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Approved American National Standard

ANSI

American National Standard for

Rotodynamic Vertical Pumps

of Radial, Mixed, and Axial Flow Types for Nomenclature and Definitions

ANSI/HI 2.1–2.2-2014

Hydraulic Institute

6 Campus Drive
First Floor North
Parsippany, New Jersey
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Approved April 8, 2014

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Foreword (Not part of Standard)

Purpose and aims of the Hydraulic Institute

The purpose and aims of the Institute are to promote the continued growth and well-being of pump users and manufacturers and further the interests of the public in such matters as are involved in manufacturing, engineering, distribution, safety, transportation, and other problems of the industry, and to this end, among other things:

a) To develop and publish standards for pumps;

b) To collect and disseminate information of value to its members and to the public;

c) To appear for its members before governmental departments and agencies and other bodies in regard to matters affecting the industry;

d) To increase the amount and to improve the quality of pump service to the public;

e) To support educational and research activities;

f) To promote the business interests of its members but not to engage in business of the kind ordinarily carried on for profit or to perform particular services for its members or individual persons as distinguished from activities to improve the business conditions and lawful interests of all of its members.

Purpose of Standards

1) Hydraulic Institute Standards are adopted in the public interest and are designed to help eliminate misunderstandings between the manufacturer, the purchaser, and/or the user and to assist the purchaser in selecting and obtaining the proper product for a particular need.

2) Use of Hydraulic Institute Standards is completely voluntary. Existence of Hydraulic Institute Standards does not in any respect preclude a member from manufacturing or selling products not conforming to the Standards.

Definition of a Standard of the Hydraulic Institute

Quoting from Article XV, Standards, of the By-Laws of the Institute, Section B:

> "An Institute Standard defines the product, material, process or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, quality, rating, testing and service for which designed."

Comments from users

Comments from users of this standard will be appreciated, to help the Hydraulic Institute prepare even more useful future editions. Questions arising from the content of this standard may be directed to the Technical Director of the Hydraulic Institute. The inquiry will then be directed to the appropriate technical committee for provision of a suitable answer.

If a dispute arises regarding contents of an Institute standard or an answer provided by the Institute to a question such as indicated above, the point in question shall be sent in writing to the Technical Director of the Hydraulic Institute, who shall initiate the appeals process.

Revisions

The Standards of the Hydraulic Institute are subject to constant review, and revisions are undertaken whenever it is found necessary because of new developments and progress in the art. If no revisions are made for five years, the standards are reaffirmed with the *ANSI Essential Requirements*.

Units of measurement

Metric units of measurement are used, and corresponding US customary units appear in brackets. Charts, graphs, and sample calculations are also shown in both metric and US customary units. Since values given in metric units are not exact equivalents to values given in US customary units, it is important that the selected units of measure to be applied be stated in reference to this standard. If no such statement is provided, metric units shall govern.

Consensus

Consensus for this standard was achieved by use of the canvass method. The following organizations, recognized as having interest in rotodynamic vertical pumps for nomenclature and definitions, were contacted prior to the approval of this revision of the standard. Inclusion in this list does not necessarily imply that the organization concurred with the submittal of the proposed standard to ANSI.

A.W. Chesterton Company
Bechtel Power Corporation
Black & Veatch Corp.
Brown and Caldwell
Colfax Fluid Handling
ekwestrel corp
Flowserve Corporation
Healy Engineering, Inc.
John Anspach Consulting
Kemet Inc.
King County Wastewater Treatment Division
Las Vegas Valley Water District
National Pump Company
Patterson Pump Company
Peerless Pump Company
Pentair, Flow Technologies
Sulzer Pumps US Inc.
WEG Electric Corp.
Xylem Inc.
Zan Kugler P.E., LLC

Committee list

Although this standard was processed and approved for submittal to ANSI by the canvass method, a working committee met many times to facilitate its development. At the time it was developed, the committee had the following members:

Co-Chair - Michael L. Mueller, Flowserve Corporation
Co-Chair - Bruce Ticknor, III, National Pump Company

Committee Members	Company
Michael S. Cropper	Sulzer Pumps (US) Inc.
Allen J. Hobratschk (Alternate)	National Pump Company
Paul J. Ruzicka	Xylem Inc. - Applied Water Systems
Fred F. Walker	Weir Floway, Inc.

Preface

Symbols are used throughout this standard to identify the pump types. The convention is to define the term in text, followed by the HI symbol in parenthesis (xx), and followed, when different, with the ISO symbol in brackets [xx].

ANSI/HI 2.3 *Rotodynamic Vertical Pumps of Radial, Mixed, and Axial Flow Types for Design and Application* complements the nomenclature and definitions content defined in this document with detailed information about the design and application of rotodynamic vertical pumps.

2 Rotodynamic vertical pumps

2.1 Types and nomenclature

2.1.1 Scope

This standard is for types, nomenclature, and definitions of vertical turbine, mixed flow, axial flow vertical diffuser, submersible motor deep-well and short-set pumps, commonly defined as vertically suspended rotor types VS0, VS1, VS2, VS3, VS6, VS7, and VS8, as well as vertical overhung impeller types VS4 and VS5 (Figure 2.1.3) that are driven by vertical electric motors or horizontal engines with right-angle gears.

2.1.2 Definition of rotodynamic vertical pumps

Rotodynamic vertical pumps are kinetic machines in which energy is continuously imparted to the pumped fluid by means of an impeller, propeller, or rotor having a vertical axis of rotation. The most common types of rotodynamic pumps are radial (centrifugal), mixed, and axial flow (propeller) pumps. Within these broad types there are many design variations in both horizontal axis and vertical axis configurations. A particular group of rotodynamic vertical pumps historically has been called *vertical turbine pumps*. The turbine pumps typically use radial, modified radial, or mixed flow impellers. (Refer to Sections 2.1.5.2 to 2.1.5.5.)

These pumps, particularly the radial flow and modified radial flow types, are usually designed for multistaging, by bolting or threading individual bowls together.

The pumping element (bowl assembly) is usually suspended by a column pipe, which also carries the liquid from the bowl (assembly) to the discharge opening.

Rotodynamic vertical pumps are normally classified as deep well, short set, or submersible motor-driven. The driver for these pump configurations is mounted either on the discharge head (line-shaft pumps); directly to the bowl assembly, either above or below (i.e., pumps with submersible motors); or in a horizontal configuration, such as an electrical motor or engine, driving through a right-angle gear.

2.1.3 Types of vertical pumps

See Figures 2.1.3 to 2.1.3.6.

2.1.3.1 Submersible – turbine bowl

This type of pump consists of an electric drive motor coupled directly to the bowl assembly. See Figure 2.1.3.1. The driving “submersible-type” motor and bowl assembly are designed to be submerged in the liquid pumped. The pumping element usually is of the turbine bowl design; however, mixed flow and propeller types are also available. This type of unit is normally used in wells and occasionally for wet pit or canned booster service. With this style pump the motor is fully submerged in the pumped liquid. A minimum velocity flow is required to cool the motor during operation. Where liquid temperatures exceed specified values, the motors must be derated according to manufacturers’ recommendations.

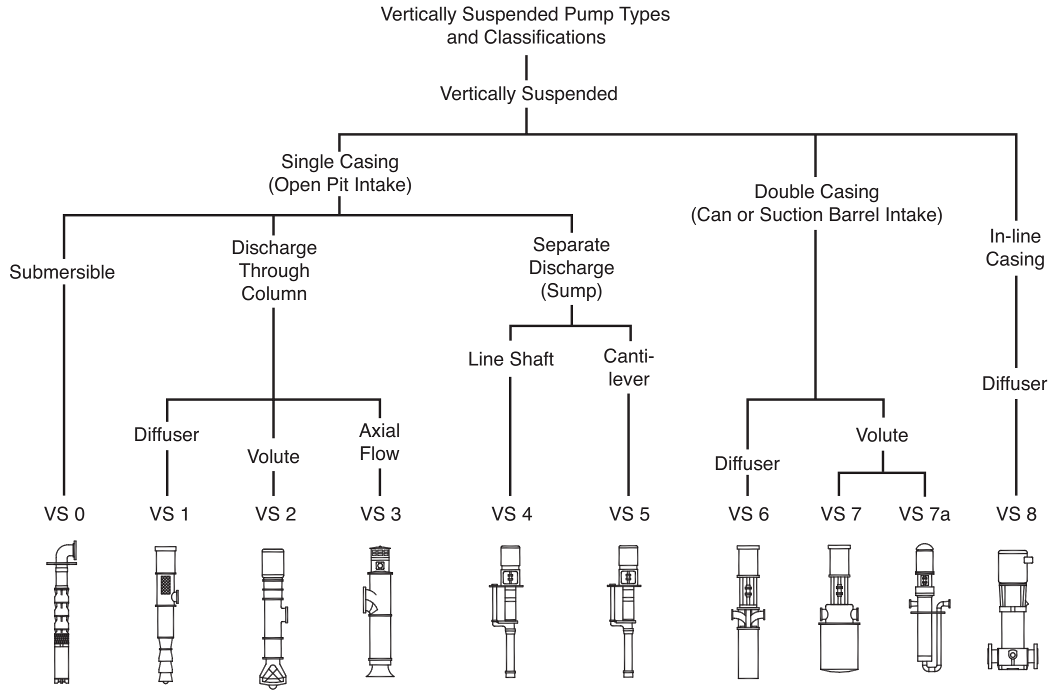


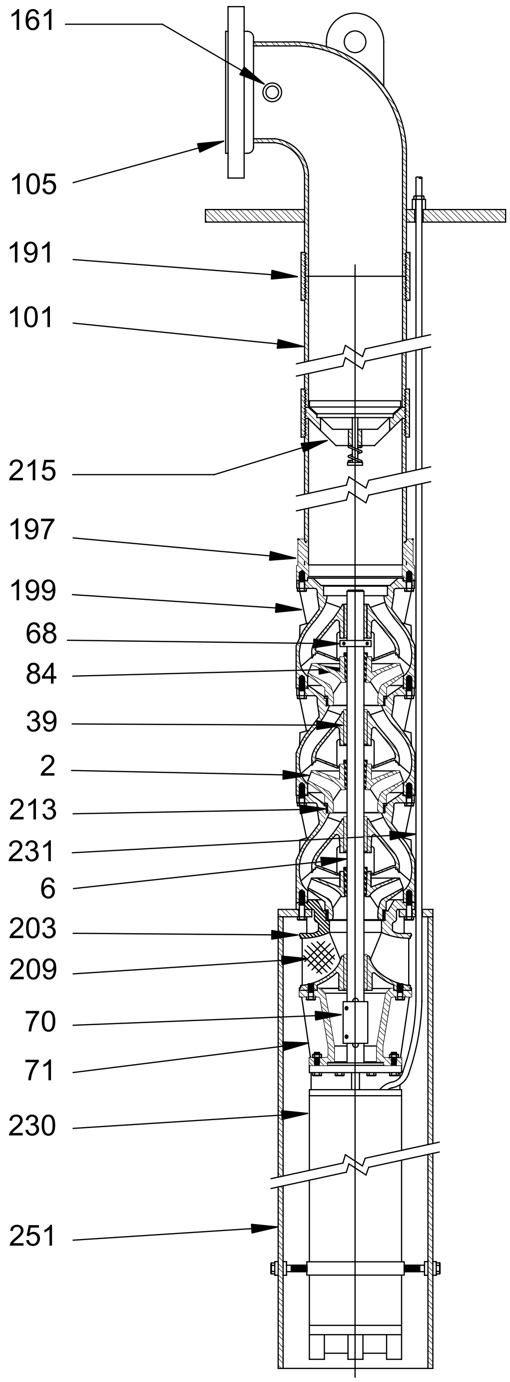
Figure 2.1.3 — Vertical pump types – vertically suspended rotor – single and multistage

2.1.3.2 Deep well (line shaft)

This type of vertical pump is commonly installed in a drilled and cased well. Its function is to move liquid (usually water) from the liquid level in the well to the surface and provide a specified discharge pressure at the surface (see Figure 2.1.3.2). The pumping element consists of a single or multistage bowl assembly. The first-stage impeller is located below the lowest liquid level. The bowl bearings are usually lubricated by the pumped liquid. The open line-shaft pump is often referred to as a *product-lubricated* or *water-lubricated pump*. The lubrication for an enclosed line-shaft pump may be oil, grease, filtered pump discharge water, or clean water from an external source. The column pipe and line-shaft assembly is either an open-type, product-lubricated assembly or enclosed-type oil or external liquid-lubricated assembly. The column pipe is supported at the surface by a discharge head. The discharge head directs the water from vertical to horizontal flow, and supports a driver or right-angle gear. A shaft sealing arrangement is contained within the discharge head. This type of pump is self-priming. Typically the vertical electric motor or vertical right-angle gear drive is of the “hollow-shaft” design. This pump type requires the consideration of shaft elongation under axial loads.

2.1.3.3 Wet pit, short set (line shaft) – single and double suction

This type of vertical pump usually is suspended in a wet pit. (See Figures 2.1.3.3a, b, c, and d.) The pumping element can be fitted with a bowl assembly of any desired specific speed. Normally the bowl assembly bearings are product-lubricated; however, they can be force-lubricated by grease, water, or other lubricants. The column pipe assembly supports the bowl assembly and houses a line shaft. The line-shaft bearings are usually open-type, product-lubricated. However, enclosed-type line shaft, force-feed lubrication with oil, grease, or water may also be supplied. A shaft sealing arrangement is contained within the discharge head on product-lubricated pumps. This type of pump is self-priming and is typically assembled by the manufacturer and shipped assembled. There is some variance in maximum length able to be accommodated by common domestic and international commercial shipping methods; however, this length is typically about 12 meters (m) (40 feet [ft]).



2	Impeller
6	Shaft, pump
39	Bearing, sleeve
68	Collar, shaft
70	Coupling, shaft
71	Adapter
84	Collet, impeller lock
101	Pipe, column
105	Elbow, discharge
161	Fitting, discharge
191	Coupling, column pipe
197	Case, discharge
199	Bowl intermediate
203	Case, suction
209	Strainer
213	Ring, bowl
215	Valve, column check (optional)
230	Motor, submersible
231	Electric cable, submersible
251	Shroud, flow (optional)

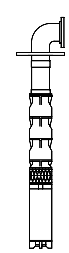


Figure 2.1.3.1 — Vertical, multistage, submersible pump (VS0)

2	Impeller
6	Shaft, pump
8	Ring, impeller
10	Shaft, head
12	Shaft, line
13	Packing
17	Gland
29	Ring, lantern
39	Bearing, sleeve
40	Deflector
55	Bell, suction
63	Bushing, stuffing box
64	Collar, protecting
66	Nut, shaft adjusting
70	Coupling, shaft
77	Lubricator
79	Bracket, lubricator
83	Stuffing box
84	Collet, impeller lock
85	Tube, shaft-enclosing
91	Stablizer, tube
101	Pipe, column
102	Bearing, throttle
103	Bearing, line shaft, enclosed
129	Plate, sole
131	Guard, coupling
183	Nut, tubing
185	Plate, tension, tube
187	Head, surface discharge
189	Flange, top column
191	Coupling, column pipe
193	Retainer, bearing, open line shaft
195	Adapter, tube
197	Case, discharge
199	Bowl, intermediate
203	Case, suction
209	Strainer (optional)
211	Pipe, suction (optional)
213	Ring, bowl

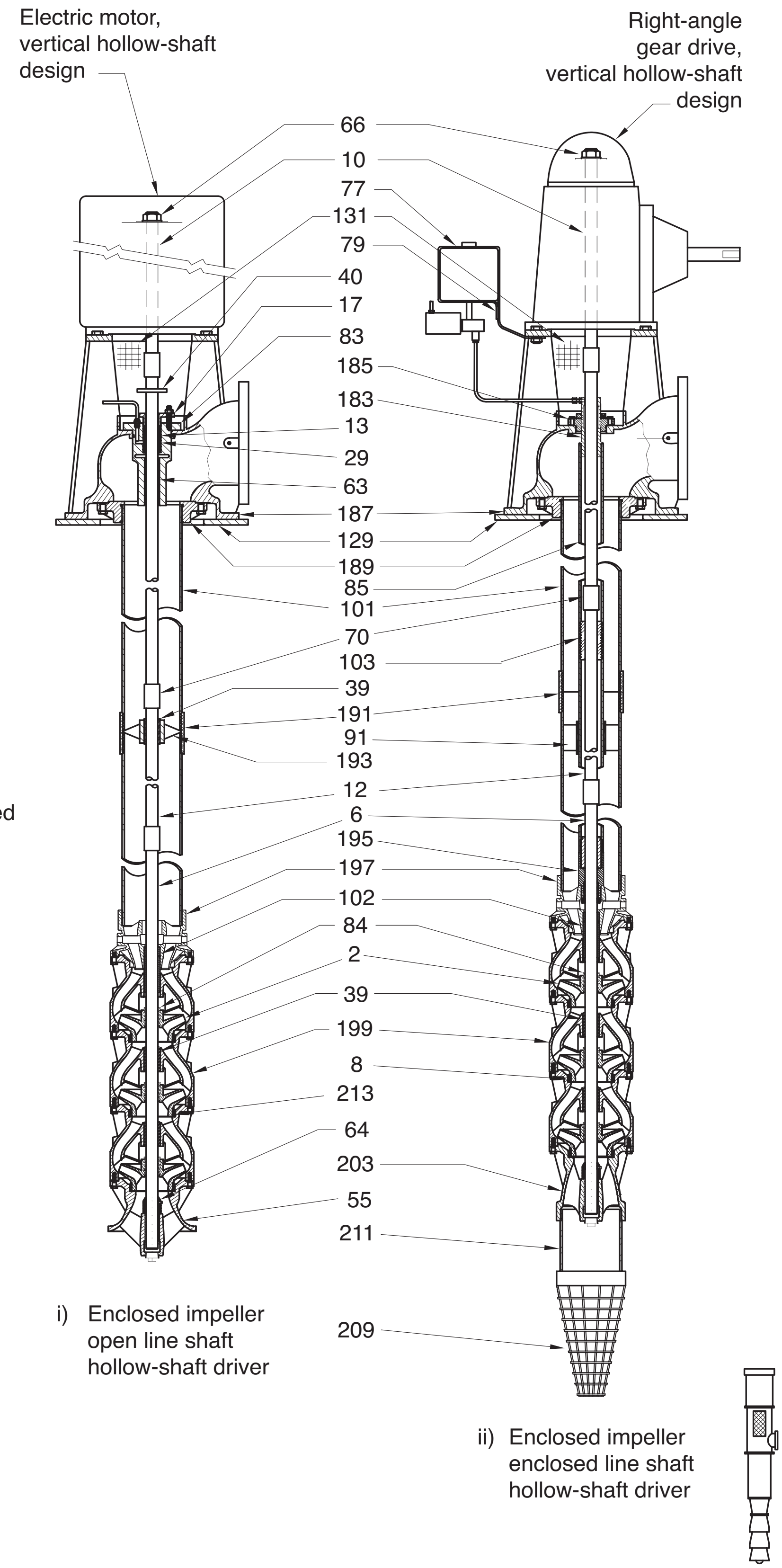
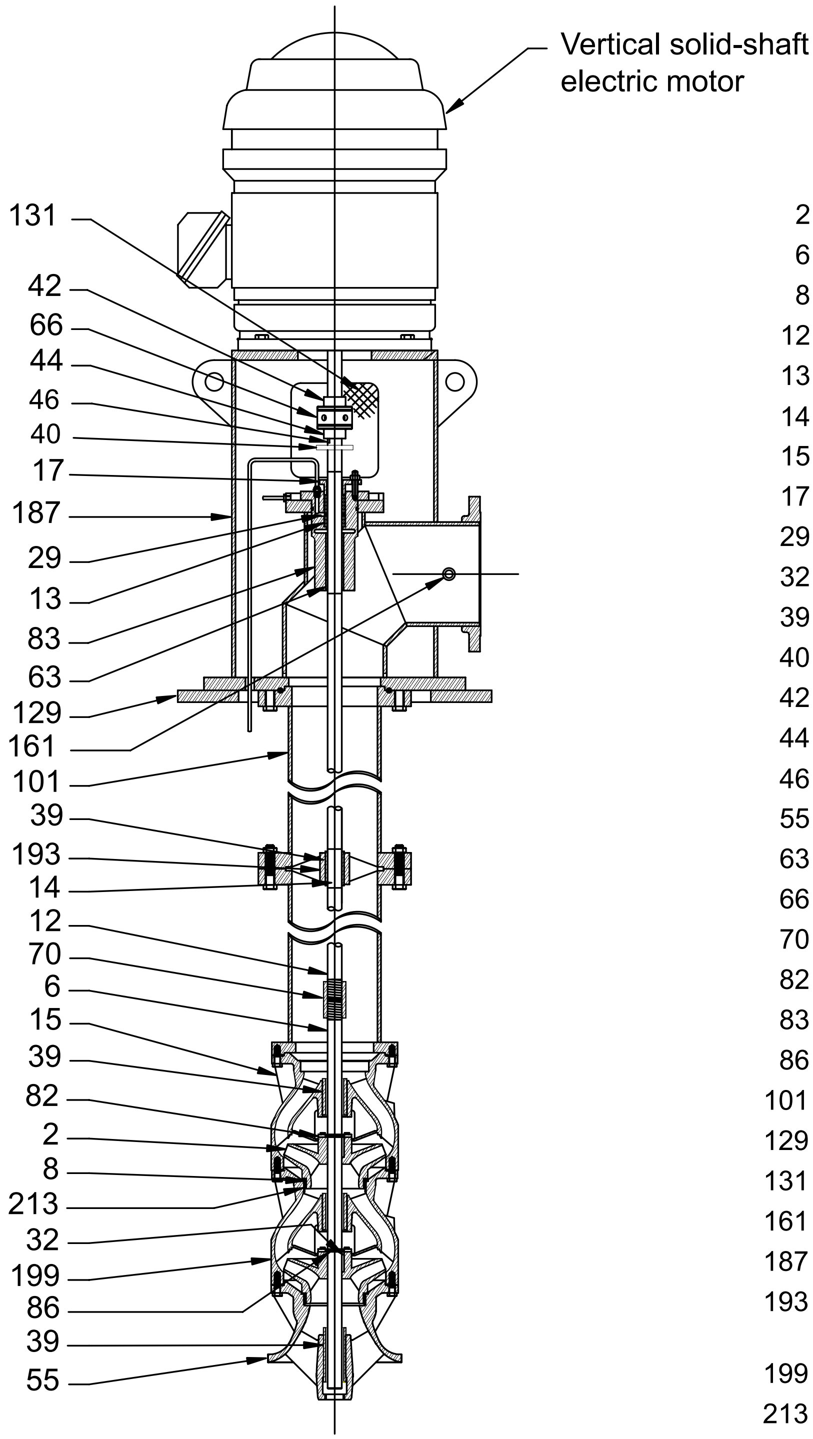


Figure 2.1.3.2 — Deep-well pumps (VS1)



2 Impeller
6 Shaft, pump
8 Ring, impeller
12 Shaft, line
13 Packing
14 Sleeve, shaft
15 Bowl, discharge
17 Gland
29 Ring, lantern
32 Key, impeller
39 Bearing, sleeve
40 Deflector
42 Coupling half, driver
44 Coupling half, pump
46 Key, coupling
55 Bell, suction
63 Bushing, stuffing box
66 Nut, shaft adjusting
70 Coupling, shaft
82 Ring, thrust, retainer
83 Stuffing box
86 Ring, thrust, split
101 Pipe, column
129 Sole plate
131 Guard, coupling
161 Fitting, discharge
187 Head, surface discharge
193 Retainer, bearing, open line shaft
199 Bowl, intermediate
213 Ring, bowl

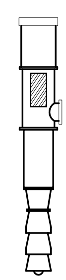


Figure 2.1.3.3a — Vertical single or multistage, short setting, open line shaft (VS1)

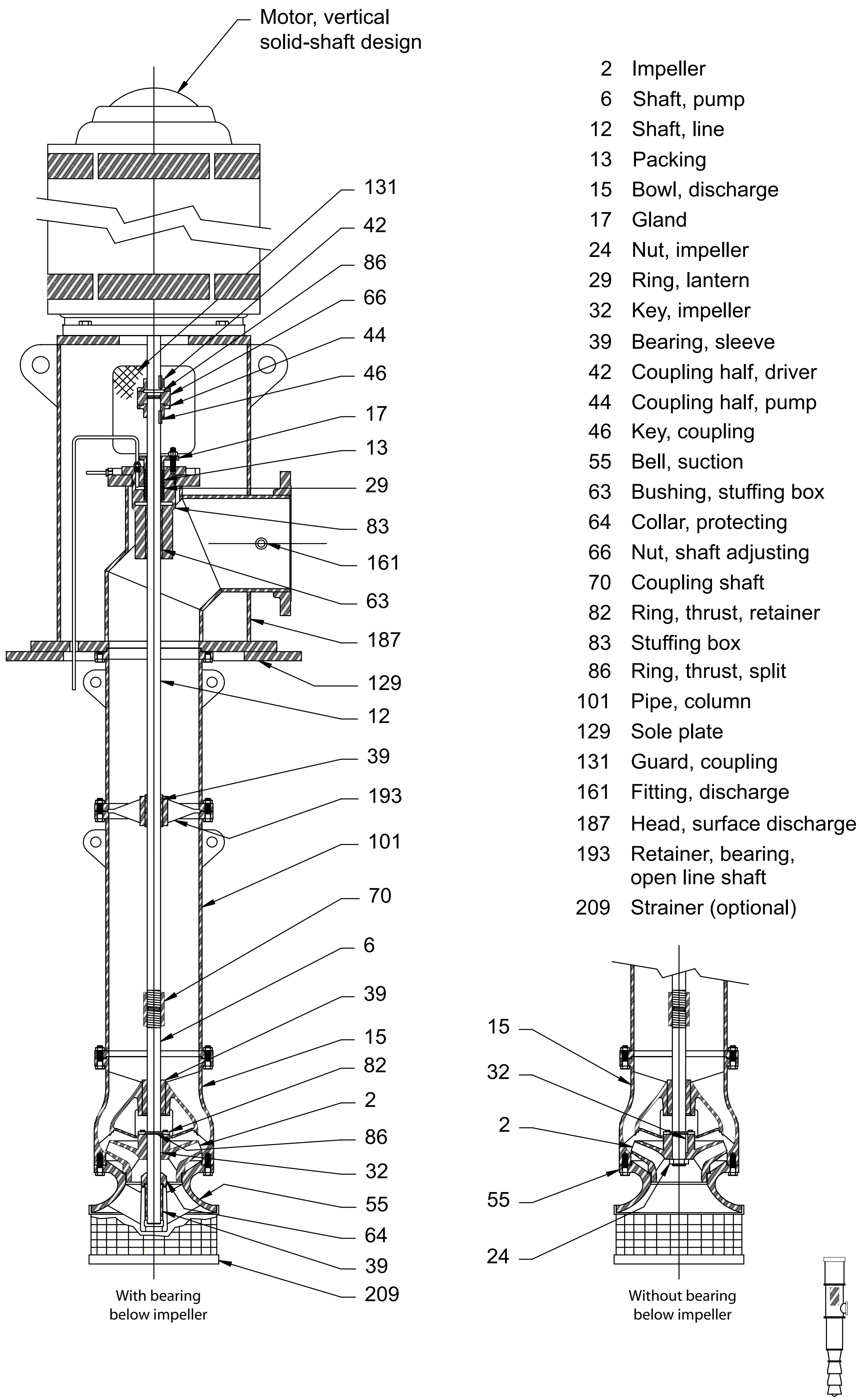
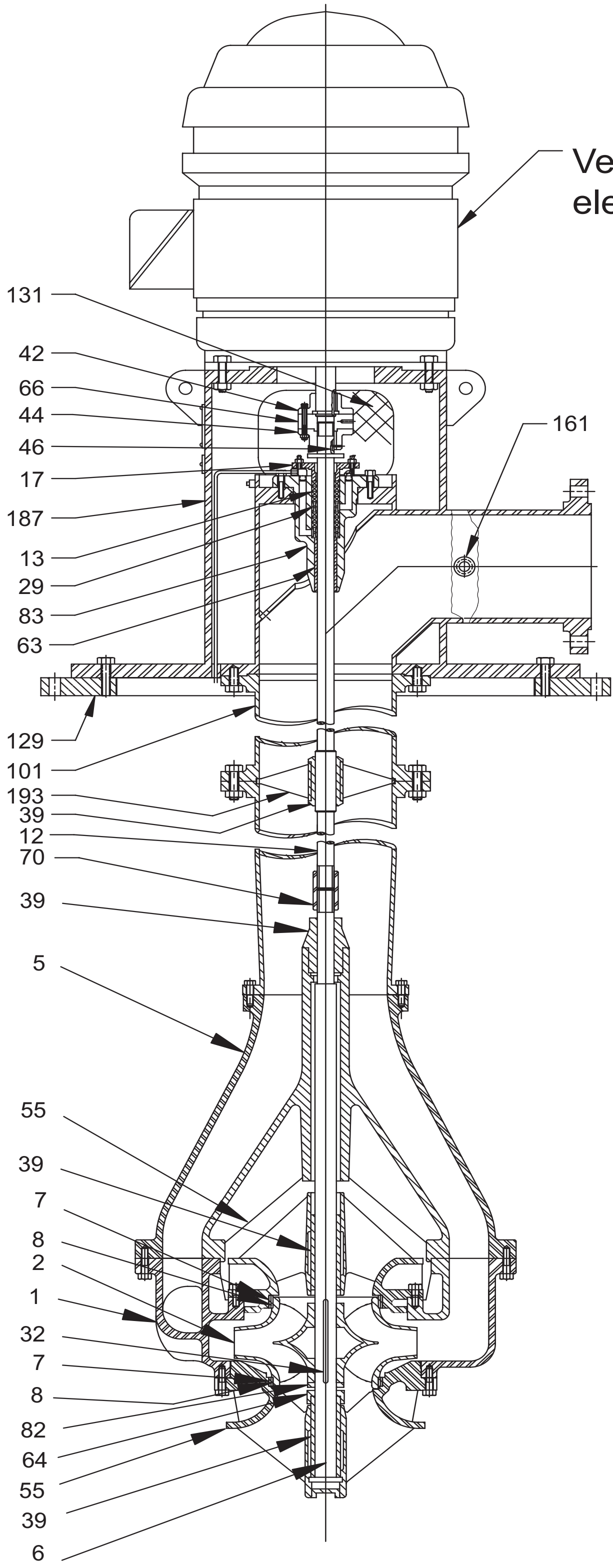


Figure 2.1.3.3b — Mixed flow vertical — open line shaft (VS1)



1	Case, volute
2	Impeller
5	Diffuser, transition
6	Shaft, pump
7	Ring, bell wearing
8	Ring, impeller
12	Shaft, line
13	Packing
17	Gland
29	Ring, lantern
32	Key, impeller
39	Bearing, sleeve
42	Coupling half, driver
44	Coupling half, pump
46	Key, coupling
55	Bell, suction
63	Bushing, stuffing box
64	Collar, sand
66	Nut, shaft adjusting
70	Coupling, shaft
82	Ring, thrust, retainer
83	Stuffing box
101	Pipe, column
129	Sole plate
131	Guard, coupling
161	Fitting, discharge
187	Head, surface discharge
193	Retainer, bearing

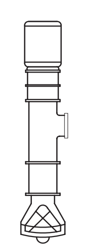
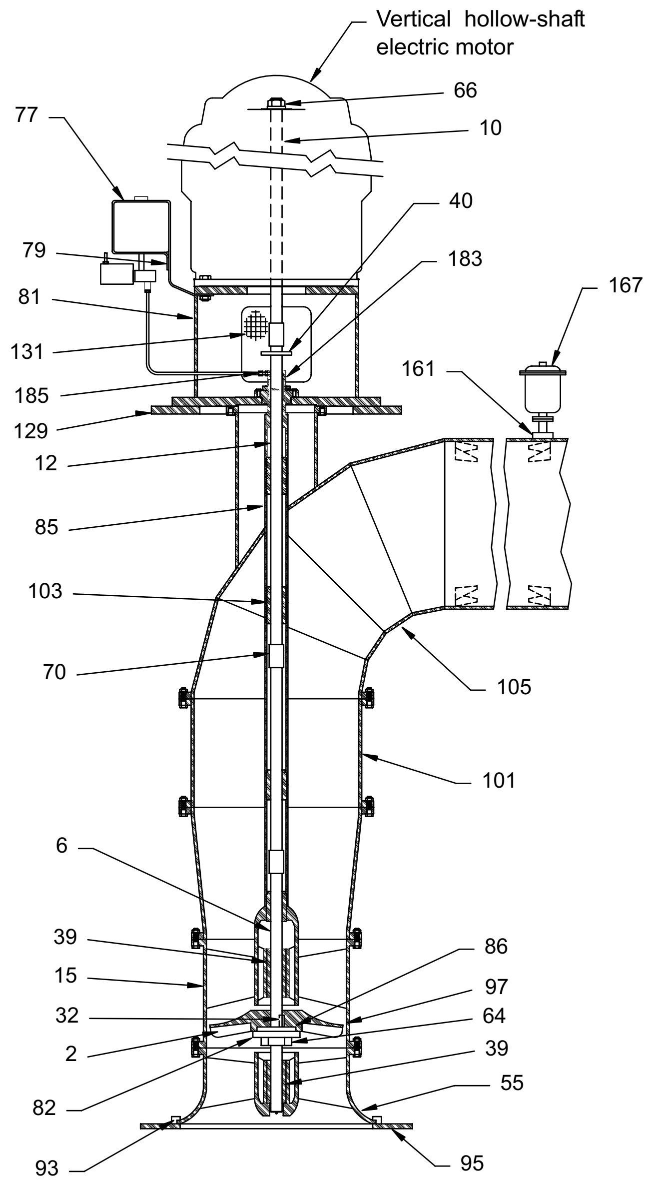


Figure 2.1.3.3c — Vertical double suction, short setting, open line shaft (VS2)



2 Impeller
6 Shaft, pump
10 Shaft, head
12 Shaft, line
15 Bowl, discharge
32 Key, impeller
39 Bearing, sleeve
40 Deflector
55 Bell, section
64 Collar, protecting
66 Nut, shaft adjusting
70 Coupling, shaft
77 Lubricator
79 Bracket, lubricator
81 Pedestal, driver
82 Ring, thrust, retainer
85 Tube, shaft-enclosing
86 Ring, thrust, split
93 Clamp, umbrella (optional)
95 Umbrella, suction (optional)
97 Liner, bowl
101 Pipe, column
103 Bearing, line shaft, enclosed
105 Elbow, discharge
129 Sole plate
131 Guard, coupling
161 Fitting, discharge
167 Valve, air and vacuum release (optional)
183 Nut, tubing
185 Plate, tension, tube

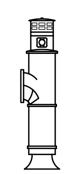
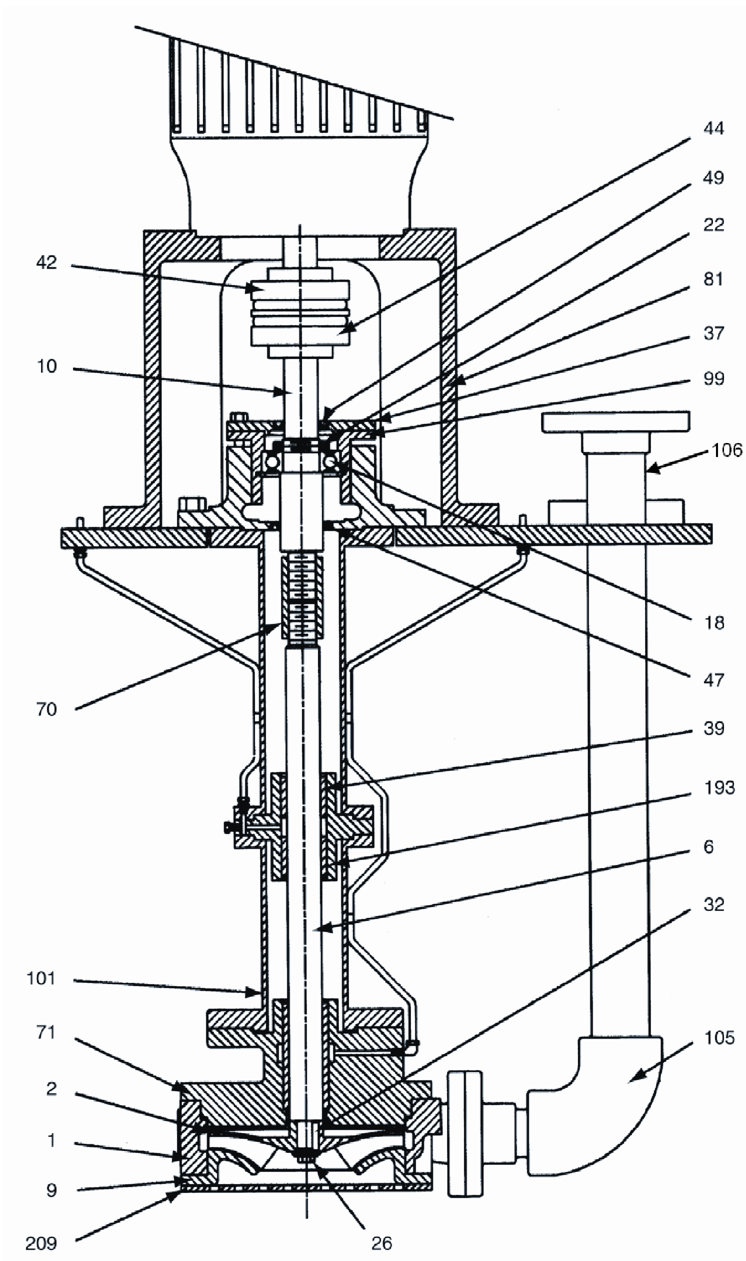


Figure 2.1.3.3d — Vertical, axial flow impeller (propeller) type (enclosed line shaft) below-floor discharge configuration (VS3)

2.1.3.4 Separate discharge sump pump (line shaft [VS4] and cantilever [VS5])

This type of vertical pump (Figures 2.1.3.4a and b) is suspended from a mounting plate into a vessel or sump. The pumping element is submerged in the pumped liquid and the pump is typically on-off controlled by the level in the sump or vessel. The pump is centrifugal, single stage, end suction with separate discharge pipe and support pipe column. The line-shaft design has bushings that are lubricated by a source other than the process. The cantilever design is overhung with no bushings below the mounting plate, but has a throttle bushing located behind the impeller to limit leakage. Above the mounting plate the shaft is supported by antifriction bearings and there is a bearing housing or drive pedestal that the pump shaft extends into or through. The driver can be directly coupled to the line shaft or through a belt assembly. Axial thrust is absorbed by the driver thrust bearing or an antifriction line-shaft bearing located above the mounting plate.



1	Casing
2	Impeller
6	Shaft, pump
9	Cover, suction
10	Shaft, head
18	Bearing, outboard
22	Locknut, bearing
32	Key, impeller
37	Cover, bearing, outboard
39	Bearing, sleeve
42	Coupling half, driver
44	Coupling half, pump
47	Seal bearing cover, inboard
49	Seal bearing cover, outboard
70	Coupling, shaft
71	Adapter
81	Pedestal, driver
99	Housing, bearing
101	Pipe, column
105	Elbow, discharge
106	Pipe, discharge
193	Retainer, bearing, open line shaft
209	Strainer

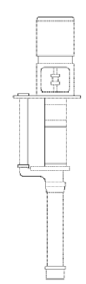
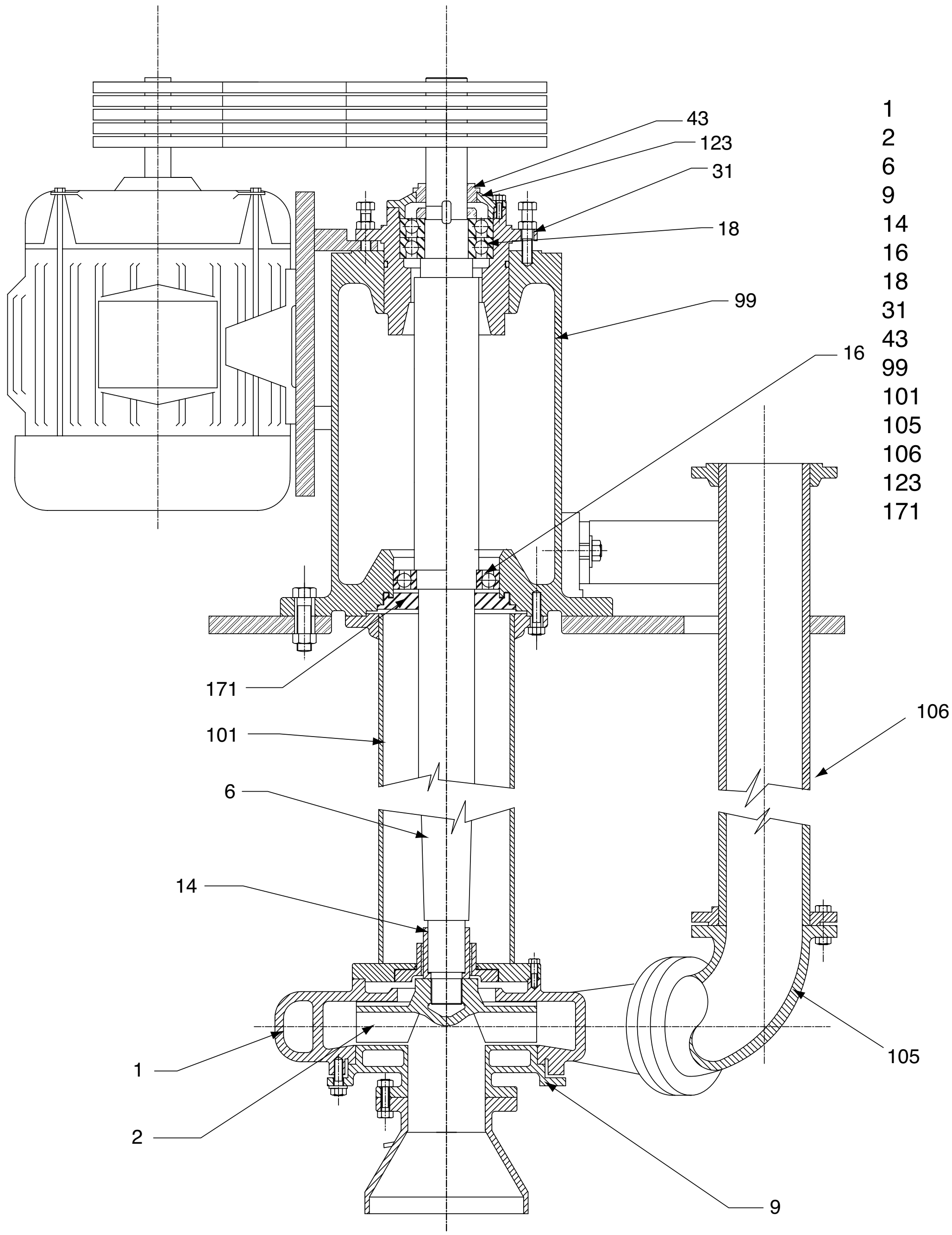


Figure 2.1.3.4a — Line-shaft design sump pump (VS4)



1 Casing
2 Impeller
6 Shaft, pump
9 Cover, suction
14 Sleeve, shaft
16 Bearing, inboard
18 Bearing, outboard
31 Housing, bearing, inboard
43 Cap, bearing, outboard
99 Housing, bearing
101 Pipe, column
105 Elbow, discharge
106 Pipe, discharge
123 Cover, bearing end
171 Bushing, throttle, auxiliary

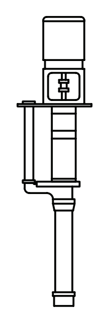


Figure 2.1.3.4b — Cantilever shaft design sump pump (VS5)

2.1.3.5 Barrel or can (line shaft)

This type of pump is mounted in an enclosed container (barrel or can) and typically is used in booster applications where inadequate suction pressure conditions exist, or where the upstream flow under pressure or vacuum must be conveyed to the pumping unit. The can pump contains the same pumping elements and column pipe as the wet pit type pumps (see Figures 2.1.3.5a and b). The line-shaft bearing assembly is usually product-lubricated. The discharge head performs the same functions as the wet pit head except the base is sealed to atmosphere. Liquids other than water are commonly pumped by this type of pump. This type of pump is very effective where inadequate system net positive suction head (NPSH) is available. Additional NPSH is created by extending the pump can length and lowering the bowl assembly by lengthening the column assembly to create additional submergence (suction head). In applications with limited floor space, and where high developed pressure is required, the vertical, multistage volute arrangement shown in Figure 2.1.3.5c may be used. This type of pump is typically assembled by the manufacturer and shipped assembled. There is some variance in maximum length able to be accommodated by common domestic and international commercial shipping methods; however, this length is typically about 12 m (40 ft).

2.1.3.6 Radial multistage in-line pump

In this type pump (see Figure 2.1.3.6) the fluid enters one nozzle of the in-line casing and is directed to the inlet of an internal multistage diffuser pump. After traveling through multiple stages, the liquid exits at the top stage of the pump where the flow is redirected via the outer sleeve to the opposing nozzle of the in-line casing. Note that this pump is sometimes mounted horizontally for special installation requirements, yet the fluid flows through the pump in the same manner described. Axial thrust loads are transmitted to the thrust bearing, which is usually located in the driver or optional housing supplied as an integral part of the pump assembly. This pump is typically floor mounted but contains a vertically suspended rotor element.

2.1.4 Classification by configuration

Listed below are the general configurations that describe vertically suspended pumps.

2.1.4.1 Discharge, above- and below-floor discharge

Vertical pump bowls discharge the pumped liquid into a column, which takes it to the discharge.

There are two basic types of pump discharge configurations. Pumps with above-floor discharge (see Figure 2.1.3.3b) and pumps with below-floor discharge (see Figure 2.1.3.3d). The driver is mounted above the floor in both.

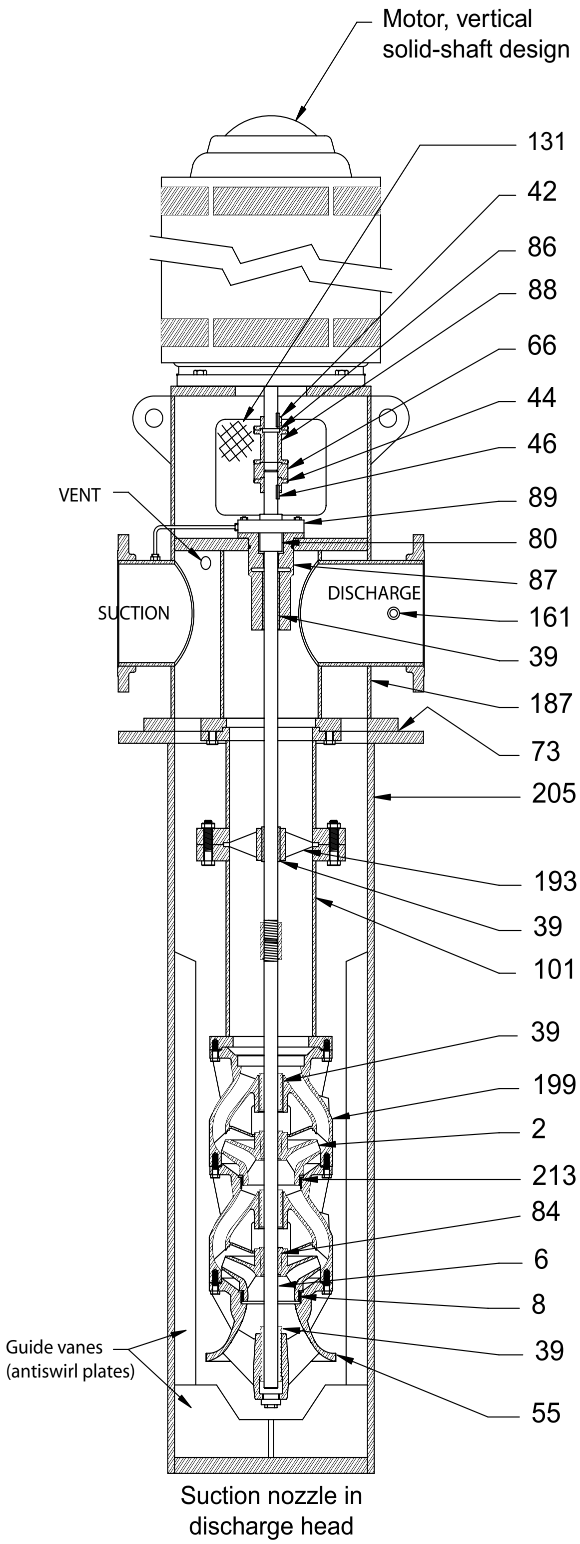
2.1.4.2 Drivers

2.1.4.2.1 Solid-shaft driver

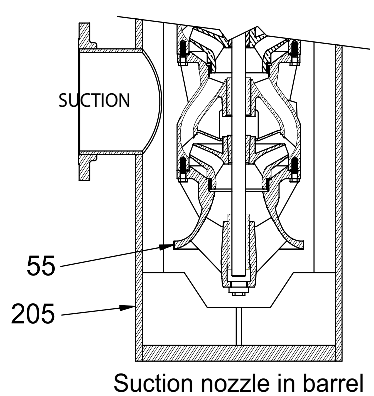
The solid-shaft driver (see Figures 2.1.3.3a, 2.1.3.3b, 2.1.3.3c, 2.1.3.5a, 2.1.3.5b, 2.1.3.5c, and 2.1.3.6) is coupled to the line shaft by an axially adjustable rigid coupling. The coupling is installed below the driver on the extended driver shaft.

2.1.4.2.2 Hollow-shaft driver

The hollow-shaft driver has a tubular shaft extending through the rotor of the driver. The pump head shaft extends through the tubular driver shaft (see Figures 2.1.3.2 and 2.1.3.3d). An assembly at the top of the motor allows adjustment of the pump shaft to lift the rotating pump assembly to provide running clearance and accommodate shaft stretch. A line-shaft coupling located in the pump discharge head is not necessarily required.



2	Impeller
6	Shaft, pump
8	Ring, impeller
39	Bearing, sleeve
42	Coupling half, driver
44	Coupling half, pump
46	Key, coupling
55	Bell, suction
66	Nut, shaft adjusting
73	Gasket
80	Seal, mechanical, rotating element
84	Collet, impeller lock
86	Ring, thrust, split
87	Seal chamber
88	Spacer, coupling
89	Seal, mechanical
101	Pipe, column
131	Guard, coupling
161	Fitting, discharge
187	Head, surface discharge
193	Retainer, bearing, open line shaft
199	Bowl, intermediate
205	Barrel or can, suction
213	Ring, bowl



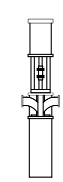
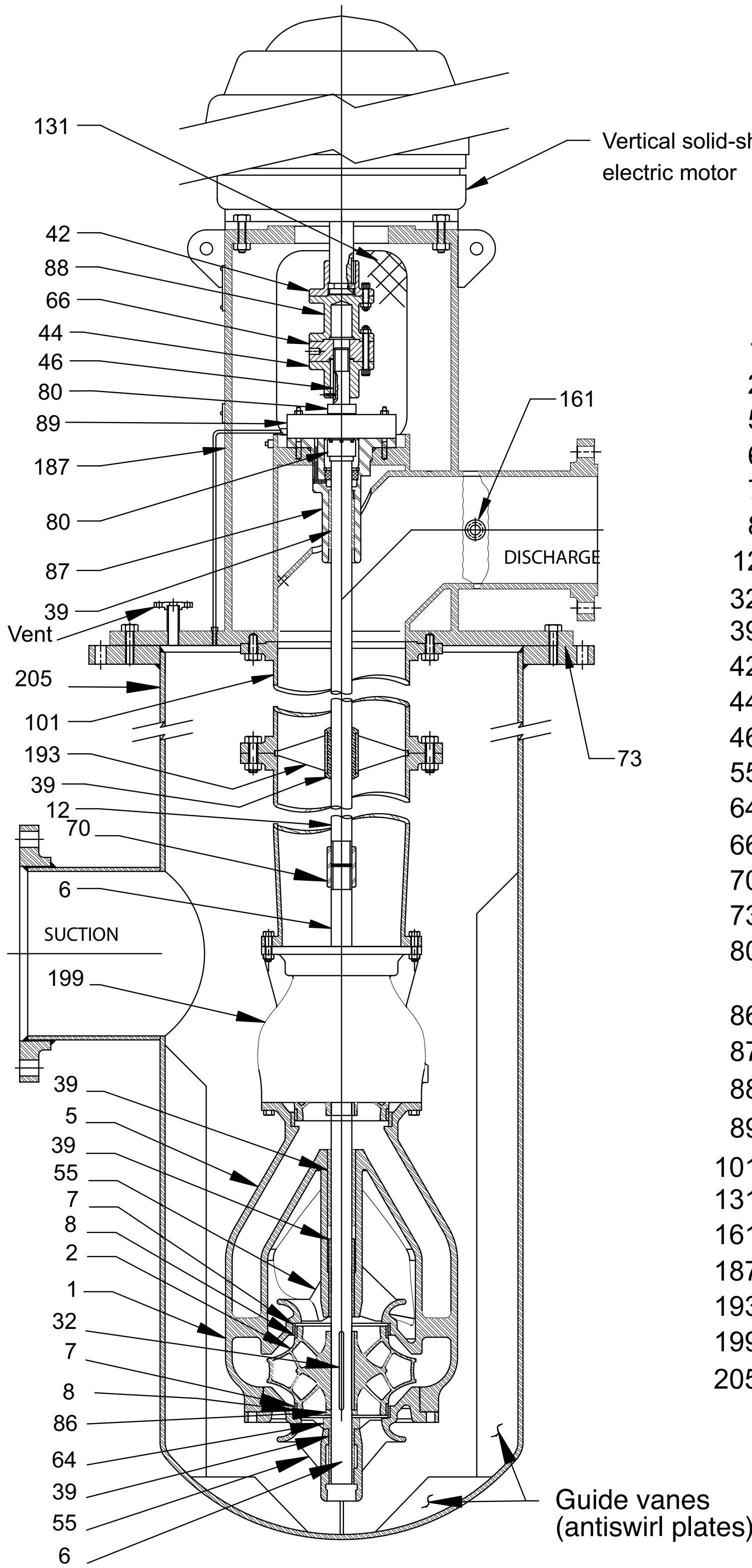


Figure 2.1.3.5a — Vertical, single, or multistage diffuser (double casing) barrel or can pump (VS6)



1	Case, volute
2	Impeller
5	Diffuser, transition
6	Shaft, pump
7	Ring, bell wearing
8	Ring, impeller
12	Shaft, line
32	Key, impeller
39	Bearing, sleeve
42	Coupling half, driver
44	Coupling half, pump
46	Key, coupling
55	Bell, suction
64	Collar, sand
66	Nut, shaft adjusting
70	Coupling, shaft
73	Gasket
80	Seal, mechanical, rotating element
86	Ring, thrust, split
87	Seal chamber
88	Spacer, coupling
89	Seal, mechanical
101	Pipe, column
131	Guard, coupling
161	Fitting, discharge
187	Head, surface discharge
193	Retainer, bearing
199	Bowl, intermediate (optional)
205	Barrel or can, suction

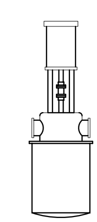
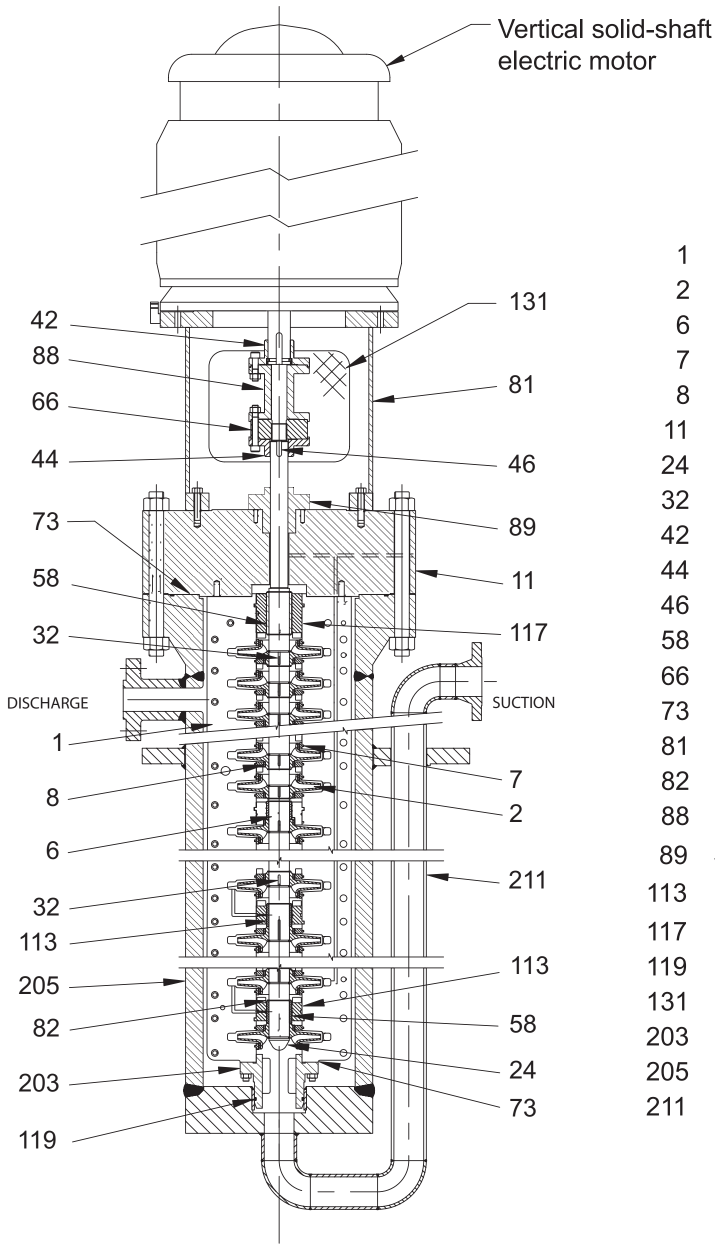


Figure 2.1.3.5b — Vertical double suction, single or multistage barrel or can pump (VS7)



1	Case, volute
2	Impeller
6	Shaft, pump
7	Ring, casing
8	Ring, impeller
11	Cover, seal chamber
24	Nut, impeller
32	Key, impeller
42	Coupling half, driver
44	Coupling half, pump
46	Key, coupling
58	Sleeve, interstage
66	Nut, shaft adjusting
73	Gasket
81	Pedestal, driver
82	Ring, thrust, retainer
88	Spacer, coupling
89	Seal, mechanical
113	Bushing, interstage
117	Bushing, pressure reducing
119	O-ring
131	Guard, coupling
203	Case, suction
205	Barrel or can, suction
211	Pipe, suction

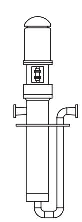
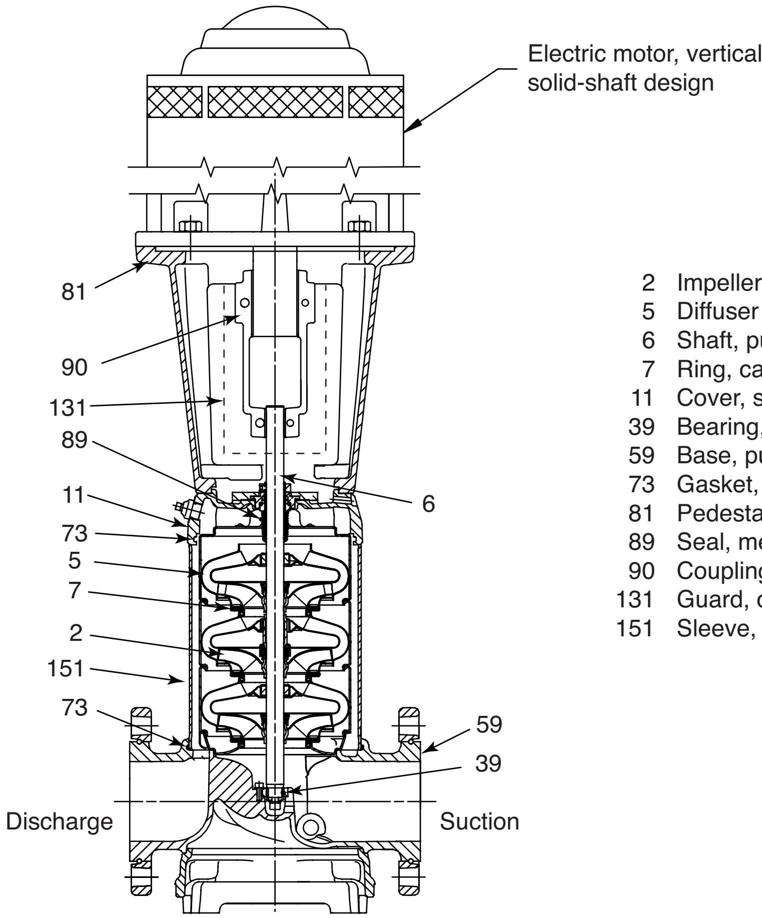


Figure 2.1.3.5c — Vertical, multistage volute (double casing) barrel or can pump (VS7a)



2 Impeller
5 Diffuser
6 Shaft, pump
7 Ring, casing
11 Cover, seal chamber
39 Bearing, sleeve
59 Base, pump suction/discharge
73 Gasket, O-ring
81 Pedestal, driver
89 Seal, mechanical
90 Coupling, split
131 Guard, coupling
151 Sleeve, outer

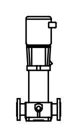


Figure 2.1.3.6 — Vertical in-line casing diffuser pump (VS8)

2.1.4.3 Open/enclosed line shaft

With open line-shaft pumps (see Figures 2.1.3.2-i, 2.1.3.3a, 2.1.3.3b, 2.1.3.3c, 2.1.3.5a, and 2.1.3.5b), the pump shafting is exposed to the pumped liquid, which also cools and lubricates the line-shaft bearings.

Enclosed line-shaft pumps (see Figure 2.1.3.2-ii and 2.1.3.3d) have the line shaft protected from the pumped liquid by the shaft enclosing tube. The line-shaft bearings may be lubricated by fresh water, oil, or some other liquid injected into the enclosing tube at the ground or floor level.

2.1.4.4 Impeller types

A typical semi-open impeller (see Figure 2.1.4.4-i and ii) has a back shroud, with integral impeller vanes, but the vanes are open to the front (no front shroud). The leakage control is adjustable between the impeller vanes and bowl or bowl liner. This is achieved by positioning the impeller shaft axially for close impeller vane-to-bowl clearance. The enclosed impeller, single and double suction (see Figure 2.1.4.4-iii, iv, and v), has both a back shroud and a front shroud. Leakage control is limited by the ring clearance. An axial flow impeller (see Figure 2.1.4.4-vi) has a single inlet with the flow entering and discharging axially (or nearly axially). Impellers of this type are sometimes called *propellers* and do not have shrouds.

2.1.5 Classification by impeller design

2.1.5.1 Specific speed (n_s), type number (K), and suction specific speed (S)

Advisory note: The user is cautioned to check carefully the basis of calculation of specific speed and suction specific speed before making comparisons because there are subtle but significant differences in methods used throughout industry and in related textbooks and literature.

Preferred terms, units, and symbols to be used in the technology of pump applications are shown in Table 2.2a.

US customary units

When calculating the value for specific speed and suction specific speed, the unit of measurement used for rate of flow is defined in US gallons per minute (gpm).

Metric units

When calculating the value for specific speed and suction specific speed, the unit of measurement used within this standard for rate of flow is cubic meters per second (m^3/s).

(An alternative method of calculating this value is to use cubic meters per hour [m^3/h] as the unit of measurement for rate of flow, which then results in a value that is $3600^{0.5}$, i.e., 60 times greater.)

Specific speed: An index of pump performance (developed total head) at the pump's best efficiency point (BEP) rate of flow, with the maximum diameter impeller, and at a given rotative speed. Specific speed is expressed by the following equation:

$$n_s = \frac{n(Q)^{0.5}}{(H)^{0.75}}$$

Where:

n_s = specific speed

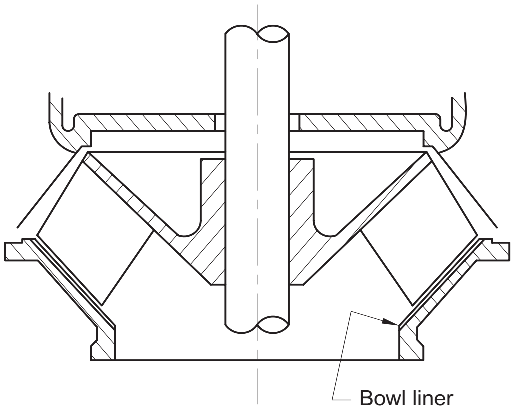
n = rotative speed, in revolutions per minute

Q = total pump flow rate, in cubic meters per second (US gallons per minute)

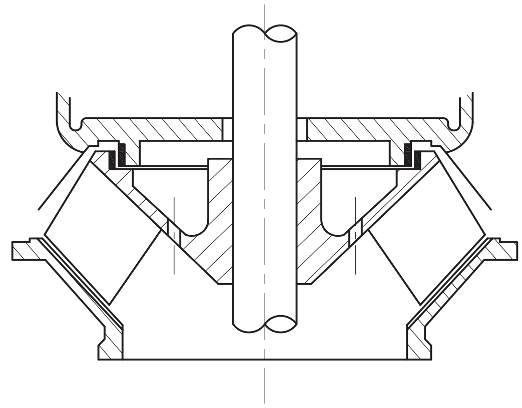
H = head per stage (measured at the bowl), in meters (feet)

NOTE: Specific speed derived using cubic meters per second and meters, multiplied by a factor 51.64, is equal to specific speed derived using US gallons per minute and feet.

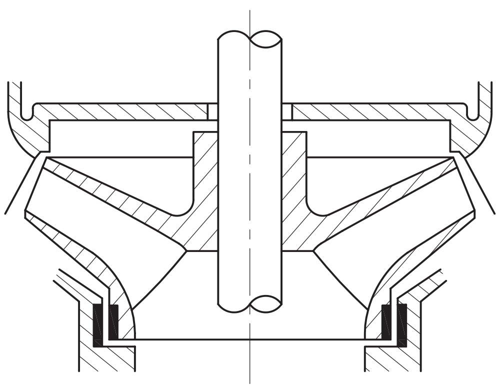
The usual symbol for specific speed in US customary units is N_s.



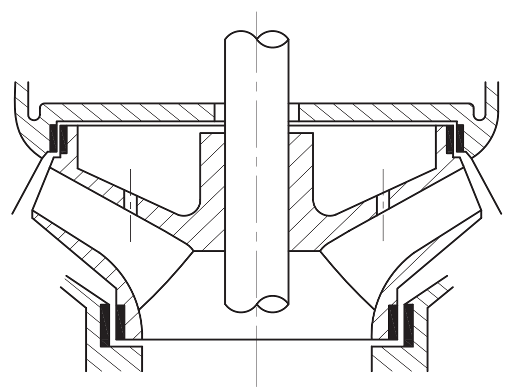
(i) Semi-open impeller
No rings



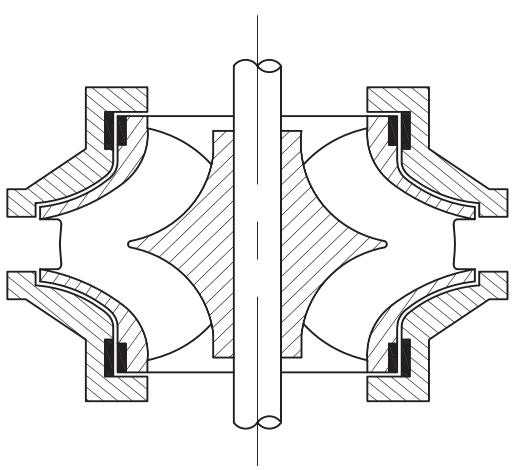
(ii) Semi-open impeller
Top rings - thrust balance type



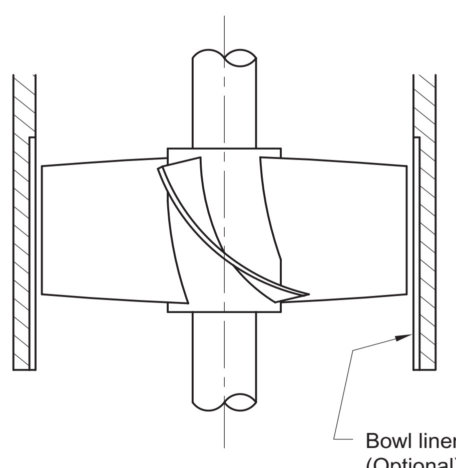
(iii) Enclosed impeller
Bottom ring only



(iv) Enclosed impeller
Top and bottom rings
thrust balance type



(v) Dual suction impeller
Top and bottom rings



(vi) Propeller

Figure 2.1.4.4 — Typical vertical pump impeller types with rings (casing and/or impeller)

An alternative definition for specific speed is sometimes used based on flow rate per impeller eye, rather than total flow rate. In a double suction impeller pump, when this alternative method is used, the resultant value of specific speed is less by a multiplying factor of 0.707.

Type number: A variation of specific speed is type number. A dimensionless quantity calculated at the point of best efficiency, which is defined by the following formula:

$$K = \frac{2\pi n Q'^{0.5}}{(gH')^{0.75}} = \frac{\omega Q'^{0.5}}{(y')^{0.75}}$$

Where:

Q' = volume rate of flow per eye, in cubic meters per second (US gallons per minute)

H' = head of the first stage, in meters (feet)

n = rotative speed, in revolutions per second

ω = angular velocity, in radians per second

y' = specific energy, in joules per kilogram (British thermal unit per pound)

NOTE: To obtain specific speed based on cubic meter per second and meters, multiply by 52.92. To obtain specific speed based on gallon per minute and feet, multiply by 2733.72

Suction specific speed: An index of pump suction operating characteristics determined at the BEP rate of flow with the maximum diameter impeller. (Suction specific speed is an indicator of the net positive suction head [NPSH3] required for given values of capacity and provides an assessment of a pump's susceptibility to internal recirculation.) Suction specific speed is expressed by the following equation:

$$S = \frac{n(Q)^{0.5}}{NPSH3^{0.75}}$$

Where:

S = suction specific speed

n = rotative speed, in revolutions per minute

Q = flow rate per impeller eye, in cubic meters per second (US gallons per minute)

= total flow rate for single suction impellers

= one half total flow rate for double suction impellers

$NPSH3$ = net positive suction head required, in meters (feet) that will cause the total head (or first-stage head of multistage pumps) to be reduced by 3%

NOTE: Suction specific speed derived using cubic meters per second and meters, multiplied by a factor of 51.64, is equal to suction specific speed derived using US gallons per minute and feet. The US customary symbol N_{ss} is sometimes used to designate suction specific speed.

The value S is an assessment of a pump's inlet design, including both the stationary casing and the rotating impeller design elements. Higher numerical values of S are associated with better NPSH capabilities. For pumps of typical suction inlet design, values range from approximately 120 to 250 (6000 to 13,000). In special designs, including inducers, values up to 700 (35,000) or higher are possible depending on the connected inlet piping, the pump's suction casing arrangement, the range of flow over which the pump must operate, size and power rating of the machine, and other considerations.

2.1.5.2 Radial flow

Pumps with this type of impeller have specific speed values at the lower end of the scale. (See Figure 2.1.5.5b, impeller profiles 1 and 2, for approximate specific speed ranges.) The liquid enters the eye of the impeller axially and is turned by the impeller vanes and shroud to exit perpendicular to the axis of the pump shaft.

2.1.5.3 Francis vane (modified radial flow)

This type of impeller usually has higher specific speeds than the radial flow type. (See Figure 2.1.5.5b, impeller profiles 3 and 4, for approximate specific speed ranges.) The impellers are normally single suction. In pumps of this type, the liquid enters the eye of the impeller axially and exits semiradially, at about a 60° to 70° angle to the shaft axis (see Figure 2.1.5.5b).

2.1.5.4 Mixed flow

The mixed flow pump has a single inlet impeller with the flow entering axially and discharging about 45° with shaft axis, to the periphery. In many cases, this style impeller has no front shroud. (For mixed flow impeller configuration, see profile 5 in Figure 2.1.5.5b with corresponding specific speed ranges.)

2.1.5.5 Axial flow

An axial flow impeller has a single inlet with the flow entering and discharging axially (or nearly axially). Impellers of this type are sometimes called *propellers* and do not have shrouds. Axial flow impellers are typically used for low-head, single-stage applications. (See Figure 2.1.5.5b for impeller profiles and for approximate specific speed ranges.)

2.1.6 General information

2.1.6.1 Duplicate performance pump

A duplicate pump is one in which the performance characteristics are the same as another pump, within the variations permitted by the Test Standards (ANSI/HI 14.6), and parts are of the same type; but by reason of improved design and/or materials, mounting dimensions and parts are not necessarily interchangeable.

2.1.6.2 Dimensionally interchangeable pump

An interchangeable pump is one in which the mounting dimensions are such that the replacement pump can be mounted on the existing foundation and match existing piping and driver, with hydraulic characteristics and materials to be specified. Interchangeability may involve some variation, not necessarily significant, as a result of manufacturing tolerances.

2.1.6.3 Identical performance and dimensional pump

An identical pump is a replica of, and is interchangeable with, a specific pump. Where it is intended that a pump is to be identical in all respects, including parts, mountings, connecting flange dimensions, and materials, it should be identified as identical with pump serial number XXXXXX. An identical pump will replicate the original pump as closely as the manufacturing tolerances allow.

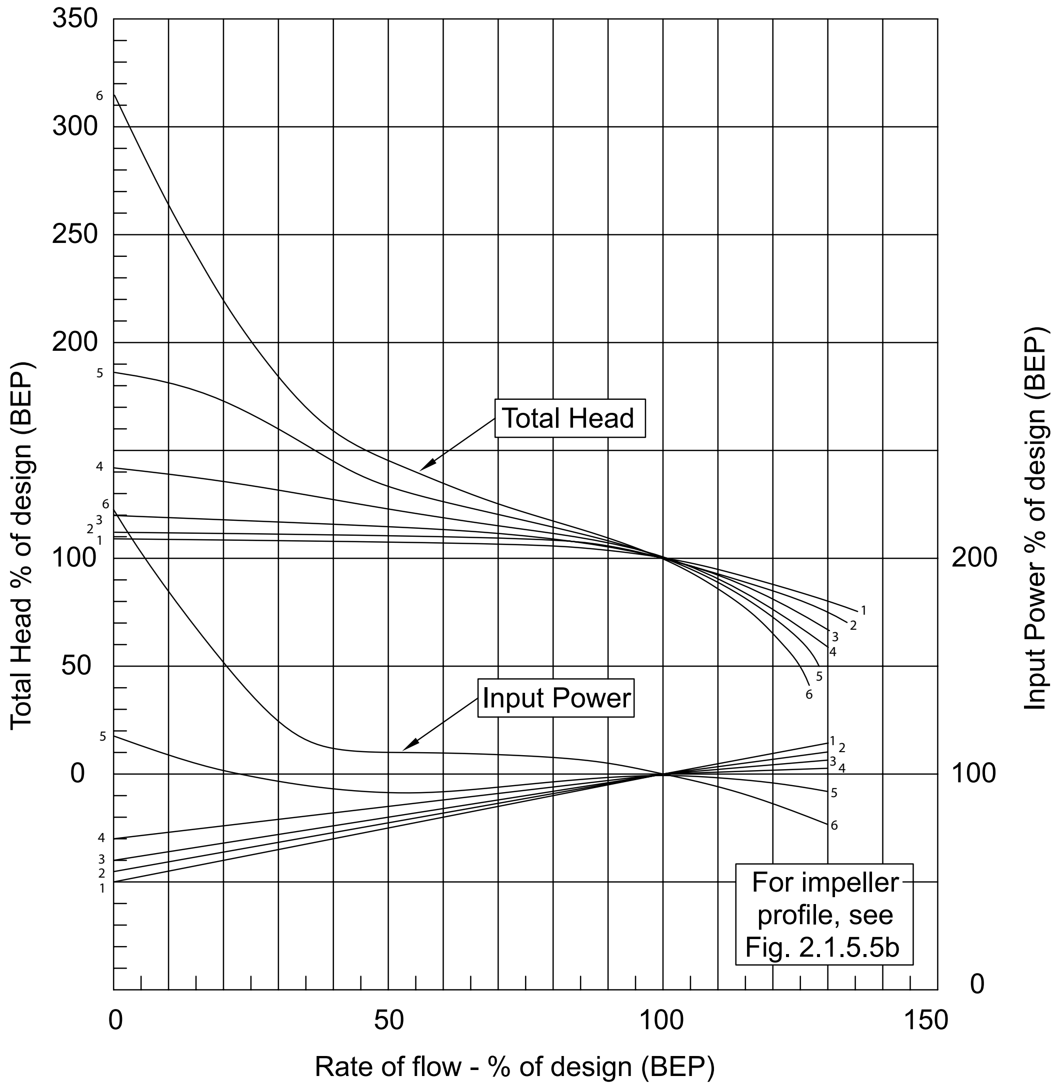


Figure 2.1.5.5a — General vertical pump characteristic curves

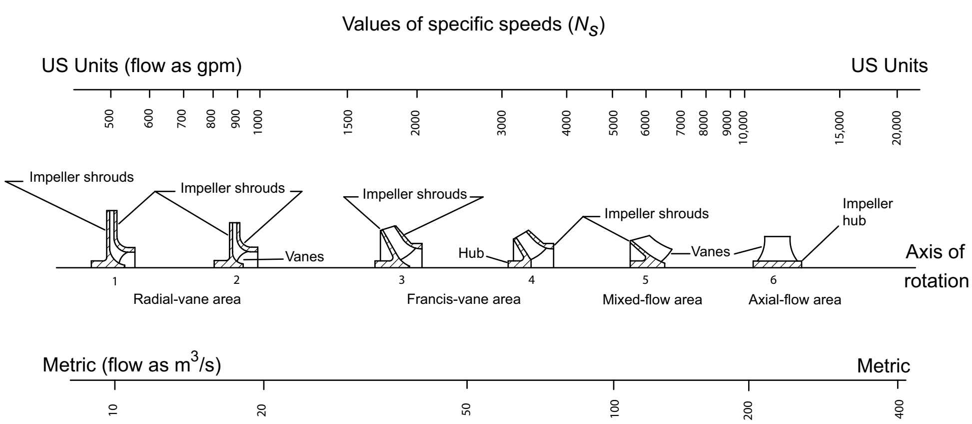


Figure 2.1.5.5b — General vertical pump impeller configuration and specific speeds

2.1.6.4 Rotation

Pump shaft rotation is determined as viewed from the driver end of the pump. Left-hand threaded line-shaft joints will tighten when driven by a counterclockwise (CCW) driver. Right-hand threaded joints will tighten when driven by a clockwise (CW) driver.

2.1.6.5 Construction

The cross-sectional drawings throughout this standard illustrate commonly used parts in their proper relationship and a few typical construction modifications but do not necessarily represent recommended design.

The figure numbers shown in Table 2.1.6.5 are for convenient cross-reference between tabulated names of parts and cross-sectional representation of standard part numbers in use by any manufacturer.

Table 2.1.6.5 — Alphabetical part name listing

Part Name	Number	Abbreviation	Definition
Adapter	71	Adpt	A machined piece used to permit assembly of two other parts or for a spacer.
Barrel or can, suction	205	Bl/can suct	A receptacle for conveying the liquid to the pump.
Base, pump suction/ discharge	59	Base, pump suction/ discharge	Component directing flow to and from the multistage pump through in-line nozzles. Component also acts as the pump mounting base.
Baseplate	23	Base Pl	A metal member on which the pump and its driver are mounted.
Bearing, inboard	16	Brg inbd	The bearing nearest the coupling of a between-bearing pump but farthest from the coupling of an end suction pump.
Bearing, line-shaft enclosed	103	Brg linesht encl	A bearing that also serves to couple portions of the shaft enclosing tube.
Bearing, outboard	18	Brg outbd	The bearing most distant from the coupling of a between-bearing pump but nearest to the coupling of an end suction pump.
Bearing, sleeve	39	Brg slv	A replaceable, cylindrical bearing secured within a stationary member.
Bearing, throttle	102	Brg thl	A replaceable, cylindrical bearing used to reduce pressure and keep water from entering the tube line.
Bell, suction	55	Bel suct	A flared tubular section for directing the flow of liquid into the pump.
Bowl, discharge	15	Bowl disch	A diffuser of an axial flow or mixed flow or turbine pump.
Bowl, intermediate	199	Bowl intmd	An enclosure within which the impeller rotates and which serves as a guide for the flow from one impeller to the next.
Bracket, lubricator	79	Bkt lubr	A means of attaching the lubricator to the pumping unit.

Table 2.1.6.5 — Alphabetical part name listing (*continued*)

Part Name	Number	Abbreviation	Definition
Bushing interstage	113	Bush, instg	A tubular-shaped replaceable piece mounted between stages.
Bushing, pressure reducing	117	Bush press red	A replaceable piece used to reduce the liquid pressure at the stuffing box by throttling the flow.
Bushing, stuffing box	63	Bush stfg box	A replaceable bushing placed in the end of the stuffing box opposite the gland.
Bushing, throttle, auxiliary	171	Bush throt aux	A stationary ring or sleeve placed in the gland of a mechanical seal subassembly to restrict leakage in the event of seal failure.
Cap, bearing, outboard	43	Cap, brg outbd	The removable upper portion of the outboard bearing housing.
Case, discharge	197	Case disch	A guide for liquid flow from bowl to pump column.
Case, suction	203	Case suct	A device used to receive the liquid and guide it to the first impeller.
Casing	1	Casing	A discharge housing to enclose the radial diffusers and impellers.
Clamp, umbrella	93	Clp umbla	A fastening used to attach the suction umbrella to suction bowl.
Collar, protecting	64	Clr protg	A rotating member for preventing the entrance of contaminating material to bearings of a vertical pump.
Collar, shaft	68	Clr sft	A ring used on a shaft to establish a shoulder.
Collet, impeller lock	84	Cllt imp lock	A tapered split sleeve used to secure the impeller to the pump shaft.
Coupling, column pipe	191	Cplg col pipe	A threaded sleeve used to couple sections of column pipe.
Coupling half, driver	42	Cplg half drvr	The coupling half mounted on driver shaft.
Coupling half, pump	44	Cplg half pump	The coupling half mounted on pump shaft.
Coupling, shaft	70	Cplg sft	A mechanism used to transmit power from the line shaft to the pump shaft or to connect two pieces of shaft.
Coupling, split	90	Cplg splt	A two-piece assembly used to transmit power from the drive shaft to the pump shaft or to connect two pieces of shafting.
Cover, bearing end	123	Cov brg end	A plate closing the outboard bearing housing.
Cover, bearing, outboard	37	Cov brg outbd	An enclosing plate for either end of the outboard bearing of a double suction or multistage pump, or for the coupling end of the bearing of an end suction pump.

Table 2.1.6.5 — Alphabetical part name listing (*continued*)

Part Name	Number	Abbreviation	Definition
Cover, stuffing box and seal chamber	11	Cov stfg box Cov seal cham	A removable piece, with stuffing box or seal chamber integral, used to enclose the outboard side of the impeller in the casing of an end suction pump.
Cover, suction	9	Cov suct	A removable piece, with which the inlet nozzle may be integral, used to enclose the suction side of the casing of an end suction pump.
Deflector	40	Defl	A flange or collar mounted on a shaft and rotating with it to prevent passage of liquid, grease, oil, or heat along the shaft.
Diffuser	5	Diff	A piece, adjacent to the impeller exit, which has multiple passages of increasing area for converting velocity to pressure.
Elbow, discharge	105	Ell disch	An elbow in an axial flow, mixed flow, or turbine pump by which the liquid leaves the pump.
Electrical cable, submersible	231	El cab subm	Cable for transmission of electrical power to motor.
Fitting, discharge	161	Ftg disch	Half coupling (threaded/flanged option).
Flange, top column	189	Flg top col	A device used to couple column to discharge head.
Gasket	73	Gskt	Resilient material of proper shape and characteristics for use in joints between parts to prevent leakage.
Gland	17	Gld	A follower that compresses packing in a stuffing box or retains the stationary element of a mechanical seal.
Guard, coupling	131	Grd cplg	A protective shield over a shaft coupling.
Head, surface discharge	187	Hd surf disch	A support for driver and pump column, and a means by which the liquid leaves the pump.
Housing, bearing	99	Hsg brg	A body in which the bearing(s) is mounted.
Housing, bearing, inboard	31	Hsg brg inbd	*See* Bearing (inboard) and Housing, bearing.
Impeller	2	Imp	The bladed member of the rotating assembly of the pump that imparts the principal force to the liquid pumped. Also called a *propeller* for axial flow.
Key, coupling	46	Key cplg	A parallel-sided piece used to transmit torque and to prevent the shaft from turning in a coupling half.
Key, impeller	32	Key imp	A parallel-sided piece used to transmit torque and to prevent the impeller from rotating relative to the shaft.
Liner, bowl	97	Lnr bowl	A replaceable cylindrical piece mounted on the discharge bowl and within which the propeller rotates.

Table 2.1.6.5 — Alphabetical part name listing (*continued*)

Part Name	Number	Abbreviation	Definition
Locknut, bearing	22	Lkbnut brg	A fastener that positions an antifriction bearing on the shaft.
Lubricator	77	Lubr	A device for applying a lubricant to the point of use.
Motor, submersible	230	Mot subm	An electrical motor for submerged-in-liquid operation.
Nut, impeller	24	Nut imp	A threaded piece used to fasten the impeller on the shaft.
Nut, shaft adjusting	66	Nut sft adj	A threaded piece for altering the axial position of the rotating assembly.
Nut, tube	183	Nut tube	A device for sealing and locking the shaft enclosing tube.
O-ring	119	O-ring	A radial or axial type seal.
Packing	13	Pkg	A lubricated material used to control leakage around the portion of the shaft located in the stuffing box.
Pedestal, driver	81	Ped drvr	A metal support for the driver of a vertical pump.
Pipe, column	101	Pipe col	A vertical pipe by which the pumping element is suspended.
Pipe, discharge	106	Pipe, disch	A vertical pipe by which the liquid leaving the discharge elbow is brought to the surface for line-shaft or cantilever shaft sump pump.
Pipe, suction	211	Pipe suct	A device for conveying the liquid to the pump's suction.
Plate, tension, tube	185	Pl tens tube	A device for maintaining tension on the shaft enclosing tube.
Retainer, bearing, open line shaft	193	Ret brg open line sft	A device used to secure bearings when open line shafting is used.
Ring, bowl	213	Ring bowl	A stationary replaceable ring to protect the bowl at the running fit with the impeller ring or the impeller. Commonly referred to as a *wear ring*.
Ring, casing	7	Ring csg	A stationary replaceable ring to protect the casing at the running fit with the impeller ring or the impeller. Commonly referred to as a *wear ring.*
Ring, impeller	8	Ring imp	A replaceable ring mounted on one or both sides of the impeller. Commonly referred to as a *wear ring*.
Ring, lantern	29	Ring ltrn	An annular piece used to establish a liquid seal around the shaft and to lubricate the stuffing-box packing.
Ring, thrust, retainer	82	Ring thr rtnr	A solid ring mounted on a shaft to keep the split thrust ring in place.

Table 2.1.6.5 — Alphabetical part name listing (*continued*)

Part Name	Number	Abbreviation	Definition
Ring, thrust, split	86	Ring thr split	A split ring mounted on a shaft to absorb the unbalanced axial thrust of the impeller in the pump.
Screw, impeller	26	Scr imp	A screw to fasten the impeller to the shaft.
Seal, bearing cover, inboard	47	Seal brg cov inbd	A contact seal for the bearing cover (inboard).
Seal, bearing cover, outboard	49	Seal brg cov outbd	A contact seal for the bearing cover (outboard).
Seal chamber	87	Seal cham	Component that forms the region between the pump shaft and casing into which the shaft seal is installed.
Seal, mechanical	89	Seal mech	A device that prevents the leakage of fluids along rotating shafts.
Seal, mechanical, rotating element	80	Seal mech rot elem	A device flexibly mounted on the shaft in or on the stuffing box and having a smooth, flat seal face held against the stationary sealing face.
Seal, mechanical, stationary element	65	Seal mech sta elem	A stationary, flat seal component on which the rotating seal element runs against. Typically harder than the mating rotating seal face.
Shaft, head	10	Sft hd	The upper shaft in a vertical pump that transmits power from the driver to the drive shaft (sometimes referred to as *shaft, top*).
Shaft, line	12	Sft ln	The shaft that transmits power from the head shaft or driver to the pump shaft.
Sleeve, interstage	58	Slv, instg	A cylindrical piece fitted over the shaft to protect the shaft at the location of an interstage bushing.
Sleeve, outer	151	Slv outer	A cylindrical piece forming the outer portion of the pump.
Sleeve, shaft	14	Slv sft	A cylindrical piece fitted over the shaft to protect the shaft through the stuffing box, or seal chamber, and the line-shaft bearings.
Shaft, pump	6	Sft pump	The shaft on which the impeller is mounted and through which power is transmitted to the impeller.
Shroud, flow	251	Shrd flo	A pipe to direct flow to pump over submersible motor surface for motor cooling.
Sole plate	129	Sole pl	A metallic pad, usually imbedded in concrete, on which the pump base is mounted.
Spacer, coupling	88	Spcr cplg	A cylindrical piece used to provide axial space for the removal of the mechanical seal without removing the driver.
Strainer	209	Str	A device used to prevent large objects from entering the pump.

Table 2.1.6.5 — Alphabetical part name listing (*continued*)

Part Name	Number	Abbreviation	Definition
Stuffing box	83	Stfg box	A portion of the casing, casing cover, or surface discharge head, through which the shaft extends and in which packing and a gland is placed to control leakage.
Tube, shaft enclosing	85	Tube sft encl	A cylinder used to protect the drive shaft, supply lubricating fluid, and provide a means for mounting bearings.
Umbrella, suction	95	Umbla suct	A formed piece attached to the suction bowl to reduce disturbance at pump inlet and reduce submergence required.
Valve, air and vacuum relief	167	Val air vac rel	A means of releasing air during start-up and releasing vacuum during shut-down.
Valve, column check	215	Val col chk	To prevent liquid backflow. Keep column filled to reduce pump upthrust on start-up.

2.1.6.6 Pump length

2.1.6.6.1 Total pump length

The total pump length is the distance measured from the lowest point of the pump assembly, including any accessories, such as a suction strainer, to the mounting surface of the surface discharge head. This length is commonly used for wet pit or short set line-shaft pumps. See Figure 2.1.6.6.1.

2.1.6.6.2 Pump setting

The pump setting is the length of column pipe used between the pump assembly and the surface discharge head. This length is commonly used for deep-well pumps.

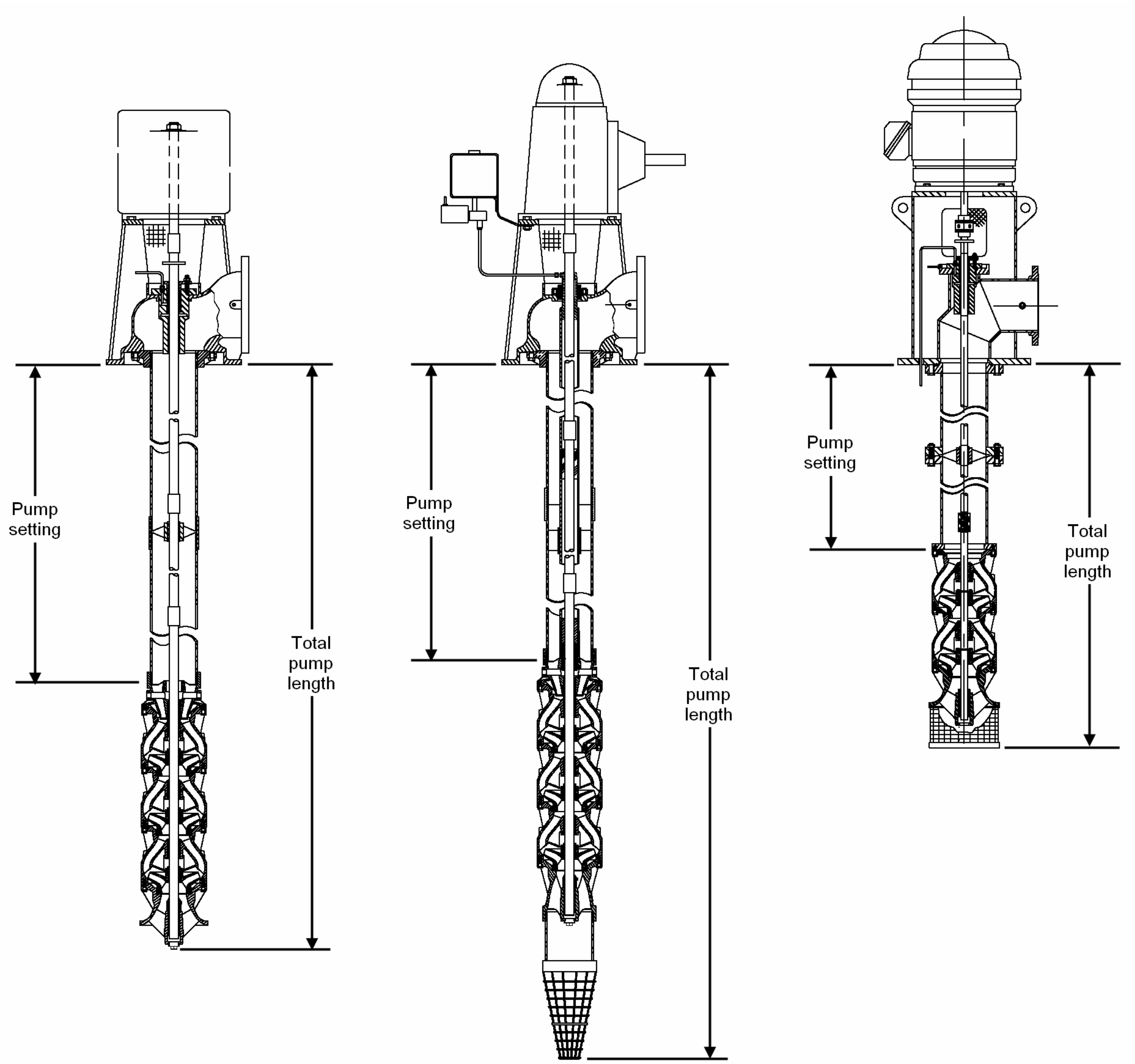


Figure 2.1.6.6.1 — Pump length

2.2 Definitions, terminology, and symbols

The purpose of this section is to define terms used in pump applications. Symbols, terms, and units are shown in Table 2.2a and subscripts in Table 2.2b.

Table 2.2a — Principal symbols

Symbol	Term	Metric unit	Abbr.	US customary unit	Abbr.	Conversion factor[a]
A	Area	square millimeter	mm^2	square inch	in^2	645.2
bar	Pressure	bar	bar	pound/square inch	psi	0.0689
BEP	Best efficiency point	cubic meter/hour	m^3/h	US gallon/minute	gpm	0.2271
D	Diameter	millimeter	mm	inch	in	25.4
δ (delta)	Deflection	millimeter	mm	inch	in	25.4
Δ (delta)	Difference	dimensionless[b]	-	dimensionless[b]	-	-
η (eta)	Efficiency	percent	%	percent	%	1
F	Force	newton	N	pounds (force)	lbf	4.448
g	Gravitational acceleration	meter/second squared	m/s^2	foot/second squared	ft/s^2	0.3048
h	Head	meter	m	foot	ft	0.3048
H	Total head	meter	m	foot	ft	0.3048
K	Type number	dimensionless	-	dimensionless	-	1
l	Static lift	meter	m	foot	ft	0.3048
n	Speed	revolution/minute	rpm	revolution/minute	rpm	1
NPSHA	Net positive suction head available	meter	m	foot	ft	0.3048
NPSHR	Net positive suction head required	meter	m	foot	ft	0.3048
NPSH3	Net positive suction head required for a 3% reduction in total head at first stage	meter	m	foot	ft	0.3048
n_s (N_s)	Specific speed	Index number	-	Index number	-	0.0194

Table 2.2a — Principal symbols (*continued*)

Symbol	Term	Metric unit	Abbr.	US customary unit	Abbr.	Conversion factor[a]
ν (nu)	Kinematic viscosity	millimeter squared/second	mm^2/s	foot squared/ second	ft^2/s	92,903
ω (omega)	Angular velocity	radians/second	rad/s			
π	pi = 3.1416	dimensionless	-	dimensionless	-	1
p	Pressure	kilopascal	kPa	pound/square inch	psi	6.895
P	Power	kilowatt	kW	horsepower	hp	0.7457
Q	Rate of flow (Capacity)	cubic meter/second	m^3/s	US gallon/minute	gpm	0.0000631
Q	Rate of flow (Capacity)	cubic meter/hour	m^3/h	US gallon/minute	gpm	0.2271
ρ (rho)	Density	kilogram/cubic meter	kg/m^3	pound mass/cubic foot	lbm/ft^3	16.02
S (N_{SS})	Suction specific speed	Index number	-	Index number	-	0.0194
s	Specific gravity	dimensionless	-	dimensionless	-	1
t	Temperature	degree Celsius	°C	degree Fahrenheit	°F	9/5 ×°C + 32
U	Residual unbalance	gram-millimeter	g-mm	ounce-inch	oz-in	720
v	Velocity	meter/second	m/s	foot/second	ft/s	0.3048
y	Specific energy	joule/kilogram	J/kg	British thermal unit/pound	Btu/lb	2326
Z	Elevation gauge distance above or below datum	meter	m	foot	ft	0.3048

[a] Conversion factor × US customary units = metric units.

[b] Δ is a dimensionless symbol used to indicate a difference. This term takes on the units of the measured or calculated quantity associated with the difference.

Table 2.2b — Subscripts

Subscript	Term	Subscript	Term
1	Test condition or model	mot	Motor
2	Specific condition or prototype	N	Normal
a	Absolute	OA	Overall unit
all	Allowable	op	Operating pressure
atm	Atmospheric	opt	Optimum
b	Barometric	ot	Operating temperature
ba	Bowl assembly	p	Pump
d	Discharge	r	Rated
dvr	Driver	s	Suction
f	Friction	stat	Static
G	Guaranteed point	t	Theoretical
g	Gauge	t,x	Total, at observed point
gr	Combined motor/pump (overall)	v	Velocity
im	Intermediate mechanism	vp	Vapor pressure
max	Maximum	w	Water
min	Minimum		

2.2.1 Rate of flow (capacity) (Q or q) [Q]

The rate of flow of a pump is the total volume throughput per unit of time at suction conditions. It includes both liquid and any dissolved or entrained gases at the stated operating conditions. Capacity is also used to define this unit of measure.

2.2.1.1 BEP rate of flow [Q_{opt}]

The rate of flow, with the defined pump's maximum impeller diameter, at which the pump efficiency is maximized.

2.2.1.2 Minimum continuous stable flow [$Q_{min\ all\ stable}$]

The lowest rate of flow at which the pump operates without a significant compromise to its mechanical integrity, i.e., within acceptable vibration, noise, and reliability expectations.

2.2.1.3 Minimum continuous thermal flow [$Q_{min\ thermal}$]

The lowest rate of flow at which the pump operates without an adverse performance impact resulting from a temperature rise in the pumped liquid.

2.2.1.4 Maximum allowable flow [$Q_{max\ all}$]

As allowed by the pump manufacturer, the greatest rate of flow at which the pump can be expected to operate continuously without risk of internal damage and as defined by operating speed and specific pumped liquid.

2.2.2 Speed (n)

The number of revolutions of the shaft in a given unit of time. Speed is typically expressed as revolutions per minute.

2.2.2.1 Maximum allowable continuous speed [$n_{max\ all}$]

The highest pump speed at which the manufacturer permits continuous operation.

2.2.2.2 Minimum allowable continuous speed [$n_{min\ all}$]

The lowest pump speed at which the manufacturer permits continuous operation.

2.2.2.3 Rated speed [n_r]

The pump operating speed directly associated with the contractual conditions of service.

2.2.3 Head (h) [H]

Head is the expression of the energy content of the liquid referred to any arbitrary datum. It is expressed in units of energy per unit weight of liquid. The measuring unit for head is meters (feet) of liquid.

2.2.3.1 Gauge head (h_g) [H_{max}]

The energy of the liquid due to its pressure above atmospheric as determined by a pressure gauge or other pressure-measuring device.

(Metric)

$$h_g = \frac{p_g}{9800 s}$$

(US customary units)

$$h_g = \frac{2.31 p_g}{s}$$

Where:

h_g = gauge head, in m (ft)

P_g = gauge pressure, in kPa (psi)

g = gravitational constant, 9.8 m/s^2 (32.2 ft/s^2)

2.2.3.2 Velocity head (h_v)

The kinetic energy of the liquid at a given cross section. Velocity head is expressed by the following equation:

$$h_v = \frac{v^2}{2g}$$

Where:

v = fluid velocity (m/s or ft/s) derived by dividing the rate of flow (m^3/s or ft^3/s) by the cross-sectional area (m^2 or ft^2) at the point of the gauge connection.

2.2.3.3 Elevation head (Z) [H_{stat}]

The potential energy of the liquid due to its elevation relative to datum level measured to the center of the pressure gauge or liquid level.

2.2.3.4 NPSH datum plane

The pump's datum is the horizontal plane through the center of the circle described by the external points of the entrance edges of the impeller blade. It is in the first stage in the case of multistage pumps. In the case of a double inlet pump with vertical or inclined axis, it is the plane through the higher center. The manufacturer should indicate the position of the plane with respect to precise reference points on the pump (see Figure 2.2.3.4).

Vertical pumps are usually performance tested in an open pit with the suction flooded. Optional tests can be performed with the pump mounted in a suction can. Irrespective of pump mounting, the pump's datum is maintained at the eye of the first-stage impeller

2.2.3.5 Total suction head (h_s), open suction

For open suction (wet pit) installations, the first-stage impeller of the bowl assembly is submerged in a pit. The total suction head (h_s) at datum is the submergence in meters (feet) of water (Z_w). The average velocity head of the flow in the pit is small enough to be neglected:

$$h_s = Z_w$$

Where:

Z_w = vertical distance in meters (feet) from free water surface to datum.

2.2.3.6 Total suction head (h_s), closed suction

For closed suction installations, the pump suction nozzle may be located either above or below grade level.

The total suction head (h_s), referred to the eye of the first-stage impeller, is the algebraic sum of the suction gauge head (h_{gs}) plus the velocity head (h_{vs}) at point of gauge attachment plus the elevation (Z_s) from the suction gauge centerline (or manometer zero) to the pump datum:

$$h_s = h_{gs} + h_{vs} + Z_s$$

The suction head (h_s) is positive when the suction gauge reading is above atmospheric pressure and negative when the reading is below atmospheric pressure by an amount exceeding the sum of the elevation head and the velocity head.

2.2.3.7 Pump total discharge head (h_d)

The total discharge head (h_d) (which includes bowl assembly head minus the pump internal hydraulic friction losses, such as suction can, column pipe, and discharge elbow) is the sum of the discharge gauge head (h_{gd}) measured after the discharge elbow plus the velocity head (h_{vd}) at the point of gauge attachment plus the elevation (Z_d) from the discharge gauge centerline to the pump datum.

$$h_d = h_{gd} + h_{vd} + Z_d$$

2.2.3.8 Pump total head (H) [$H_{t,x}$]

This is the measure of energy increase per unit weight of the liquid, imparted to the liquid by the pump, and is the difference between the total discharge head and the total suction head.

This is the head normally specified for pumping applications because the complete characteristics of a system determine the total head required.

2.2.3.9 Bowl assembly total head (H_{ba})

A bowl assembly is the pumping element of a rotodynamic vertical pump and typically consists of a suction bell, a shaft, one or more stages, and miscellaneous parts, such as bearings, bolts, and keys. Each stage consists of a single bowl, a single impeller, and miscellaneous parts.

Most manufacturers publish “catalog” performance curves showing predicted performance based on a single-stage bowl assembly. When evaluating a performance curve, the user is cautioned to check carefully the basis for the curve because it may be based on either single-stage or multistage performance. Unless otherwise specified, bowl assembly performance is defined as single-stage bowl assembly performance.

For a multistage bowl assembly, single-stage bowl head and power is approximately equal to the multistage performance divided by the number of stages. However, inlet and outlet losses may reduce the single-stage bowl assembly performance compared with that of single bowl assembly performance calculated from multistage performance.

The bowl assembly head (H_{ba}) (which is the head normally shown on the manufacturer’s performance curve) is the gauge head (h_{gd}) measured at a gauge connection located on the column pipe downstream from the bowl assembly, plus the velocity head (h_{vd}) at point of gauge connection, plus the vertical distance (Z_d) from datum to the pressure gauge centerline, minus the submergence Z_w, which is the vertical distance from datum to the liquid level.

$$H_{ba} = h_{dg} + h_{vd} + Z_d - Z_w$$

2.2.3.10 Atmospheric head (h_{atm})

Local atmospheric pressure expressed in meters (feet).

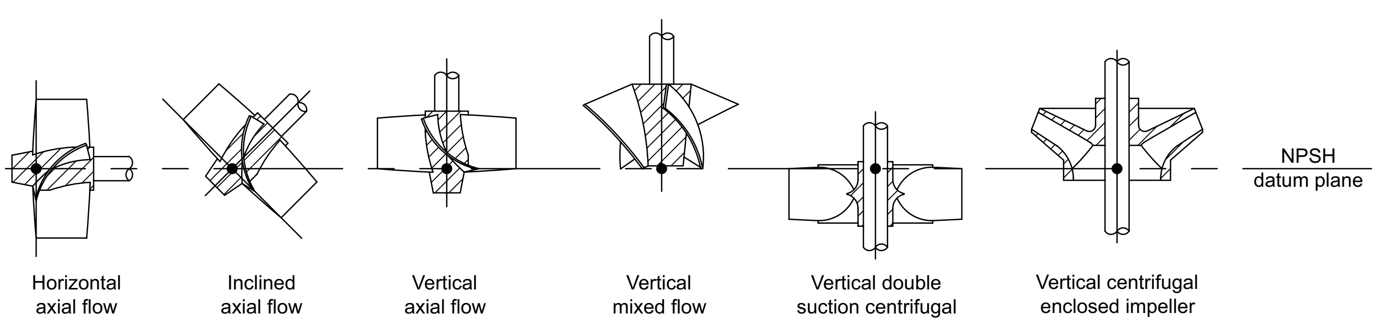


Figure 2.2.3.4 — Datum elevation for various pump designs at eye of first-stage impeller

2.2.3.11 Friction head (h_f or h_J)

Friction head is the hydraulic energy required to overcome frictional resistance of a piping system to liquid flow. Vertical pumps have many different configurations, and each pump has its own internal friction head losses.

2.2.4 Condition points

2.2.4.1 Rated condition point [$_r$ or $_d$]

Rated condition applies to the rate of flow, head, and speed of the pump, as specified by the order.

2.2.4.2 Specified condition point

Specified condition point is synonymous with rated condition point.

2.2.4.3 Normal condition point

Applies to the point at which the pump will normally operate. It may be the same as the rated condition point, or it may be to the left or right of BEP. It also may be at a reduced speed.

2.2.4.4 Best efficiency point (BEP) [Q_{opt}]

The rate of flow and head at which the pump efficiency is a maximum at rated rpm.

2.2.4.5 Shutoff

The condition of zero flow where no liquid is flowing from the pump, but the pump is primed and running.

2.2.4.6 Allowable operating region

This is the flow range at the specified speeds with the impeller supplied, as limited by cavitation, heating, vibration, noise, shaft deflection, fatigue, and other similar criteria. This range (see typical performance as illustrated on Figure 2.2.4.6) shall be specified by the manufacturer. See ANSI/HI 9.6.3 *Rotodynamic (Centrifugal and Vertical) Pumps for Allowable Operating Region* for additional details.

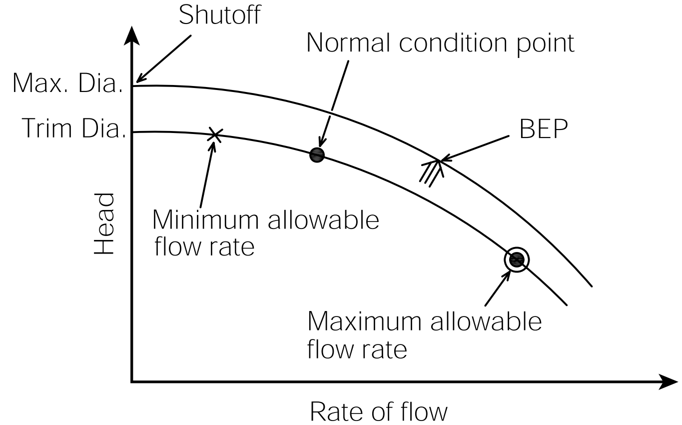


Figure 2.2.4.6 — Typical performance curve for rotodynamic pumps of lower specific speed design

2.2.5 Suction conditions

2.2.5.1 Submerged suction

A submerged suction exists when the centerline of the pump inlet port is below the level of the liquid in the supply tank and the liquid is exposed to atmosphere. However, the absolute pressure of the liquid entering the centerline of the pump inlet port may still be below atmospheric pressure while the pump is operating, even with submerged suction.

2.2.5.2 Flooded suction

Flooded suction implies that the liquid will flow from a source to the pump with the average pressure at the intake port staying above atmospheric pressure when the pump is operating at a specified rate of flow.

2.2.5.3 Static suction lift (l_s)

Static suction lift is a hydraulic pressure below atmospheric at the inlet of the first-stage impeller datum of the pump.

2.2.5.4 Net positive suction head available (NPSHA)

Net positive suction head available is the total suction head in meters (feet) of liquid absolute, determined at the first-stage impeller datum, less the absolute vapor pressure of the liquid, in meters (feet):

$$NPSHA = h_{sa} - h_{vp}$$

Where:

h_{sa} = total suction head absolute = $h_{atm} + h_s$

or $NPSHA = h_{atm} + h_s - h_{vp}$

In can pumps (see Figure 2.1.3.5a), NPSHA is often determined at the suction flange. Because NPSHR is determined at the first-stage impeller, the NPSHA value must be adjusted to the first-stage impeller by adding the difference in elevation and subtracting the losses in the can (see ANSI/HI 2.3 *Rotodynamic Vertical Pumps for Design and Application)*.

2.2.5.5 Net positive suction head required (NPSHR)

A minimum NPSH given by the manufacturer or supplier for a pump achieving a specified performance at the specified rate of flow, speed, and pumped liquid (occurrence of visible cavitation, increase of noise and vibration due to cavitation, beginning of head or efficiency drop, head or efficiency drop of a given amount, limitation of cavitation erosion).

2.2.5.6 Net positive suction head required resulting in 3% loss of total head (NPSH3)

NPSH3 is defined as the value of NPSHR at which the first-stage total head drops by 3% due to cavitation.

2.2.5.7 Maximum suction pressure ($p_{s\ max}$) [$p_{1\ max\ op}$ or $p_{1\ max\ all}$]

This is the highest suction pressure to which the pump will be subjected during operation.

2.2.6 Power

2.2.6.1 Electric motor input power (P_{mot}) [P_1]

The electrical input power to the motor.

$$P_{mot[\text{hp}]} = \frac{P_{mot[\text{kW}]}}{0.746}$$

2.2.6.2 Pump input power (P_p) [P], brake horsepower

The power needed to drive the complete pump assembly, including bowl assembly input power, line-shaft power loss, mechanical seal or gland packing friction losses, and thrust bearing loss. With pumps having built-in thrust bearing, the power delivered to the pump shaft coupling is equal to the pump input power. With pumps that rely on the driver thrust bearing, the thrust bearing loss shall be added to the power delivered to the pump shaft. It is also called *brake horsepower*.

2.2.6.3 Bowl assembly input power (P_{ba})

The power delivered to the bowl assembly shaft.

2.2.6.4 Pump output power (P_w)

The power imparted to the liquid by the pump. It is also called *pump hydraulic horsepower*.

(Metric, kW)

$$P_w = \frac{Q \times H \times \rho \times g}{1000}$$

Where Q is in cubic meters per second, H is in meters, ρ (rho) is in kilograms per cubic meter, and g is the gravity constant in meters per second squared (9.81 m/s^2).

(US customary units, hp)

$$P_w = \frac{Q \times H \times \rho \times s}{247,000}$$

Where Q is in gallons per minute, H is in feet, ρ is in pounds per cubic feet, and s is specific gravity - dimensionless.

2.2.6.5 Overall efficiency (η_{OA})

This is the ratio of the energy imparted to the liquid (P_w) by the pump, to the energy supplied to the driver (P_{dvr}); that is, the ratio of the water horsepower to the power input to the motor, expressed in percent. This is sometimes referred to as the *wire-to-water efficiency*.

$$\eta_{OA} = \frac{P_w}{P_{mot}} \times 100$$

2.2.6.6 Pump efficiency (η_p) [η]

The ratio of the pump output power (P_w) to the pump input power (P_p); that is, the ratio of the water horsepower to the brake horsepower, expressed in percent.

$$\eta_p = \frac{P_w}{P_p} \times 100$$

2.2.6.7 Bowl assembly efficiency (η_{ba})

This is the efficiency obtained from the bowl assembly, excluding all hydraulic and mechanical losses within other pump components. This is the efficiency usually shown on the manufacturer's published performance curve.

2.2.7 Pump pressures

2.2.7.1 Working pressure [p_d or $p_{2\ max\ op}$]

The maximum discharge pressure that could occur in the pump when it is operated at rated speed and suction pressure for the given application.

2.2.7.2 Maximum allowable working pressure [MAWP]

Maximum continuous pressure for which the manufacturer has designed the pump (or any part to which the term is referred) when handling the specified fluid at the specified maximum operating temperature. This pressure shall be equal to or greater than the maximum discharge pressure. In the case of double casing can pumps, the maximum allowable casing working pressure on the suction side may be different from that on the discharge side.

2.2.7.3 Maximum discharge pressure [$p_{d\ max}$ or $p_{2\ max\ op}$]

The highest discharge pressure to which the pump will be subjected during operation.

2.2.7.4 Field-test pressure

The maximum static test pressure to be used for leak-testing a closed pumping system in the field if the pumps are not isolated. Usually this is taken as 125% of the maximum allowable casing working pressure. Where mechanical seals are used, this pressure may be limited by the pressure-containing capabilities of the seal.

See Section 2.2.7.2, Maximum allowable working pressure. Consideration of this may limit the field-test pressure of the pump to 125% of the maximum allowable casing working pressure on the suction side of double casing can type pumps and certain other pump types.

2.2.8 Impeller balancing

2.2.8.1 Single-plane balancing (formerly called *static balancing*)

Correction of residual unbalance to a specified maximum limit by removing or adding weight in one correction plane only. Can be accomplished statically using balance rails or by spinning.

2.2.8.2 Two-plane balancing (formerly called *dynamic balancing*)

Correction of residual unbalance to a specified limit by removing or adding weight in two correction planes. Accomplished by spinning on appropriate balancing machines.

2.2.9 Rotodynamic vertical pump icons – vertically suspended

This section identifies icons used to represent the various product designs described in this standard. These designations support internationally recognized ISO 13709 and API 610 standards.

2.2.9.1 Vertically suspended – single suction

2.2.9.1.1 Submersible

2.2.9.1.1.1 Submersible VS0

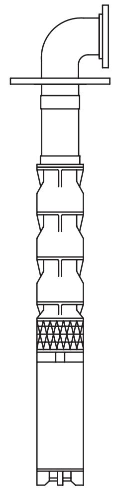


Figure 2.2.9.1.1.1 — Submersible turbine (VS0)

2.2.9.1.2 Discharge through column

2.2.9.1.2.1 Diffuser VS1

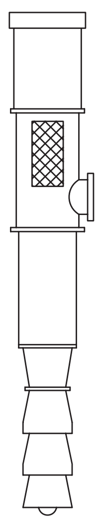


Figure 2.2.9.1.2.1 — Discharge through column – diffuser – wet pit (VS1)

2.2.9.1.2.2 Volute VS2

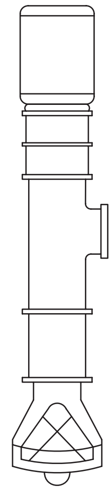


Figure 2.2.9.1.2.2 — Discharge through column – volute – wet pit (VS2)

2.2.9.1.2.3 Axial flow VS3

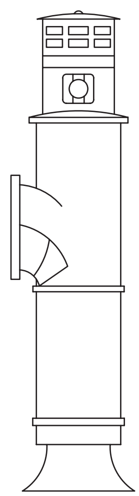


Figure 2.2.9.1.2.3 — Discharge through column – axial flow – wet pit (VS3)

2.2.9.1.3 Separate discharge

2.2.9.1.3.1 Line-shaft VS4

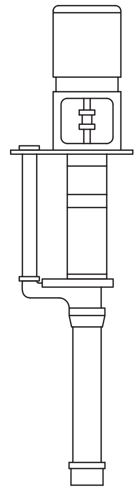


Figure 2.2.9.1.3.1 — Separate discharge – line shaft – vertical sump (VS4)

2.2.9.1.3.2 Cantilever VS5

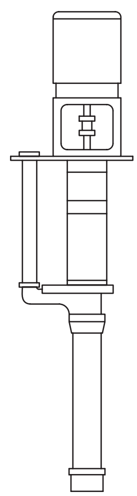


Figure 2.2.9.1.3.2 — Separate discharge – cantilever (VS5)

2.2.9.2 Vertically suspended – double casing

2.2.9.2.1 Diffuser VS6

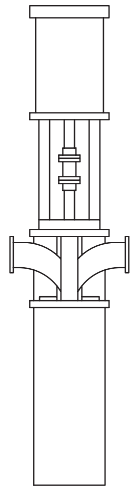


Figure 2.2.9.2.1 — Vertically suspended – double casing – double suction – diffuser (VS6)

2.2.9.2.2 Double casing volute type pumps

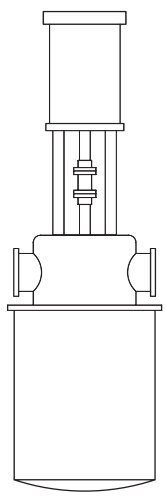


Figure 2.2.9.2.2a — Vertically suspended – double casing - volute - diffuser (VS7)

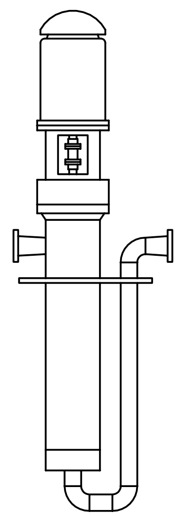


Figure 2.2.9.2.2b — Vertical volute multistage double casing pump (VS7a)

2.2.9.3 Vertically suspended in-line casing diffuser

2.2.9.3.1 Vertically suspended floor mounted in-line casing diffuser VS8

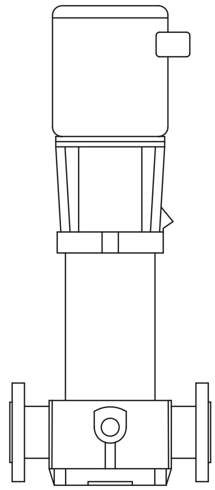


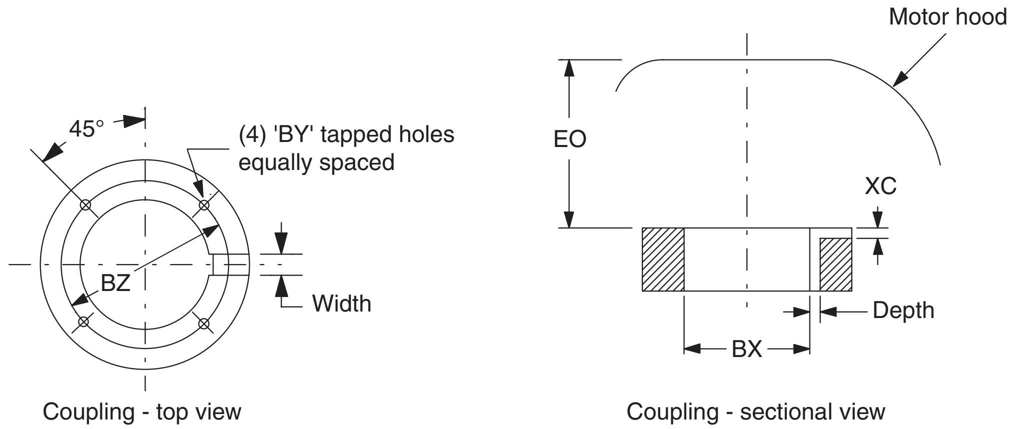
Figure 2.2.9.3.1 — Vertically suspended – in-line casing – multistage diffuser (VS8)

Appendix A

Hollow-shaft driver

This appendix is not part of ANSI/HI 2.1–2.2 and is included for informative purposes only.

The hollow-shaft drivers (see Figures 2.1.3.2 and 2.1.3.3d) have the top section of the head shaft installed inside the tubular hollow driver shaft. The coupling of the head shaft to driver is arranged on top of the motor and has a provision for axial line-shaft adjustment. Standard dimensions for the coupling are shown in Figure A.1 on page 44.



Top drive coupling

Coupling dimensions (inches)				Keyway (inches)[a]		Hood clearance (inches)
Coupling bore BX[b]	BY	BZ	XC	Width	Depth	EO[c]
0.751	10-32	1.375	0.38	0.187	0.109	2.25
0.876	10-32	1.375	0.38	0.187	0.109	2.63
1.001	10-32	1.375	0.43	0.250	0.140	3.00
1.188	0.250-20	1.750	0.43	0.250	0.140	3.50
1.251	0.250-20	1.750	0.43	0.250	0.140	3.75
1.251	0.250-20	1.750	0.56	0.375	0.203	3.75
1.438	0.250-20	2.125	0.56	0.375	0.203	4.30
1.501	0.250-20	2.125	0.56	0.375	0.203	4.50
1.688	0.250-20	2.500	0.56	0.375	0.203	5.00
1.751	0.250-20	2.500	0.56	0.375	0.203	5.25
1.938	0.250-20	2.500	0.68	0.500	0.265	5.80
2.001	0.250-20	2.500	0.68	0.500	0.265	6.00
2.188	0.375-16	3.250	0.68	0.500	0.265	6.50
2.251	0.375-16	3.250	0.68	0.500	0.265	6.75
2.438	0.375-16	3.250	0.81	0.625	0.327	7.30
2.501	0.375-16	3.250	0.81	0.625	0.327	7.50
2.688	0.375-16	3.750	0.81	0.625	0.327	8.00
2.751	0.375-16	3.750	0.81	0.625	0.327	8.25
2.938	0.375-16	4.250	0.94	0.750	0.390	10.00
3.188	0.375-16	4.250	0.94	0.750	0.390	10.00
3.438	0.375-16	4.500	1.06	0.875	0.453	10.00
3.688	0.375-16	5.000	1.06	0.875	0.453	10.00
3.938	0.375-16	5.000	1.06	0.875	0.453	10.00

[a] American Standard, Gib-Head, Taper Stock and Square type keys fit the above dimensions.

[b] Tolerances for the “BX” dimension are +0.001 in, -0.000 in, up to and including 1.5-in diameter, and +0.002 in, -0.000 in for larger diameters.

[c] The “EO” dimension, which is clearance from coupling top to inside of hood, is based upon a minimum dimension of three times the BX dimension for shaft diameters 2.75 in and smaller and 10 in for shaft diameters 2.94 through 3.94 in.

Figure A.1 — Vertical hollow-shaft driver coupling dimensions

Appendix B

Index

This appendix is included for informative purposes only and is not part of this standard. It is intended to help the user gain a better understanding of the factors referenced in the body of the standard.

Note: an f. indicates a figure, and a t. indicates a table.

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