;

[0022] FIG. 6 is a bottom plan, cross-section view of the casing of the pump shown in FIG. 1, taken along the line VI-VI of FIG. 1;

[0023] FIG. 7 is an elevation, partial cross-section view of the pump shown in FIG. 1, taken along the line VII-VII of FIG. 8, illustrating the pump outlet;

[0024] FIG. 8 is a perspective view of the pump shown in FIG. 1, and including a drive disassembly system attached thereto;

[0025] FIG. 9 is another perspective view of the pump shown in FIG. 8, illustrating removal of the drive mechanism via the drive disassembly system;

[0026] FIG. 10 is a perspective view of the drive shaft and impeller shown in FIG. 1;

[0027] FIG. 11 is an exploded, partial cross-section view of the pump shown in FIG. 1, illustrating an impeller inspection port;

[0028] FIG. 12A is a perspective, cross-section view of the casing of the pump shown in FIG. 1;

[0029] FIG. 12B is a perspective view of the pump shown in FIG. 1, illustrating features on the inlet side of the pump; and

[0030] FIG. 13 illustrates centralizing single-start Acme threads.

[0031] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate embodiments of the disclosure and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DETAILED DESCRIPTION

[0032] The present disclosure provides a self-priming centrifugal pump, shown as pump 10 in, e.g., FIGS. 1, 3 and 8, which includes various features providing increased pump efficiency and/or facilitating installation, inspection and maintenance, among other benefits.

[0033] For example, as shown in FIG. 1 and further described in detail below, centrifugal pump 10 includes volute 34 having a geometry and configuration which tends to “aim” pressurized fluid toward outlet aperture 20 to aid in efficient fluid discharge. Outlet aperture 20 has a rounded, gradual transition area 102 leading to outlet adapter 98 to further facilitate discharge of pressurized fluid with minimal losses. Fastener bosses 104 are similarly rounded and shaped to minimize eddying and turbulence in the vicinity of outlet aperture 20 and direct the flow efficiently through outlet aperture 20.

[0034] Further, both inlet pump chamber 30 and outlet pump chamber 32 are substantially free of stiffening ribs, which also promotes a smooth and laminar fluid flow through chambers 30, 32 and minimizing turbulence. More particularly, inlet and outlet pump chambers 30, 32 are each substantially defined by respective inner surfaces of casing 12, and by respective surfaces of partition wall 24 as shown in FIG. 5 and further described below. These surfaces are substantially free of stiffening ribs such that no stiffening ribs are disposed within the fluid flow paths through chambers 30, 32. In order to provide strength to casing 12, stiffening ribs 100 are located at the outside surface of the pump casing 12 as shown, e.g., in FIG. 3. An alternative design of stiffening ribs 100A is shown in FIGS. 3A and 3B.

[0035] Still further efficiency and performance is realized by locating drain plugs 130, 134 (FIGS. 11 and 12B, respectively) and their associated drain channels 132 (FIG. 11) and 136 (FIG. 12A) at locations outside the flow path of volute 34, in order to provide for gravitationally draining the pump casing 12 without introducing any features in the vicinity of volute 34 which can cause turbulence or eddying and thereby mitigating abrasive wear during pump operation.

[0036] With regard to serviceability, pump 10 includes combination port 82 (FIG. 3) which doubles as a flapper access portion and a fill port for adding liquid (e.g., water) to casing 12 for pump priming. Fill vent 92 facilitates this priming functionality, while combination port cover 84 provides a single integral unit for covering both port 82 and vent 92. Combination port 82 both reduces manufacturing cost and complexity by requiring only one aperture through casing 12 for two functions, while also facilitating installation and maintenance of pump 10 as described below.

[0037] Pump 10 may also be used in conjunction with drive disassembly system 50 (FIGS. 8 and 9) to facilitate removal of drive mechanism 40 from pump casing 12 for service or inspection. Reinstallation of drive mechanism 40 is also made easier by drive disassembly system 50, as described in detail below.

[0038] Within drive mechanism 40, drive shaft 46 couples to impeller 44 via coarse threads 72, 76 (FIG. 2), which promotes ease of installation and prevents cross-threading. In order to maintain a high level of concentricity between drive shaft 46 and impeller 44, the coarse threads are supplemented with a tight-tolerance fit between distal nubbin 70 formed on drive shaft 46 and bore 74 formed in impeller 44, as shown in FIG. 2.

[0039] Pump 10 further includes provisions for inspecting and maintaining impeller 44 from the inlet side of casing 12, by removal of inspection cover 110 and inspection side wear plate 112, as shown in FIG. 11.

[0040] Various features of centrifugal pump 10 are described in turn below. The embodiment disclosed below is not intended to be exhaustive or limit the invention to the precise forms disclosed in the following detailed description. Rather, the embodiment is chosen and described so that others skilled in the art may utilize its teachings. Moreover, it is appreciated that a pump made in accordance with the present disclosure may include any one of the following features or any combination of the following features, and may exclude any number of the following features as required or desired for a particular application.

[0041] 1. Smoothed Interior Surfaces

[0042] Centrifugal pump 10 includes several features related to pump casing 12 which, individually and in the aggregate, contribute to enhanced pump efficiency and performance by minimizing turbulent flows and eddying of fluid as it passes from inlet aperture 18 to outlet aperture 20 via inlet pump chamber 30 and outlet pump chamber 32.

[0043] For example, beginning at inlet aperture 18 shown in FIG. 1, inlet adapter 90 may include a necked portion 91 with a gradually increasing flow area as fluid passes from inlet conduit 140 (FIG. 3) through adapter 90 and toward inlet aperture 18 in casing 12. For example and as shown in FIG. 1, the flow area may be substantially constant through a cylindrical portion of adapter 90, and may then gradually increase through a tapered (e.g., frustoconical) necked portion 91 which continuously increases the diameter of a circular flow area. This continuous and gradual increase provides a smooth, low-turbulence flow of fluid from inlet conduit 140 through inlet aperture 18 and into inlet pump chamber 30, as necked portion 91 gradually relieves fluid pressure at inlet aperture 18 and allows fluid to more slowly and smoothly transition its flow direction downward through pump chamber 30 toward impeller 44.

[0044] Moreover, providing necked portion 91 in inlet adapter 90 allows centrifugal pump 10 to be used with a variety of nominal sizes for inlet conduit 140 and outlet conduit 142 (FIG. 3) for given sizes of inlet and outlet apertures 18, 20. For example, adapters 90 and 98 may allow a given size of centrifugal pump 10 (e.g., a 3-inch, 4-inch or 6-inch pump, referring to the nominal size of outlet conduit 142) to be used with various sizes of inlet and outlet conduits 140, 142 by providing the appropriate set of adapters. For conduits 140 or 142 which do not match the size of apertures 18 or 20 respectively, a necked portion (e.g., necked portion 91) permits this size disparity while avoiding or minimizing a

fluid efficiency penalty from an abrupt change in flow area from conduit 140, 142 and aperture 18, 20 respectively. It is contemplated that either, both or neither of inlet and outlet adapters 90, 98 may include a necked portion to facilitate smooth flow as required or desired for a particular application.

[0045] In an exemplary embodiment, inlet and outlet conduits 140 and 142 are provided with the same nominal size while aperture 18 is larger than aperture 20. Necked portion 91 provides a gradual “step up” of the flow path area through inlet adapter 90 to accommodate an inlet fluid conduit 140 of a smaller flow area than inlet aperture 18. At the same time, outlet adapter 98 may have a flow area substantially equal to outlet aperture 20, in order to receive pressurized flow from volute 34 without posing an impediment to smooth flow. Outlet adapter 98 therefore may not need a necked portion similar to necked portion 91 of inlet adapter 90.

[0046] After passing into inlet pump chamber 30, fluid is drawn into channels 45 of impeller 44, which rotates under power provided by drive shaft 46 to accelerate the fluid outwardly into fluid channel 36 of volute 34, as best seen in FIGS. 4 and 5. In the illustrative embodiment of FIGS. 1, 11, impeller 44 is a “double curvature” design including two fluid channels 45 defining a fluid flow path which spirals radially outwardly. Although the illustrated design of impeller 44 is well suited to a “trash pump” application for centrifugal pump 10 (e.g., where pump 10 accepts fluids with solids in suspension or other non-uniform fluid characteristics), it is appreciated that other designs may be used for impeller 44 as required or desired for a particular application.

[0047] Pressurized fluid discharged from impeller 44 to volute 34 travels through the spiral-shaped volute fluid channel 36 to discharge opening 38, which defines discharge axis A_v , “aimed” to pass directly through outlet aperture 20 as further described below. The pressurized fluid is directed by discharge opening 38 along volute discharge axis A_v , such that the fluid passes directly through outlet pump chamber 32 and toward outlet aperture 20, as shown in FIGS. 4 and 5 and further described in detail below.

[0048] As the pressurized fluid approaches outlet aperture 20, outlet transition area 102 and fastener bosses 104 provide rounded and smooth transition surfaces to facilitate smooth fluid flow from outlet pump chamber 32 to outlet adapter 98 and ultimately to outlet conduit 142 (FIG. 3). Specifically, referring to FIG. 5, the transition from the substantially horizontal top wall of outlet side wall 16 of casing 12 to the substantially vertical side wall of outlet adapter 98 (i.e., the “internal edge” of outlet aperture 20) is a radiused (also known as “filleted”) transition in which the radius of the fillet is generally commensurate with the thickness of the adjacent portion of outlet side wall 16. In an exemplary embodiment, for example, the radius of the fillet varies from as little as equal to the minimum thickness of outlet side wall 16 to as much as 1.3 the minimum thickness. In the illustrated embodiment, for example, the radius of the fillet around outlet aperture 20 is 0.75 inches while the wall thickness is 0.57 inches, though of course these nominal values will vary depending on the size and power of pump 10. In exemplary embodiments, the nominal fillet radius is at least 131% of the minimum wall thickness.

[0049] Fastener bosses 104 may be provided at the interior surfaces of casing 12 (i.e., within inlet and/or outlet pump chambers 30, 32) adjacent inlet and/or outlet apertures 18, 20. Fastener bosses 104 provide for sufficient material to be avail-

able for threaded engagement of fasteners **105** with casing **12** to connect adapters **90**, **98** to inlet and outlet side walls **14**, **16** respectively, as shown in FIG. 1. Referring to the depiction of bosses **104** adjacent to outlet aperture **20** in FIGS. 5-7, it can be seen that bosses **104** have a rounded profile which facilitates smooth flow from outlet chamber **32** to outlet adapter **98** via outlet aperture **20**.

[0050] As best seen in FIGS. 1 and 7, fastener bosses **104** provide a smoothly rounded, convex distal surface at their respective ends, and transition to an annular concave surface which forms the junction between the convex end surface and the adjacent inner surface of outlet side wall **16**. This concave-to-convex transition avoids abrupt corners or other sharp features within the fluid flow path in outlet chamber **32**, and particularly avoids such sharp features in the fluid flow path along volute discharge axis A_v . In this way, rounded bosses **104** prevent or minimize turbulence in the fluid flow which might otherwise compromise pump efficiency and performance.

[0051] Although the lower-pressure space in inlet chamber **30** is less susceptible to adverse performance impacts relating to the shape of bosses **104** around inlet aperture **18** or any other threaded aperture in casing **12**, the same rounded shape of bosses **104** is provided for maximum pump efficiency.

[0052] Referring now to the bottom plan view of fastener bosses **104** in FIG. 6, three fastener bosses **104** closest to the volute discharge opening **38** are illustrated. In the context of FIG. 6, the three bosses **104** in question are shown along right side portion of outlet aperture **20** and within outlet chamber **32**. As illustrated, these bosses **104** are contoured in a “tear drop” shape, in which a pointed end of the tear drop is pointing toward outlet aperture **20**. This tear drop shape for fastener bosses **104** promotes a substantially laminar flow over the outer surface of bosses **104** as fluid discharged from volute **34** advances toward outlet aperture **20**.

[0053] Turning now to FIGS. 3 and 3A-3B, yet another flow-enhancing feature is illustrated in the form of exterior ribs **100** and **100A** respectively, which are integrally and monolithically provided as a portion of the exterior of casings **12** and **12A** respectively. Ribs **100** and **100A** both serve to strengthen and rigidify casing **12** in order to prevent or minimize any potential bulging or flexing of the material of casing **12** from the substantial pressures (positive or negative) which may be developed in pump chambers **30**, **32**.

[0054] In FIG. 3, a central vertical rib **100** extends from a lower base **106** upwardly to outlet aperture **20** and outlet adapter **98** on either side of casing **12**. For purposes of the present discussion, the “bottom” of pump **10** is base **106** while outlet aperture **20** and adapter **98** is at the “top” of pump **10**. “Vertical” is the direction extending from bottom to top. In addition, a plurality of front-to-back stiffening ribs **100** extend from the inlet side of casing **12**, along inlet side wall **14**, and terminate at the central vertical rib **100**. A further set of front-to-back ribs **100** extend from the drive side of casing **12** along outlet side wall **16**, and terminate at the vertical central rib **100** at staggered vertical positions as compared to the inlet-side ribs **100** such that each of drive-side ribs **100** intersect the central vertical rib **100** at a different vertical position than each of the inlet-side ribs **100**, as shown in FIG. 3. For purposes of the present discussion, the “front” of pump **10** is considered as the side from which drive shaft **46** projects, and the “back” of pump **10** is the side including inlet

aperture **18** and adapter **90**. The “front-to-back” direction is substantially perpendicular to the “vertical” direction as illustrated in FIG. 3.

[0055] On the vertical face of outlet side wall **16**, ribs **100** all emanate radially outwardly from a common center, as best seen in FIG. 8. In particular, nine ribs **100** extend radially outwardly along the vertical face from outer drive aperture **22** (FIG. 9), round the corner at the junction between the vertical and side faces of outlet side wall **16**, and extend back to vertical rib **100** as noted above. A similar radially outwardly extending set of six ribs **100** are formed on the vertical face of inlet side wall **14**, as best seen in FIG. 12B.

[0056] An alternative casing **12A** having a different arrangement of ribs **100A** is shown in FIGS. 3A and 3B. For purposes of the present disclosure, casings **12**, **12A** having ribs **100**, **100A** respectively are interchangeable with the other components of pump **10**. Accordingly, a reference to casing **12** herein is also a reference to casing **12A**, unless otherwise specifically stated. Moreover, casing **12A** is substantially similar to casing **12** described herein, with reference numerals of casing **12A** corresponding to the reference numerals of casing **12**, except with an “A” appended thereto. Structures of casing **12** correspond to similar structures denoted by corresponding reference numerals of casing **12A**, except as otherwise noted.

[0057] As best seen in FIG. 3A, five ribs **100A** extend generally radially outwardly from a central area of outlet side wall **16**, similar to the radially arranged ribs **100** described above. However, only the two lowermost ribs **100** extend horizontally from the rim around outer drive aperture **22**, round the corner at the junction between the vertical and side faces of outlet side wall **16**, and extend backwardly toward inlet side wall **14**. An uppermost rib **100A** extends vertically along the vertical face of outlet side wall **16** but, unlike the lowermost ribs **100A**, does not join the rim around outer drive aperture **22**. Two intermediate ribs **100A** are disposed between the lowermost and uppermost ribs **100A**, and extend radially outwardly from the central area of outlet side wall **16**. Like the uppermost rib **100A**, the intermediate ribs **100A** do not join the rim around outer drive aperture **22**.

[0058] As shown in FIGS. 3A and 3B and in contrast to casing **12** described above, casing **12A** lacks a vertical rib and does not have any stiffening ribs on inlet side wall **14**. In the illustrated embodiment, ribs **100A** are provided only on the high-pressure (i.e., outlet) side of casing **12A**, to which provides resistance to bulging or flexing of outlet side wall **16**. However, the size, number and extent of ribs **100A** are optimized, as shown in FIG. 3A and described above, to provide this resistance with a minimum of added material and expense. The low-pressure (i.e., inlet) side of casing **12A** has no ribs because, in the illustrated application, inlet side wall **14** alone may be sufficient to avoid excessive material flex from the relatively lower (and negative) pressures experienced in inlet pump chamber **30** (FIG. 5).

[0059] The disposition of ribs **100** and **100A** only on the exterior surface of casings **12** and **12A** allows their strengthening function to be met without introduction of stiffening ribs inside pump chambers **30** and **32**. More particularly, the portion of inlet pump chamber **30** extending from inlet aperture **18** to impeller **44** is free of stiffening ribs along the interior surfaces of inlet side wall **14**, as well as along the surface of partition wall **24** which cooperates with such interior surfaces to form inlet chamber **30**. Similarly, the portion of outlet pump chamber **32** disposed generally between

volute discharge opening 38 and outlet aperture 20 is also free of interior ribs along the interior surfaces of outlet side wall 16 and the adjacent portion of partition wall 24 which cooperates with such interior surfaces to form outlet chamber 32. Accordingly, the portions of pump chambers 30 and 32 directly disposed in the flow path of fluid passing through centrifugal pump 10 are free from any stiffening ribs or other features designed for selective strengthening of inlet side or outlet side walls 14, 16.

[0060] Advantageously, the lack of ribs or other stiffening features in the flow paths within casings 12 and 12A facilitates flow with a minimum of turbulence and eddying, which reduces wear from fluid and solids in suspension while preserving hydraulic efficiency. Meanwhile, the provision of external ribs 100, 100A as shown in FIGS. 3 and 3A-3B respectively (described in detail above) provide the strength and rigidity to casings 12, 12A associated with such strengthening features.

[0061] 2. Volute Discharge

[0062] In FIG. 4, volute discharge axis A_v is illustrated from the front, i.e., from a perspective facing a “spin plane” of impeller 44 that is perpendicular to its axis of rotation. In FIG. 5, volute discharge axis A_v is illustrated from the side, i.e., from a perspective facing a vertical center plane containing the axis of rotation of impeller 44.

[0063] FIG. 4 illustrates that the spiral-shaped pathway of volute 34 does not terminate in a discharge opening defining a vertical discharge axis, but rather, continues its spiral-shaped pathway to produce the illustrated axis A_v which directs fluid flow from discharge opening 38 across the center plane of casing 12 and back toward outlet aperture 20, which resides on the opposite side of the center plane. Channel 36 is a spiral-shaped structure as illustrated, and defines a correspondingly spiral-shaped flow axis centrally located in channel 36 and extending through the entire extent of channel 36. As fluid flows through channel 36, it follows this spiral-shaped flow axis until it is discharged at discharge opening 38.

[0064] In the illustrated embodiment, discharge axis A_v is tangent to this spiral-shaped flow axis at discharge opening 38, and is oriented or “aimed” to pass directly through outlet aperture 20. In an exemplary embodiment, axis A_v is also perpendicular to a plane defined by discharge opening 38. This angled and aimed arrangement for axis A_v directs pressurized fluid flowing from discharge opening 38 directly toward outlet aperture 20, thereby minimizing turbulence, deceleration or eddying of fluid along the side walls of outlet side wall 16 of casing 12 as the fluid flows toward and through outlet aperture 20.

[0065] Turning to the side view of FIG. 5, axis A_v is also shown to be forwardly angled with respect to a vertical direction, i.e., angled with respect to the substantially vertical walls of inlet and outlet side walls 14 and 16, while also being non-perpendicular with the substantially horizontal base 106 and opposing top portions of inlet and outlet side walls 14, 16. Moreover, axis A_v is generally aimed toward outlet aperture 20, as viewed in the side section view of FIG. 5, to promote discharge from discharge opening 38 with a maximum volume of fluid received at outlet aperture 20 and a minimum volume of fluid traveling at high speed along partition wall 24 disposed adjacent volute 34. Directing flow from discharge opening 38 along a path angled away from the adjacent par-

tion wall 24 avoids frictional interaction between the fluid and partition wall 24, and thereby promotes efficient operation of centrifugal pump 10.

[0066] 3. Drain Channels

[0067] Turning now to FIGS. 11, 12A and 12B, drain channels 132 (FIG. 11) and 136 (FIG. 12A) passing through selected locations within casing 12 are illustrated. Drain channels 132, 136 are both in direct fluid communication with respective lower portions of outlet pump chamber 32, such that drain plugs 130, 134 (FIG. 12B) respectively can be removed to allow fluid trapped in outlet pump chamber 32 to be drained from casing 12 by gravity and without inverting centrifugal pump 10. In particular, both drain channels 132, 136 are in direct fluid communication with a sump region 138 formed in a lower portion of casing 12.

[0068] In the illustrated embodiment, centrifugal pump 10 is a self-priming “wet prime” pump design. In the illustrated self-priming pump design, casing 12 is designed to retain water or other liquid within sump region 138 when pump 10 is not operating. Impeller 44 can draw fluid stored in sump region 138 upon activation of pump 10, and can expel any entrapped air from the outlet aperture 20 while picking up additional liquid until a vacuum at inlet aperture 18 is created to draw additional liquid into casing 12 from the source. At this point, the pump is “primed” and ready for regular service. As described in detail below, the liquid in sump region 138 may be initially introduced into casing 12 via a combination fill port and flapper access port 82 (FIG. 3). In the context of the present disclosure, the “air” in the casing is the non-pumpable fluid (i.e. gas) which resides in the casing during normal operation.

[0069] As best seen in FIG. 12A, sump region 138 has a central portion which is in direct fluid communication with impeller 44, while the remainder of the sump region is separated from impeller 44 by the wall forming volute 34. As illustrated in FIGS. 11 and 12A respectively, drain channels 132, 136 are arranged outside the volute flow path and on opposite sides of volute 34 and impeller 44, and are therefore in indirect fluid communication with the central portion of sump 138 accessed by impeller 44. That is, the draining of the central portion of sump 138 via drain channels 132 and/or 136 would require the fluid to first migrate to the other portions of sump region 138 (i.e., the portions not in direct fluid communication with impeller 44), and then enter channel 132 or 136.

[0070] In this way, drain channels 132, 136 do not form any apertures or other features which are in direct fluid communication with, or form any part of, volute 34. Therefore, drain channels 132, 136 do not interrupt or otherwise affect the fluid mechanics of impeller 44. For purposes of the present disclosure, two distinct fluid areas are in “direct” fluid communication if fluid exchange between the two areas does not require the fluid flow path to change direction or otherwise “turn a corner.” By contrast, two distinct fluid areas are in “indirect” fluid communication if fluid exchange between the two areas does require the fluid flow path to change direction or otherwise “turn a corner.”

[0071] 4. Combination Fill/Inspection Port

[0072] Turning now to FIG. 3, port 82 is shown in an upper end of inlet side wall 14 of casing 12. Port 82 serves as a combination port, accomplishing two functions: access to flapper valve 80 and related structures for, e.g., installation, replacement or maintenance; and as a fill port for adding liquid to casing 12, and particularly for adding liquid to sump region 138, shown in FIGS. 1 and 11 and described above.

[0073] Turning to FIG. 1, flapper valve 80 is shown in its installed, seated position upon inlet adapter 90. In an exemplary embodiment, flapper valve 80 is formed as a resilient polymer or rubber material which bears against the annular inner surface of inlet adapter 90 (i.e., adjacent necked portion 91) to prevent flow of fluid from inlet pump chamber 30 back through inlet aperture 18 and inlet adapter 90, while resiliently bending or “flapping” away from its seated position about a living hinge 81 (FIG. 3) so that liquid can be freely admitted to inlet pump chamber 30 via inlet adapter 90 and inlet aperture 18. Living hinge 81 connects flapper valve 80 to a valve mount portion 83, which is attached to adapter 90 by fasteners 88 and retainers 86A, 86B as illustrated.

[0074] When centrifugal pump 10 is in service, inlet conduit 140 and outlet conduit 142 may both be rigidly affixed to adapters 90, 98, respectively. In addition, base 106 of casing 12 may be affixed to the underlying surface, such as by mounting bolts 107 shown in FIG. 3. For these and other reasons, disconnection of inlet adapter 90 to access flapper valve 80 and its associated structures may not be practical or time efficient. However, because flapper valve 80 may be made from a relatively soft and resilient material such as polymer or rubber, relatively frequent inspection, maintenance or repair may be necessary. Combination port 82 offers access to flapper valve 80 from the top portion of centrifugal pump 10, which is typically the most accessible portion to a service person when pump 10 is mounted in a service location and configuration.

[0075] To allow or prevent access to port 82, combination port cover 84 is provided. When cover 84 is affixed to casing 12 by fasteners 114, fill port cover portion 94 provides a seal (in cooperation with an O-ring positioned about the periphery of port 82) around flapper access port 82, which fluidly isolates inlet pump chamber 30 from the ambient environment and thereby allows vacuum or suction pressure to develop therewithin for proper operation of pump 10. When removed, as shown in FIG. 3, port 82 allows a service person to remove fasteners 88, retainers 86A and 86B, and flapper valve 80 for inspection, maintenance and/or repair. Additionally, because port 82 is offset along a front-to-back direction with respect to flapper valve 80 as shown in FIG. 1, removal of port cover 84 also allows for a visual inspection of flapper valve 80 and its associated structures without removal of the same from inlet adapter 90.

[0076] Turning again to FIG. 3, casing 12 includes fill vent 92 which offers selective fluid communication between outlet pump chamber 32 and the ambient environment. Fill vent 92 facilitates the use of combination port 82 as a fill port for admitting liquid into casing 12, and specifically to sump region 138 from the inlet side, by allowing displaced air to vent to the ambient atmosphere from outlet pump chamber 32 via vent 92 as water flows into sump 138 from the inlet side. Combination port cover 84 also serves to fluidly isolate outlet pump chamber 32 from the ambient environment when cover 84 is installed upon casing 12, by covering vent 92 with fill vent cover portion 96 (and an O-ring positioned about the periphery of vent 92). As best seen in FIG. 3, fill vent cover portion 96 is formed as a forward extension of fill port cover portion 94 in order to pass over partition wall 24 and onto fill vent 92. In the illustrated embodiment, fill port cover portion 94 and fill vent cover portion 96 are integrally and monolithically formed as a single component.

[0077] In one exemplary embodiment, fasteners 114 used to connect combination port cover 84 to combination port 82

include an enlarged flat fastener head having a fastener aperture 116 formed therethrough. For field inspections and maintenance, field surface fasteners 114 facilitate removal and installation of combination port cover 84 by engagement with a service person's hand, any wrench or clamp capable of engaging the flat head portion of fasteners 114. Alternatively as shown in FIG. 9, rod R may be passed through fastener aperture 116 to gain leverage.

[0078] 5. Assembly and Alignment of Drive Shaft and Impeller

[0079] FIGS. 1, 2 and 10 illustrate the connection between drive shaft 46 and impeller 44. As described in further detail below, this connection facilitates initial assembly and subsequent reassembly by providing a coarse threaded engagement which is easy to thread and difficult to cross-thread. In order to maintain a desired concentricity between the rotational axis of impeller 44 and axis A_D drive shaft 46, distal nubbin 70 formed on drive shaft 46 defines a tight clearance fit with a corresponding bore 74 formed in impeller 44.

[0080] Referring to FIG. 1, drive shaft 46 protrudes from a front surface of casing 12 as part of drive mechanism 40 attached thereto. In addition to drive shaft 46, drive mechanism 40 includes a plurality of bearings 47 supported by drive shaft housing 42 and rotatably supporting drive shaft 46, such that drive shaft 46 can freely rotate with respect to housing 42. Drive side wear plate 48 is connected to drive shaft 46 and biased by a biasing element (illustrated as a compression spring) into firm engagement with drive shaft housing 42 and away from contact with impeller 44. Cover plate 49 connects to the front (i.e. outer) surface of housing 42 to retain and protect bearings 47 (which may be, for example, a ball bearing or roller bearing). Impeller 44 is fixed to drive shaft 46 (as described further below) and forms the final component of drive mechanism 40.

[0081] When drive mechanism 40 is initially assembled or reassembled (e.g., after inspection or maintenance) as illustrated in FIG. 10, male threads 72 of drive shaft 46 are engaged with the correspondingly formed female threads 76 of impeller 44 to affix drive shaft 46 to impeller 44, as best seen in FIG. 2. In the illustrated embodiment, threads 72 and 76 are coarse threads which promote easy initial thread alignment and engagement and correspondingly deter cross-threading or other mis-engagement of male threads 72 with female threads 76. In one exemplary embodiment, best seen in FIG. 2, threads 72 and 76 are trapezoidal thread forms, sometimes referred to as “acme” threads, which provide a relatively loose thread engagement and a robust resistance to cross-threading. An exemplary embodiment of “coarse” trapezoidal threads useable in connection with the present disclosure are Acme “Centralizing Screw Threads” of tolerance class 4C as defined in ANSI/ASME B1.5-1997, the entire disclosure of which is hereby expressly incorporated by reference herein. The use of such coarse trapezoidal threads 72, 76 ensure that when drive shaft 46 is inserted through the other components of drive mechanism 40 and initially engaged with impeller 44, rotation of drive shaft 46 with respect to impeller 44 in the tightening direction causes a reliably proper thread engagement.

[0082] Further detail regarding class 4C centralizing threads in accordance with the present disclosure is provided in Tables 7a, 7b and 8-11 below and FIG. 13.

TABLE 7a

American National Standard Centralizing Acme Single-Start Screw Threads - Formulas for Determining Diameters (ASME/ANSI B1.5-1988) D = Nominal Size or Diameter in Inches P = Pitch = 1 ÷ Number of Threads per Inch	
No.	
Classes 2C, 3C, and 4C External Threads (Screws)	
1	Major Diam., Max = D (Basic).
2	Major Diam., Min = D minus tolerance from Table 11, cols. 7, 8, or 10.
3	Pitch Diam., Max = Int. Pitch Diam., Min (Formula 9) minus allowance from Table 9, cols. 3, 4, or 5.
4	Pitch Diam., Min = Ext. Pitch Diam., Max (Formula 3) minus tolerance from Table 10.
5	Minor Diam., Max = D minus P minus allowance from Table 11, col. 3.
6	Minor Diam., Min = Ext. Minor Diam., Max (Formula 5) minus 1.5 × Pitch Diam. tolerance from Table 10.
Classes 2C, 3C, and 4C Internal Threads (Nuts)	
7	Major Diam., Min = D plus allowance from Table 11, col. 4.
8	Major Diam., Max = Int. Major Diam., Min (Formula 7) plus tolerance from Table 11, cols. 7, 9, or 11.
9	Pitch Diam., Min = D Minus P/2 (Basic).
10	Pitch Diam., Max = Int. Pitch Diam., Min (Formula 9) plus tolerance from Table 10.
11	Minor Diam., Min = D minus 0.9P.
12	Minor Diam., Max = Int. Minor Diam., Min (Formula 11) plus tolerance from Table 11, col. 6.

TABLE 7b

Limiting Dimensions of American National Standard Centralizing Acme Single-Start Screw Threads, Classes 2C, 3C, and 4C (ASME/ANSI B1.5-1988)											
		Nominal Diameter, D									
		½	⅜	¾	⅞	1	1⅛	1¼	1⅜	1½	
		Threads per Inch*									
Limiting Diameters		10	8	6	6	5	5	5	4	4	
External Threads											
Classes 2C, 3C, and 4C, Major Diameter	Max	0.5000	0.6250	0.7500	0.8750	1.0000	1.1250	1.2500	1.3750	1.5000	
Class 2C, Major Diameter	Min	0.4975	0.6222	0.7470	0.8717	0.9965	1.1213	1.2461	1.3709	1.4957	
Class 3C, Major Diameter	Min	0.4989	0.6238	0.7487	0.8736	0.9985	1.1234	1.2483	1.3732	1.4982	
Class 4C, Major Diameter	Min	0.4993	0.6242	0.7491	0.8741	0.9990	1.1239	1.2489	1.3738	1.4988	
Classes 2C, 3C, and 4C, Minor Diameter	Max	0.3800	0.4800	0.5633	0.6883	0.7800	0.9050	1.0300	1.1050	1.2300	
Class 2C, Minor Diameter	Min	0.3594	0.4570	0.5371	0.6615	0.7509	0.8753	0.9998	1.0719	1.1965	
Class 3C, Minor Diameter	Min	0.3704	0.4693	0.5511	0.6758	0.7664	0.8912	1.0159	1.0896	1.2144	
Class 4C, Minor Diameter	Min	0.3731	0.4723	0.5546	0.6794	0.7703	0.8951	1.0199	1.0940	1.2188	
Class 2C, Pitch Diameter	{	Max	0.4443	0.5562	0.6598	0.7842	0.8920	1.0165	1.1411	1.2406	1.3652
		Min	0.4306	0.5408	0.6424	0.7663	0.8726	0.9967	1.1210	1.2186	1.3429
Class 3C, Pitch Diameter	{	Max	0.4458	0.5578	0.6615	0.7861	0.8940	1.0186	1.1433	1.2430	1.3677
		Min	0.4394	0.5506	0.6534	0.7778	0.8849	1.0094	1.1339	1.2327	1.3573
Class 4C, Pitch Diameter	{	Max	0.4472	0.5593	0.6632	0.7880	0.8960	1.0208	1.1455	1.2453	1.3701
		Min	0.4426	0.5542	0.6574	0.7820	0.8895	1.0142	1.1388	1.2380	1.3627
Internal Threads											
Classes 2C, 3C, and 4C, Major Diameter	Min	0.5007	0.6258	0.7509	0.8759	1.0010	1.1261	1.2511	1.3762	1.5012	
Classes 2C and 3C, Major Diameter	Max	0.5032	0.6286	0.7539	0.8792	1.0045	1.1298	1.2550	1.3803	1.5055	
Class 4C, Major Diameter	Max	0.5021	0.6274	0.7526	0.8778	1.0030	0.1282	1.2533	1.3785	1.5036	
Classes 2C, 3C, and 4C, Minor Diameter	Min	0.4100	0.5125	0.6000	0.7250	0.8200	0.9450	0.0700	1.1500	1.2750	
	Max	0.4150	0.5187	0.6083	0.7333	0.8300	0.9550	1.0800	1.1625	1.2875	
Class 2C, Pitch Diameter	{	Min	0.4500	0.5625	0.6667	0.7917	0.9000	1.0250	1.1500	1.2500	1.3750

TABLE 7b-continued

Limiting Dimensions of American National Standard Centralizing Acme Single-Start Screw Threads, Classes 2C, 3C, and 4C (ASME/ANSI B1.5-1988)												
Class 3C, Pitch Diameter	{	Max	0.4637	0.5779	0.6841	0.8096	0.9194	1.0448	1.1701	1.2720	1.3973	
		Min	0.4500	0.5625	0.6667	0.7917	0.9000	1.0250	1.1500	1.2500	1.3750	
Class 4C, Pitch Diameter	{	Max	0.4564	0.5697	0.6748	0.8000	0.9091	1.0342	1.1594	1.2603	1.3854	
		Min	0.4500	0.5625	0.6667	0.7917	0.9000	1.0250	1.1500	1.2500	1.3750	
		Max	0.4546	0.5676	0.6725	0.7977	0.9065	1.0316	1.1567	1.2573	1.3824	
Nominal Diameter, D												
Threads per Inch*												
Limiting Diameters												
External Threads												
Classes 2C, 3C, and 4C, Major Diameter	Max	1.7500	2.0000	2.2500	2.5000	2.7500	3.0000	3.5000	4.0000	4.5000	5.0000	
Class 2C, Major Diameter	Min	1.7454	1.9951	2.2448	2.4945	2.7442	2.9939	3.4935	3.9930	4.4926	4.9922	
Class 3C, Major Diameter	Min	1.7480	1.9979	2.2478	2.4976	2.7475	2.9974	3.4972	3.9970	4.4968	4.9966	
Class 4C, Major Diameter	Min	1.7487	1.9986	2.2485	2.4984	2.7483	2.9983	3.4981	3.9980	4.4979	4.9978	
Classes 2C, 3C, and 4C, Minor Diameter	Max	1.4800	1.7300	1.8967	2.1467	2.3967	2.4800	2.9800	3.4800	3.9800	4.4800	
Class 2C, Minor Diameter	Min	1.4456	1.6948	1.8572	2.1065	2.3558	2.4326	2.9314	3.4302	3.9291	4.4281	
Class 3C, Minor Diameter	Min	1.4640	1.7136	1.8783	2.1279	2.3776	2.4579	2.9574	3.4568	3.9563	4.4558	
Class 4C, Minor Diameter	Min	1.4685	1.7183	1.8835	2.1333	2.3831	2.4642	2.9638	3.4634	3.9631	4.4627	
Class 2C, Pitch Diameter	{	Max	1.6145	1.8637	2.0713	2.3207	2.5700	2.7360	3.2350	3.7340	4.2330	4.7319
		Min	1.5916	1.8402	2.0450	2.2939	2.5427	2.7044	3.2026	3.7008	4.1991	4.6973
Class 3C, Pitch Diameter	{	Max	1.6171	1.8665	2.0743	2.3238	2.5734	2.7395	3.2388	3.7380	4.2373	4.7364
		Min	1.6064	1.8555	2.0620	2.3113	2.5607	2.7248	3.2237	3.7225	4.2215	4.7202
Class 4C, Pitch Diameter	{	Max	1.6198	1.8693	2.0773	2.3270	2.5767	2.7430	3.2425	3.7420	4.2415	4.7409
		Min	1.6122	1.8615	2.0685	2.3181	2.5676	2.7325	3.2317	3.7309	4.2302	4.7294
Internal Threads												
Classes 2C, 3C, and 4C, Major Diameter	Min	1.7513	2.0014	2.2515	2.5016	2.7517	3.0017	3.5019	4.0020	4.5021	5.0022	
Classes 2C and 3C, Major Diameter	Max	1.7559	2.0063	2.2567	2.5071	2.7575	3.0078	3.5084	4.0090	4.5095	5.0100	
Class 4C, Major Diameter	Max	1.7539	2.0042	2.2545	2.5048	2.7550	3.0052	3.5056	4.0060	4.5063	5.0067	
Classes 2C, 3C, and 4C, Minor Diameter	{	Min	1.5250	1.7750	1.9500	2.2000	2.4500	2.5500	3.0500	3.5500	4.0500	4.5500
		Max	1.5375	1.7875	1.9667	2.2167	2.4667	2.5750	3.0750	3.5750	4.0750	4.5750
Class 2C, Pitch Diameter	{	Min	1.6250	1.8750	2.0833	2.3333	2.5833	2.7500	3.2500	3.7500	4.2500	4.7500
		Max	1.6479	1.8985	2.1096	2.3601	2.6106	2.7816	3.2824	3.7832	4.2839	4.7846
Class 3C, Pitch Diameter	{	Min	1.6250	1.8750	2.0833	2.3333	2.5833	2.7500	3.2500	3.7500	4.2500	4.7500
		Max	1.6357	1.8860	2.0956	2.3458	2.5960	2.7647	3.2651	3.7655	4.2658	4.7662
Class 4C Pitch Diameter	{	Min	1.6250	1.8750	2.0833	2.3333	2.5833	2.7500	3.2500	3.7500	4.2500	4.7500
		Max	1.6326	1.8828	2.0921	2.3422	2.5924	2.7605	3.2608	3.7611	4.2613	4.7615

*All other dimensions are in inches. The selection of threads per inch is arbitrary and for the purpose of establishing a standard.

TABLE 8

American National Standard Centralizing Acme Single-Start Screw Thread Data (ASME/ANSI B1.5-1988)										
Identification	Diameters				Thread Data					
	Centralizing, Classes 2C, 3C, and 4C				Lead Angle at Basic Pitch Diameter*					
	Nominal Sizes	Threads per Inch,*	Basic Major Diameter,	Pitch Diameter, D ₂ =	Minor Diameter, D ₁ =	Pitch,	Thickness at Pitch Line,	Basic Height of Thread,	Basic Width of Flat,	Centralizing Classes 2C, 3C, and 4C, λ
(All Classes)	n	D	(D - h)	(D - 2h)	P	t = P/2	h = P/2	F = 0.3707P	Deg	Min
1/4	16	0.2500	0.2188	0.1875	0.06250	0.03125	0.03125	0.0232	5	12
5/16	14	0.3125	0.2768	0.2411	0.07143	0.03571	0.03571	0.0265	4	42
3/8	12	0.3750	0.3333	0.2917	0.08333	0.04167	0.04167	0.0309	4	33
7/16	12	0.4375	0.3958	0.3542	0.08333	0.04167	0.04167	0.0309	3	50
1/2	10	0.5000	0.4500	0.4000	0.10000	0.05000	0.05000	0.0371	4	3
5/8	8	0.6250	0.5625	0.5000	0.12500	0.06250	0.06250	0.0463	4	3
3/4	6	0.7500	0.6667	0.5833	0.16667	0.08333	0.08333	0.0618	4	33
7/8	6	0.8750	0.7917	0.7083	0.16667	0.08333	0.08333	0.0618	3	50
1	5	1.0000	0.9000	0.8000	0.20000	0.10000	0.10000	0.0741	4	3
1 1/8	5	1.1250	1.0250	0.9250	0.20000	0.10000	0.10000	0.0741	3	33
1 1/4	5	1.2500	1.1500	1.0500	0.20000	0.10000	0.10000	0.0741	3	10
1 3/8	4	1.3750	1.2500	1.1250	0.25000	0.12500	0.12500	0.0927	3	39
1 1/2	4	1.5000	1.3750	1.2500	0.25000	0.12500	0.12500	0.0927	3	19
1 3/4	4	1.7500	1.6250	1.5000	0.25000	0.12500	0.12500	0.0927	2	48
2	4	2.0000	1.8750	1.7500	0.25000	0.12500	0.12500	0.0927	2	26
2 1/4	3	2.2500	2.0833	1.9167	0.33333	0.16667	0.16667	0.1236	2	55
2 1/2	3	2.5000	2.3333	2.1667	0.33333	0.16667	0.16667	0.1236	2	36
2 3/4	3	2.7500	2.5833	2.4167	0.33333	0.16667	0.16667	0.1236	2	21
3	2	3.0000	2.7500	2.5000	0.50000	0.25000	0.25000	0.1853	3	19
3 1/2	2	3.5000	3.2500	3.0000	0.50000	0.25000	0.25000	0.1853	2	48
4	2	4.0000	3.7500	3.5000	0.50000	0.25000	0.25000	0.1853	2	26
4 1/2	2	4.5000	4.2500	4.0000	0.50000	0.25000	0.25000	0.1853	2	9
5	2	5.0000	4.7500	4.5000	0.50000	0.25000	0.25000	0.1853	1	55

*All other dimensions are given in inches.

TABLE 9

American National Standard Centralizing Acme Single-Start Screw Threads - Pitch Diameter Allowances (ASME/ANSI B1.5-1988)				
Allowances on External Threads†				
Centralizing				
Nominal Size Range*		Class 2C,	Class 3C,	Class 4C,
Above	To and Including	0.008 $\sqrt{D}$	0.006 $\sqrt{D}$	0.004 $\sqrt{D}$
0	3/16	0.0024	0.0018	0.0012
3/16	5/16	0.0040	0.0030	0.0020
5/16	7/16	0.0049	0.0037	0.0024
7/16	9/16	0.0057	0.0042	0.0028
9/16	11/16	0.0063	0.0047	0.0032
11/16	13/16	0.0069	0.0052	0.0035
13/16	15/16	0.0075	0.0056	0.0037
15/16	1 1/16	0.0080	0.0060	0.0040
1 1/16	1 3/16	0.0085	0.0064	0.0042
1 3/16	1 5/16	0.0089	0.0067	0.0045
1 5/16	1 7/16	0.0094	0.0070	0.0047
1 7/16	1 9/16	0.0098	0.0073	0.0049
1 9/16	1 7/8	0.0105	0.0079	0.0052
1 7/8	2 1/8	0.0113	0.0085	0.0057

TABLE 9-continued

American National Standard Centralizing Acme Single-Start Screw Threads - Pitch Diameter Allowances (ASME/ANSI B1.5-1988)				
Allowances on External Threads†				
Centralizing				
Nominal Size Range*		Class 2C,	Class 3C,	Class 4C,
Above	To and Including	0.008 $\sqrt{D}$	0.006 $\sqrt{D}$	0.004 $\sqrt{D}$
2 1/8	2 3/8	0.0120	0.0090	0.0060
2 3/8	2 5/8	0.0126	0.0095	0.0063
2 5/8	2 7/8	0.0133	0.0099	0.0066
2 7/8	3 1/4	0.0140	0.0105	0.0070
3 1/4	3 3/4	0.0150	0.0112	0.0075
3 3/4	4 1/4	0.0160	0.0120	0.0080
4 1/4	4 3/4	0.0170	0.0127	0.0085
4 3/4	5 1/2	0.0181	0.0136	0.0091

All dimensions are given in inches.

*The values in cols. 3 to 5 are to be used for any size within the range shown in cols. 1 and 2. These values are calculated from the mean of the range.

It is recommended that the sizes given in Table 8 be used whenever possible.

†An increase of 10 percent in the allowance is recommended for each inch, or fraction thereof, that the length of engagement exceeds two diameters.

TABLE 10

American National Standard Centralizing Acme Single-Start Screw Threads - Pitch Diameter Tolerances ¹ (ASME/ANSI B1.5-1988) (For any particular size of thread, the pitch diameter tolerance is obtained by adding the diameter increment from the upper half of the table to the pitch increment from the lower half of the table. Example: A 0.250-16-ACME-2C thread has a pitch diameter tolerance of 0.00300 + 0.00750 = 0.0105 inch.)			
Nom.	Class of Thread		
	2C	3C	4C
Dia., ² D	.006√D	.0028√D	.002√D
1/4	.00300	.00140	.00100
5/16	.00335	.00157	.00112
3/8	.00367	.00171	.00122
7/16	.00397	.00185	.00132
1/2	.00424	.00198	.00141
5/8	.00474	.00221	.00158
3/4	.00520	.00242	.00173
7/8	.00561	.00262	.00187
1	.00600	.00280	.00200
1 1/8	.00636	.00297	.00212
1 1/4	.00671	.00313	.00224
1 3/8	.00704	.00328	.00235
1 1/2	.00735	.00343	.00245
1 3/4	.00794	.00370	.00265
2	.00849	.00396	.00283
2 1/4	.00900	.00420	.00300
2 1/2	.00949	.00443	.00316
2 3/4	.00995	.00464	.00332
3	.01039	.00485	.00346
3 1/2	.01122	.00524	.00374
4	.01200	.00560	.00400

TABLE 10-continued

American National Standard Centralizing Acme Single-Start Screw Threads - Pitch Diameter Tolerances ¹ (ASME/ANSI B1.5-1988) (For any particular size of thread, the pitch diameter tolerance is obtained by adding the diameter increment from the upper half of the table to the pitch increment from the lower half of the table. Example: A 0.250-16-ACME-2C thread has a pitch diameter tolerance of 0.00300 + 0.00750 = 0.0105 inch.)			
4 1/2	.01273	.00594	.00424
5	.01342	.00626	.00447
...	...	...	...
Thds. per Inch, n	Class of Thread		
	2C	3C	4C
Inch, n	.030√1/n	.014√1/n	.010√1/n
16	.00750	.00350	.00250
14	.00802	.00374	.00267
12	.00866	.00404	.00289
10	.00949	.00443	.00316
8	.01061	.00495	.00354
6	.01225	.00572	.00408
5	.01342	.00626	.00447
4	.01500	.00700	.00500
3	.01732	.00808	.00577
2 1/2	.01897	.00885	.00632
2	.02121	.00990	.00707
1 1/2	.02449	.01143	.00816
1 1/3	.02598	.01212	.00866
1	.03000	.01400	.01000

All dimensions are given in inches.

¹The equivalent tolerance on thread thickness is 0.259 times the pitch diameter tolerance.²For a nominal diameter between any two tabulated nominal diameters, use the diameter increment for the larger of the two tabulated nominal diameters.

TABLE 11

American National Standard Centralizing Acme Single-Start Screw Threads - Tolerances and Allowances for Major and Minor Diameters** (ASME/ANSI B1.5-1988)										
		Allowance From Basic Major and Minor-Diameters (All Classes)			Toler. on Minor	Tolerance on Major Diameter Plus on Internal, Minus on External Threads				
		Minor Diam.†	Internal Thread		Diam.*** All	Class 2C External				
		All	Major	Minor	Internal	and	Class 3C		Class 4C	
Size (Nom.)	Thds* per Inch	External Threads (Minus)	Diam.‡ (Plus 0.0010√D)	Diam.‡ (Plus 0.1P)	Threads, (Plus 0.05P)	Internal Threads, 0.0035√D	External Thread, 0.0015√D	Internal Thread, 0.0035√D	External Thread, 0.0010√D	Internal Thread, 0.0020√D
¼	16	0.010	0.0005	0.0062	0.0050	0.0017	0.0007	0.0017	0.0005	0.0010
⅜ ₁₆	14	0.010	0.0006	0.0071	0.0050	0.0020	0.0008	0.0020	0.0006	0.0011
⅝	12	0.010	0.0006	0.0083	0.0050	0.0021	0.0009	0.0021	0.0006	0.0012
⅞ ₁₆	12	0.010	0.0007	0.0083	0.0050	0.0023	0.0010	0.0023	0.0007	0.0013
½	10	0.020	0.0007	0.0100	0.0050	0.0025	0.0011	0.0025	0.0007	0.0014
⅝	8	0.020	0.0008	0.0125	0.0062	0.0028	0.0012	0.0028	0.0008	0.0016
¾	6	0.020	0.0009	0.0167	0.0083	0.0030	0.0013	0.0030	0.0009	0.0017
⅞	6	0.020	0.0009	0.0167	0.0083	0.0033	0.0014	0.0033	0.0009	0.0019
1	5	0.020	0.0010	0.0200	0.0100	0.0035	0.0015	0.0035	0.0010	0.0020
1⅛	5	0.020	0.0011	0.0200	0.0100	0.0037	0.0016	0.0037	0.0011	0.0021
1¼	5	0.020	0.0011	0.0200	0.0100	0.0039	0.0017	0.0039	0.0011	0.0022
1⅜	4	0.020	0.0012	0.0250	0.0125	0.0041	0.0018	0.0041	0.0012	0.0023
1½	4	0.020	0.0012	0.0250	0.0125	0.0043	0.0018	0.0043	0.0012	0.0024
1¾	4	0.020	0.0013	0.0250	0.0125	0.0046	0.0020	0.0046	0.0013	0.0026
2	4	0.020	0.0014	0.0250	0.0125	0.0049	0.0021	0.0049	0.0014	0.0028
2¼	3	0.020	0.0015	0.0333	0.0167	0.0052	0.0022	0.0052	0.0015	0.0030
2½	3	0.020	0.0016	0.0333	0.0167	0.0055	0.0024	0.0055	0.0016	0.0032
2¾	3	0.020	0.0017	0.0333	0.0167	0.0058	0.0025	0.0058	0.0017	0.0033
3	2	0.020	0.0017	0.0500	0.0250	0.0061	0.0026	0.0061	0.0017	0.0035
3½	2	0.020	0.0019	0.0500	0.0250	0.0065	0.0028	0.0065	0.0019	0.0037

TABLE 11-continued

American National Standard Centralizing Acme Single-Start Screw Threads - Tolerances and Allowances for Major and Minor Diameters** (ASME/ANSI B1.5-1988)										
Size (Nom.)	Thds* per Inch	Allowance From Basic Major and Minor-Diameters (All Classes)			Toler. on Minor		Tolerance on Major Diameter Plus on Internal, Minus on External Threads			
		Minor Diam.†			Diam.*** All		Class 2C External			
		Internal Thread								
		All	Major	Minor	Internal	and	Class 3C		Class 4C	
		External Threads (Minus)	Diam.‡ (Plus 0.0010√D)	Diam.† (Plus 0.1P)	Threads, (Plus 0.05P)	Internal Threads, 0.0035√D	External Thread, 0.0015√D	Internal Thread, 0.0035√D	External Thread, 0.0010√D	Internal Thread, 0.0020√D
4	2	0.020	0.0020	0.0500	0.0250	0.0070	0.0030	0.0070	0.0020	0.0040
4½	2	0.020	0.0021	0.0500	0.0250	0.0074	0.0032	0.0074	0.0021	0.0042
5	2	0.020	0.0022	0.0500	0.0250	0.0078	0.0034	0.0078	0.0022	0.0045

*All other dimensions are given in inches. Intermediate pitches take the values of the next coarser pitch listed.

**Values for intermediate diameters should be calculated from the formulas in column headings, but ordinarily may be interpolated.

***To avoid a complicated formula and still provide an adequate tolerance, the pitch factor is used as a basis, with the minimum tolerance set at 0.005 in.

†The minimum clearance at the minor diameter between the internal and external thread is the sum of the values in columns 3 and 5.

‡The minimum clearance at the major diameter between the internal and external thread is equal to col. 4.

Tolerance on minor diameter of all external threads is 1.5 x pitch diameter tolerance.

[0083] When threads **72**, **76** are fully engaged, impeller **44** becomes rotatably fixed in the drive direction to the distal end of drive shaft **46**. That is to say, when impeller is rotated in the fluid-accelerating direction by drive shaft **46**, the engagement of threads **72**, **76** tends to be tightened and the full engagement of threads **72**, **76** is maintained. When impeller **44** is rotated in the opposite (i.e., non-functional) direction, threads **72**, **76** will tend to disengage. Thus, to connect drive shaft **46** to impeller **44**, impeller **44** is immobilized and drive shaft **46** is rotated in the tightening direction until threads **72**, **76** are engaged. Subsequent operation of pump **10** will ensure that this engagement is maintained, and therefore drive shaft **46** is selectively rotatably fixed to impeller **44**. To disconnect drive shaft **46** from impeller **44**, impeller **44** is immobilized and drive shaft **46** is rotated in the opposite direction to disengage threads **72**, **76**.

[0084] As male threads **72** and female threads **76** approach full engagement as shown in FIG. 2, distal nubbin **70** formed at the end of drive shaft **46** encounters a correspondingly formed bore **74** formed in impeller **44**. Both nubbin **70** and bore **74** may be machined to a tight tolerance in order to concentrically align drive shaft **46** and impeller **44** with a precise and close-tolerance fit upon final assembly. In one exemplary embodiment, the total radial clearance between distal nubbin **70** and bore **74** is less than 0.004 inches, such as between 0.001 inches and 0.003 inches. Advantageously, the interaction between nubbin **70** and bore **74** reduces or eliminates any non-concentricity between drive shaft axis A_D and the intended rotational axis of impeller **44**. In an exemplary embodiment, the threaded connection formed by threads **72**, **76** allows for a relatively large radial play of drive shaft axis A_D relative to the rotational axis of impeller **44**. That is, when drive shaft **46** is connected to by threads **72**, **76** and not by nubbin **70** and bore **74**, the opposite end of drive shaft **46** is allowed to move radially such that drive shaft axis A_D becomes angled with respect to the rotational axis of impeller **44**.

[0085] In one exemplary embodiment, this radial play may be between 0.001 inches and 0.003 inches, as defined in ANSI/ASME B1.5-1997, the entire disclosure of which is hereby expressly incorporated by reference herein. By con-

trast, when nubbin **70** and bore **74** are engaged in addition to threads **72**, **76** such that impeller **44** is tightened fully against the adjacent shoulder of drive shaft **46**, this radial play is eliminated and drive shaft axis A_D becomes substantially concentric with the rotational axis of impeller **44**.

[0086] Although drive shaft **46** includes the male features used to connect drive shaft **46** to impeller **44** (i.e., male threads **72** and nubbin **70**) and impeller **44** includes the female features (i.e., female threads **76** and bore **74**), it is contemplated that this arrangement can be reversed as required or desired for a particular design. That is, either component can be provided with male threads **72** and the other component can be provided with the corresponding female threads **76**. Similarly, either component can be provided with a male centering feature such as nubbin **70**, and the other component can be provided with the corresponding female feature such as bore **74**.

[0087] 6. Drive Disassembly System

[0088] Turning now to FIGS. 8 and 9, drive disassembly system **50** used for disconnecting and connecting drive mechanism **40** from casing **12** and the remainder of pump **10** is illustrated. As described below, the components of drive disassembly system **50** may be connected to pump **10** when to facilitate removal and/or installation of drive mechanism **40**, and can be disconnected from pump **10** during regular operation.

[0089] Drive disassembly system **50** includes guide rail **52** selectively received within blind bore **66** (FIG. 1) formed in a central stiffener **28**. Stiffener **28** extends along a front-to-back direction from the vertical portion of outlet side wall **16** to partition wall **24**, and provides a structural support which inhibits bulging or deflection of outlet side wall **16** under the high pressures developed within outlet pump chamber **32**. The strength and structural integrity afforded by stiffener **28** and its associated structures also firmly supports guide rail **52** within bore **66**.

[0090] In an exemplary embodiment, guide rail **52** is snugly received in bore **66**. For example, the total radial clearance between guide rail **52** and bore **66** may be between 0.0015 inches and 0.0055 inches. When so snugly received, guide rail

52 has minimal radial play and therefore firmly supports drive mechanism 40 during assembly and disassembly procedures as described further below.

[0091] In order to axially fix guide rail 52 in its fully received position in bore 66, rail keeper 56 may be used to engage notch 54 formed in guide rail 52 (FIG. 9). Rail keeper 56 may then be fastened to casing 12 in order to axially fix rail keeper 56 and guide rail 52 to casing 12.

[0092] Rail guide 58 includes bearing 60 sized to be slidably received over guide rail 52, and flange 62 is fixed to bearing 60 (e.g., by welding).

[0093] When drive disassembly system 50 is used to remove drive mechanism 40 from casing 12, guide rail is first installed as described above. A portion of the standard installation fasteners 43 holding drive mechanism 40 in place (FIG. 1) are removed, such as the four fasteners 43 closest to guide rail 52. Bearing 60 is then slid onto the previously installed guide rail 52 until flange 62 of rail guide 58 abuts casing 12, as shown in FIG. 8. Fasteners 65 are passed through apertures 64 (not shown) formed in of flange 62 to bolt rail guide 58 to drive mechanism 40 at the locations where standard fasteners 43 were removed. In an exemplary embodiment, apertures 64 through flange 62 are oversized relative to fasteners 65, which allows fasteners 65 to move slightly within apertures 64 such that alignment of drive disassembly system 50 relative to casing 12 can be controlled by interaction between guide rail 52 and bearing 60, rather than between flange 62 and casing 12.

[0094] Fasteners 65 used in connection with drive disassembly system 50 are larger than standard fasteners 43 used to secure drive shaft housing 42 to casing 12 (FIG. 1). In this way, fasteners 43 are allowed pass through the threaded apertures 64 in the flange of drive shaft housing 42 (i.e., without threadably engaging threaded apertures 64), but fasteners 65 threadably connect to apertures 64. In this way, drive mechanism 40 is fixed to casing 12 by fasteners 43, while rail guide 58 is fixed to housing 42 by the larger threaded fasteners 65.

[0095] With rail guide 58 affixed to drive shaft housing 42 and slidably received upon guide rail 52, drive mechanism 40 is ready to be removed from outer drive aperture 22 formed in outlet side wall 16 of casing 12, as illustrated in FIG. 9. Any remaining fasteners 43 affixing drive shaft housing 42 to casing 12 are removed to free drive mechanism 40 from the remainder of pump 10.

[0096] Turning to FIG. 9, drive mechanism 40 may then be pulled free of casing 12 using guide rail 52 for support of drive mechanism 40. Advantageously, guide rail 52 accepts the weight of drive mechanism 40, allowing the service person to focus on guiding drive mechanism 40 safely free of casing 12 without having to also support the weight manually. In addition, caster 68 may be affixed to a lower portion of drive shaft housing 42, such as by caster bracket 69, in order to cooperate with guide rail 52 to provide support for the weight of drive mechanism 40 during removal or installation in casing 12. In the illustrated embodiment, standard fasteners 43 may be removed along the bottom portion of housing 42 to expose threaded apertures 64 (not shown), such that fasteners 65 can be threadably engaged with apertures 64 to affix bracket 69 to housing 42 in a similar fashion to rail guide 58 described above.

[0097] For installation or reinstallation of drive mechanism 40 via drive disassembly system 50, the steps of removal are simply repeated in reverse. During final alignment of drive mechanism 40, after it is received in outer drive aperture 22

and through inner drive aperture 26 (FIG. 5), fasteners 65 may be loosened as needed to allow for any needed readjustment.

[0098] 7. Impeller Inspection

[0099] Turning now to FIG. 11, inspection cover 110 and inspection side wear plate 112 are shown removed from their seated positions within casing 12 to expose outer inspection aperture 124 leading to inlet pump chamber 30, as well as inner inspection aperture 126 leading to volute 34, fluid channel 36 and impeller 44 seated in the central bore of volute 34.

[0100] In an exemplary embodiment, inspection side wear plate 112 is fixed to inspection cover 110, such as by fasteners. When so fixed, removal of inspection cover 110 also removes inspection side wear plate 112 as a single unit to allow access to inlet pump chamber 30, volute 34 and impeller 44 for inspection, maintenance or repair. When inspection cover 110 and wear plate 112 are reinstalled to casing 12 through outer inspection aperture 124, the previous spacing and configuration between the wear surface of wear plate 112 and the adjacent bearing surface of impeller 44 is maintained.

[0101] In order to set and maintain such proper spacing, fastener 114 may be used to affix inspection cover 110 and inspection side wear plate 112 to casing 12 via cannulated bolt 118 and bolt fixation plate 120. Only one of this fastener arrangement is illustrated in FIG. 11 for clarity, it being understood that the illustrative embodiment uses four such fastener arrangements for each of fastener apertures 116 formed in inspection cover 110.

[0102] Fastener apertures 116 are threaded to receive the correspondingly threaded shaft of cannulated bolt 118. The length of the threaded portion of cannulated bolt 118 is such that each bolt 118 may protrude beyond the distal end of aperture 116 to bear against the adjacent face of casing 12, which prevents inspection cover 110 from fully seating against casing 12 because the distal end of bolts 118 contact casing 12 before cover 110. In this way, the spacing of inspection side wear plate 112 from impeller 44 can be controlled by adjusting cannulated bolts 118 to protrude more or less beyond the distal end of fastener apertures 116.

[0103] In order to rotationally fix cannulated bolts 118 in a desired position corresponding to proper axial spacing between wear plate 112 and impeller 44, fixation plate 120 and fastener 122 are provided. Fixation plate 120 includes a bolt head receiving aperture 121 which is generally polygonal in order to rotationally fix cannulated bolt 118 to fixation plate 120 when the hexagonal head of bolt 118 is received within aperture 121. In an exemplary embodiment, aperture 121 is a "twelve point" style of the type commonly used in wrenches and sockets and designed to rotatably fix to hex bolt heads. Aperture 121 is placed over the head of bolt 118, such that fastener slot 123 aligns with fixation aperture 117 formed in inspection cover 110. Fastener 122 is then passed through slot 123 and into threaded engagement with aperture 117, rotationally and axially fixing bolt fixation plate 120 to inspection cover 110, and therefore fixing the rotational orientation and axial adjustment of cannulated bolt 118. Fastener 114 (described in detail above) is then passed through the central bore of cannulated bolt 118 and threadably engaged with the adjacent threaded aperture of casing 12 to affix inspection cover 110 thereto.

[0104] While this invention has been described as having an exemplary design, the present invention can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles.

Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains and which fall within the limits of the appended claims.

What is claimed is:

1. A centrifugal pump comprising:
 - a drive mechanism;
 - an impeller drivingly connected to the drive mechanism;
 - a casing having an inlet and an outlet, the casing comprising:
 - an inlet-side wall having an inlet aperture formed therein;
 - an outlet-side wall joined to the inlet-side wall to form a cavity within the casing, the outlet-side wall having an outlet aperture;
 - a volute disposed in the casing and in fluid communication with the inlet aperture and the outlet aperture, the volute having a central opening sized to receive the impeller and a spiral-shaped fluid channel such that the fluid channel progresses radially outwardly toward a volute discharge opening, the volute discharge opening defining a longitudinal discharge axis which extends through the outlet aperture,
 - whereby the volute is adapted to receive fluid accelerated outwardly by the impeller, direct the fluid radially outwardly through the spiral-shaped fluid channel, and discharge the fluid along the longitudinal discharge axis toward the outlet aperture.
2. The centrifugal pump of claim 1, wherein the casing defines a vertical center plane containing an axis of rotation of the impeller, and the longitudinal discharge axis is oriented to cross the vertical center plane.
3. The centrifugal pump of claim 1, wherein the impeller defines a spin plane perpendicular to the axis of impeller rotation, the discharge axis is angled with respect to the spin plane.
4. The centrifugal pump of claim 3, wherein the casing further comprises a partition wall interposed between the inlet-side wall and the outlet-side wall to form an inlet pump chamber and an outlet pump chamber, the partition wall having an inner drive aperture positioned to allow fluid communication between the inlet pump chamber and the outlet pump chamber via the inner drive aperture.
5. The centrifugal pump of claim 4, wherein the discharge axis is angled away from the partition wall.
6. The centrifugal pump of claim 4, wherein the casing further comprises a plurality of fastener bosses disposed within the outlet pump chamber and adjacent the outlet aperture, the fastener bosses each having a smooth, rounded outer surface.
7. The centrifugal pump of claim 6, wherein the fastener bosses each have a convex distal surface and a concave surface at the junction between the convex distal surface and the adjacent inner surface of the outlet pump chamber.
8. The centrifugal pump of claim 6, wherein the fastener bosses define a tear drop shape with a pointed end of the tear drop shape pointing toward the outlet aperture, whereby the fastener bosses promote laminar flow of fluid discharged from the volute and advanced toward the outlet aperture.
9. The centrifugal pump of claim 4, wherein the casing of the pump comprises a sump region formed in a lower region of the outlet pump chamber, the sump region including a

central portion in direct fluid communication with the impeller and a peripheral portion in indirect fluid communication with the impeller,

the casing further comprising at least one drain channel in direct fluid communication with the peripheral portion of the sump region and in indirect fluid communication with the central portion of the sump region, whereby the at least one drain channel does not form any part of the volute.

10. The centrifugal pump of claim 9, wherein the casing comprises a first drain channel and a second drain channel, the first and second drain channels positioned on opposite side of the volute.

11. The centrifugal pump of claim 1, wherein the pump further comprises an inlet adapter connected to the inlet aperture, the inlet adapter including a necked portion in which a flow area through the inlet adapter gradually increases along a flow direction toward the inlet aperture.

12. The centrifugal pump of claim 11, wherein:

the pump further comprises an outlet adapter connected to the outlet aperture, the outlet adapter having a substantially cylindrical fluid passage, and

the inlet and outlet adapters configured to receive a common nominal size of fluid conduit and the necked portion of the inlet adapter leading to the inlet aperture having larger area than the outlet aperture.

13. The centrifugal pump of claim 1, wherein the outlet aperture comprises an outlet transition area having a radiused internal edge operable to facilitate smooth flow therethrough, the outlet transition area defining a nominal radius at least equal to a minimum thickness of the outlet-side wall.

14. The centrifugal pump of claim 13, wherein the nominal radius of the outlet transition area is at least 131% of the minimum thickness of the outlet-side wall.

15. The centrifugal pump of claim 1, further comprising a plurality of stiffening ribs extending along and integrally formed with the inlet-side wall and the outlet-side wall of the casing, the stiffening ribs disposed only on an exterior surface of the casing.

16. The centrifugal pump of claim 15, wherein a plurality of ribs on the outlet-side wall extend along a substantially vertical face of the outlet-side wall, round a corner at the junction between the vertical face a side face of the outlet-side wall, and extend along a front-to-back direction on the side face.

17. The centrifugal pump of claim 16, wherein the plurality of extend radially outwardly along the vertical face from a central area of the vertical face.

18. The centrifugal pump of claim 1, wherein the outlet-side wall of the casing comprises an outer drive aperture sized to receive the drive mechanism.

19. A centrifugal pump comprising:

a drive mechanism;

an impeller drivingly connected to the drive mechanism;

a flapper valve;

a casing having an inlet and an outlet, the casing comprising:

an inlet-side wall having an inlet aperture formed therein, the flapper valve positioned at the inlet aperture to admit a flow of fluid into the casing via the inlet aperture while preventing a flow of fluid out of the casing via the inlet aperture;

- an outlet-side wall joined to the inlet-side wall to form a cavity within the casing, the outlet-side wall having an outlet aperture;
- a partition wall interposed between the inlet-side wall and the outlet-side wall to form an inlet pump chamber and an outlet pump chamber, the partition wall having an inner drive aperture positioned to allow fluid communication between the inlet pump chamber and the outlet pump chamber via the inner drive aperture;
- a combination port formed in the casing near the flapper valve, the combination port sized and positioned to allow access to the flapper valve by a maintenance person, and to allow fluid to be added to the inlet pump chamber; and
- a fill vent formed through the casing on an opposite side of the partition wall as the combination port, such that the fill vent allows fluid communication between the outlet pump chamber and the ambient environment, whereby liquid added to the inlet pump chamber is allowed to flow to the outlet pump chamber via the inner drive aperture while air contained in the outlet pump chamber vents to atmosphere via the fill vent.
- 20.** The centrifugal pump of claim **19**, further comprising a combination port cover comprising:
- a fill port cover portion sized to be received over the combination port to fluidly isolate the combination port from the ambient environment; and
- a fill vent cover portion sized to be received over the fill vent to fluidly isolate the fill vent from the ambient environment.
- 21.** The centrifugal pump of claim **20**, wherein the fill vent cover portion is formed as a forward extension of the fill port cover portion in order to pass over the partition wall onto the fill vent.
- 22.** The centrifugal pump of claim **20**, wherein the fill port cover portion and the fill vent cover portion are integrally, monolithically formed as a single component.
- 23.** The centrifugal pump of claim **19**, wherein the outlet-side wall of the casing comprises an outer drive aperture formed therein, the outer drive aperture sized to receive the drive mechanism.
- 24.** A centrifugal pump comprising:
- a drive shaft having a first coarse thread and a first centering feature;
- an impeller drivingly connected to the drive shaft, the impeller having a second coarse thread and a second centering feature, the second coarse thread engageable with the first coarse thread of the drive shaft to selectively rotatably fix the drive shaft to the impeller, and the second centering feature engageable with the first centering feature to concentrically align the impeller with the drive shaft.
- 25.** The centrifugal pump of claim **24**, wherein the first coarse thread of the impeller is a female thread and the second coarse thread of the drive shaft is a male thread.
- 26.** The centrifugal pump of claim **24**, wherein the first and second coarse threads are trapezoidal threads.
- 27.** The centrifugal pump of claim **24**, wherein the first centering feature is a bore formed in the impeller and the second centering feature is a nubbin formed at a distal end of the drive shaft.
- 28.** The centrifugal pump of claim **27**, wherein the nubbin and the bore fit together with a radial clearance of less than 0.004 inches.
- 29.** The centrifugal pump of claim **24**, wherein the drive shaft is part of a drive mechanism further comprising:
- a casing having an inlet and an outlet, the casing comprising:
- an inlet-side wall having an inlet aperture formed therein;
- an outlet-side wall joined to the inlet-side wall to form a cavity within the casing, the outlet-side wall having an outlet aperture;
- a drive shaft housing affixed to the casing, the drive shaft rotatably received in the drive shaft housing;
- at least one bearing supported by the drive shaft housing and rotatably supporting the drive shaft;
- a drive side wear plate connected to the drive shaft; and
- a biasing element between the drive side wear plate and the impeller which biases the drive side wear plate toward the drive shaft housing and away from the impeller.
- 30.** The centrifugal pump of claim **29**, wherein:
- the first centering feature of the drive shaft comprises a locating nubbin at a distal end thereof;
- the second centering feature of the impeller includes a locating bore sized to receive the locating nubbin;
- the drive shaft is operably connected to the impeller by engagement of the first coarse thread with the second coarse thread, thereby allowing for a radial play in the drive shaft, and
- the drive shaft is concentrically located with respect to the impeller by a close-tolerance interaction between the locating nubbin and the locating bore such that the radial play is eliminated.
- 31.** The centrifugal pump of claim **30**, wherein the radial play is less than 0.004 inches.
- 32.** The centrifugal pump of claim **29**, wherein the outlet-side wall includes an outer drive aperture formed therein, the outer drive aperture sized to receive the impeller, the casing further comprising:
- a partition wall interposed between the inlet-side wall and the outlet-side wall to form an inlet pump chamber and an outlet pump chamber, the partition wall having an inner drive aperture positioned to allow fluid communication between the inlet pump chamber and the outlet pump chamber via the inner drive aperture.
- 33.** A centrifugal pump comprising:
- a drive mechanism;
- an impeller drivingly connected to the drive mechanism;
- a casing having an inlet and an outlet, the casing comprising:
- an inlet-side wall having an inlet aperture formed therein;
- an outlet-side wall joined to the inlet-side wall to form a cavity within the casing, the outlet-side wall having an outlet aperture;
- a bore extending inwardly from the exterior of the outlet-side wall whereby the bore is accessible to a user of the pump;
- a drive disassembly system comprising:
- a guide rail sized to be snugly received within the bore; and
- a rail guide having a bearing and a flange fixed to the bearing, the bearing sized to be slidably received on the guide rail while the flange is fixed to the drive

mechanism, such that the drive mechanism can be assembled into or removed from the casing while being supported by the guide rail.

34. The centrifugal pump of claim **33**, wherein the casing further comprises:

a partition wall interposed between the inlet-side wall and the outlet-side wall to form an inlet pump chamber and an outlet pump chamber, the partition wall having an inner drive aperture positioned to allow fluid communication between the inlet pump chamber and the outlet pump chamber via the inner drive aperture; and
a stiffener extending through the outlet pump chamber from the outlet-side wall to the partition wall, the stiffener having the bore formed therein as a blind bore.

35. The centrifugal pump of claim **33**, wherein:

the drive mechanism includes a housing secured to the casing by a plurality of first fasteners passing through a corresponding plurality of annularly arranged apertures formed in the housing, the first fasteners threadably received in the casing; and

the flange of the rail guide is secured to the casing by a plurality of second fasteners threadably received in a plurality of annularly arranged apertures formed in the flange,

the plurality of annularly arranged apertures formed in the flange of the rail guide oversized relative to the size of the plurality of second fasteners, whereby alignment of the drive disassembly system relative to the casing is a function of interaction between the guide rail and the bearing rather than between the flange and the casing.

36. The centrifugal pump of claim **33**, wherein an outer surface of the guide rail includes a notch positioned to be adjacent the exterior of the outlet-side wall when the guide rail is fully received in the bore, the drive disassembly system

further comprises a rail keeper shaped to engage the notch and thereafter be secured to the casing such that the rail keeper and the casing cooperate to axially fix the guide rail with respect to the casing.

37. The centrifugal pump of claim **36**, wherein the drive disassembly system further comprises a caster selectively fixed to the drive mechanism, the caster positioned to cooperate with the guide rail to support the drive mechanism while the drive mechanism is assembled into or removed from the casing.

38. A method of disassembling a drive mechanism from a centrifugal pump, the method comprising:

inserting a rail into a bore formed in a casing of the pump, such that the rail fits snugly within the bore;
sliding a rail guide over the rail and into engagement with the pump;

affixing the rail guide to the drive mechanism while maintaining the rail guide in sliding engagement with the rail; and

disconnecting the drive mechanism from the casing and sliding the drive mechanism away from the casing using the support of the rail.

39. The method of claim **38**, further comprising affixing a caster to a lower portion of the drive mechanism, the step of disconnecting including rolling the caster on a support surface.

40. The method of claim **38**, further comprising reconnecting the drive mechanism to the casing using the support of the rail.

41. The method of claim **38**, further comprising, after the step of inserting the rail into the bore, of connecting a rail keeper to the casing, the rail keeper engaging a notch formed in the rail to axially fix the rail relative to the casing.

* * * * *