

American Water Works Association
ANSI/AWWA E101-88
(Revision of ANSI/AWWA E101-77 [R82])



AWWA STANDARD
FOR
**VERTICAL TURBINE PUMPS— LINE SHAFT
AND SUBMERSIBLE TYPES**



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AMERICAN WATER WORKS ASSOCIATION

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Foreword

This foreword is for information only and is not a part of AWWA E101.

I. History of Standard. This standard for vertical turbine pumps presents the composite findings from studies conducted from 1949 to 1986 by committees consisting of manufacturers, consumers, and engineers. The first standard was published in 1955. In 1961 the standard was revised to include standards for submersible vertical turbine pumps. Additional technical changes were added in the 1971 revision. Solid shaft motors were added in the 1977 revision, together with numerous editorial changes and soft conversions to the international system of units. The 1977 standard was reaffirmed in 1982 without revision.

The standard is intended to serve as a guide in the preparation of specifications for the procurement of vertical turbine pumps in normal water service, as well as an aid in designing pumps to be used for special conditions. Material lists are provided from which the purchaser can select the proper pump metals or alloys for a particular installation or wear environment. If any special items are not listed by the purchaser, the selection of pump material will be made by the pump manufacturer.

II. Information Regarding Use of This Standard. The pump manufacturer will require local basic data prior to furnishing a pump and driver that will meet the buyer's needs. The information will include such items as the type of prime mover and pump that is being requested, as well as the operating range and other pertinent items that will be necessary in designing the unit. A specification form that will provide the manufacturer with the needed information, as well as any exceptions to the standard that the user may wish to include, is given in Appendix B.

In addition to the information required on the suggested specification form, the purchaser should include provisions for the following items in supplementary specifications.

1. In all cases
 - a. Standard used—that is, AWWA E101, Standard for Vertical Turbine Pumps—Line Shaft and Submersible Types.
 - b. Certification and test results by manufacturer (Sec. A-3.3.2, Sec. A-6.2.2, Sec. B-3.3.2, and Sec. B-6.2.2), if required.
 - c. Sanitary codes (Sec. A-3.5 and Sec. B-3.5).
 - d. Liquid to be pumped (Sec. A-1 and Sec. B-1).
 - e. Details of installation, if other than a well (Sec. A-1 and Sec. B-1).
 - f. Whether the impellers are to be enclosed, open, or of the semiopen type (Sec. A-4.2.2 or Sec. A-4.3.2 and Sec. B-4.7), if there is a preference.
 - g. Performance tests (Sec. A-6.1 and Sec. B-6.1) that will be required, if any.
 - h. If field conditions of installation are to be duplicated in the laboratory test arrangement (Sec. A-6.3 and Sec. B-6.3), provide complete details and a description of the arrangement.
 - i. If pump bowl assembly tests are not to be made in open sumps (Sec. A-6.5 and Sec. B-6.5), specify test conditions.

- j. If bowl size exceeds 20 in. (500 mm) OD, specify the basis for performance guarantees (Sec. A-6.9.3 and Sec. B-6.8).
- k. If tests other than those specified in this standard are to be performed (Sec. A-6.12 and Sec. B-6.11), specify.
- 2. For line-shaft vertical turbine pumps, also specify
 - a. Type of motor, if other than specified in Sec. A-4.1.2.
 - b. Whether an oil-lubricated pump (Sec. A-4.2) or a water-lubricated pump (Sec. A-4.3) is desired.
 - c. Table 1 lists two or more materials for certain parts. If there is a preference for one material or the other, specify in each instance.
 - d. Whether pump-column sections are to be joined by threaded couplings or by flanges.
- 3. For submersible vertical turbine pumps, also specify
 - a. Whether a strainer (Sec. B-4.4) will be required.
 - b. Discharge-elbow head loss (Sec. B-5.3), if this is essential.
 - c. Table 4 lists two or more materials for certain parts. If there is a preference for one material or the other, specify in each instance.
 - d. Whether pump column sections are to be joined by threaded couplings or by flanges.

III. Major Revisions. The AWWA Standards Committee on Vertical Turbine Pumps (formerly ANSI B58) was reactivated in 1985 to review the 1977 standard and to make revisions. The committee made several editorial changes for clarity and accuracy. The material lists in Tables 1 and 4 were revised to delete references to obsolete standards and to comply with current manufacturing practices. A formula for design of shaft couplings was added as Sec. A-4.1.4. Tables for selection of electrical cables for submersible pumps, which were included in earlier standards, were deleted as not appropriately being a part of a pump standard.

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AWWA STANDARD FOR

VERTICAL TURBINE PUMPS— LINE

SHAFT AND SUBMERSIBLE TYPES

Part A— Line-Shaft Vertical Turbine Pumps

SECTION A-1: SCOPE AND PURPOSE

Part A of this standard provides minimum requirements for line-shaft vertical turbine pumps utilizing discharge column pipe up to and including 16 in. (400 mm) in size. The standard deals with a pump configuration up to and including the driver. Only electric motors are referred to as prime movers.

Purchasers who intend to use the pumps for pumping liquids other than clear, cold water should modify the requirements to fit conditions of intended use, preferably after consultation with pump manufacturers.

SECTION A-2: DEFINITIONS

A-2.1 *Line-shaft vertical turbine pump:* A vertical-shaft centrifugal or mixed-flow pump with rotating impeller or impellers, and with discharge from the pumping element coaxial with the shaft. The pumping element is suspended by the conductor system, which encloses a system of vertical shafting used to transmit power to the impellers, the prime mover being external to the flow stream.

A-2.2 *Pump:* For purposes of this standard, a pump may be defined as a device used to provide energy for initiating or maintaining the movement of liquid. A pump consists of three elements, defined as follows:

A-2.2.1 *The pump bowl assembly* is either a single or multistage, centrifugal or mixed-flow vertical pump with discharge coaxial with the shaft. It has open, semiopen, or enclosed impellers. Assemblies are constructed for use with either open or enclosed line shafts.

A-2.2.2 *The column-and-shaft assembly* consists of the column pipe that suspends the pump bowl assembly from the head assembly and serves as a conductor for the fluid from the pump bowl assembly to the discharge head. Contained within the column pipe is the line shaft, which transmits the power from the driver to the pump shaft. The line shaft is maintained in alignment throughout its length by means of bearings and may be enclosed in a shaft-enclosing tube and generally lubricated with oil, or it may be open and lubricated with the fluid that is being pumped.

A-2.2.3 *The head assembly* consists of the driver, the base from which the column-and-shaft assembly and the bowl assembly are suspended, and may include the discharge head, which directs the fluid into the desired piping system.

A-2.2.3.1 *The driver* is the mechanism mounted on the head assembly that transmits or furnishes the power to the top shaft. It may contain the means for impeller adjustment, and it provides a bearing to carry the thrust load. It may or may not be a prime mover.

A-2.2.3.2 *The discharge tee*, in a discharge-below-base installation, is separated from the head assembly and installed in a column pipe at a desired distance below the head assembly.

A-2.3 *Driver*: For purposes of this standard, a driver may be defined as a device used to provide mechanical energy for the operation of a pump. Types of drivers are defined as follows:

A-2.3.1 *The vertical hollow-shaft motor drive* is an electric motor having a motor shaft that has been bored on the center of its axis to receive the top shaft of the pump. Impeller adjustment is made at the upper end of the motor, and a means to carry the thrust on a bearing within the motor is provided.

A-2.3.2 *The vertical solid-shaft motor drive* is an electric motor having a conventional solid shaft coupled to the top shaft of the pump. The coupling should provide a means for impeller adjustment. The mechanical and hydraulic thrust of the pump is carried by a thrust bearing in the motor.

A-2.3.3 *The vertical hollow-shaft right-angle gear drive* is a gear mechanism having a shaft that has been bored on the center of its axis to receive the top shaft of the pump. The horizontal shaft of the gear drive receives its power from the prime mover and, through a pair of bevel gears, transmits it to the top shaft. Impeller adjustment is made at the upper end of the gear drive, and a means to carry the thrust on a bearing within the gear drive is provided.

A-2.3.4 *The vertical hollow-shaft belted drive* is a flat- or V-belt-driven mechanism having a shaft that has been bored on the center of its axis to receive the top shaft of the pump. Impeller adjustment is made at the upper end of the belted drive, and a means to carry the thrust on a bearing within the belted drive is provided.

A-2.3.5 *The combination drive* includes a means for operating the pump with two or more prime movers.

A-2.4 *Datum*: The elevation of that surface from which the weight of the pump is supported. This is normally the elevation of the underside of the discharge head or head base plate.

A-2.5 *Setting*: The nominal vertical distance, in feet (metres), from the datum to the column pipe connection at the bowl assembly.

A-2.6 *Static water level*: The vertical distance, in feet (metres), from the datum to the level of the atmospheric surface while no water is being drawn from the pool.

A-2.7 *Pumping water level*: The vertical distance, in feet (metres), from the datum to the level of the atmospheric surface while the specified fluid flow is being drawn from the pool.

A-2.8 *Drawdown*: The difference, in feet (metres), between the pumping water level and the static water level.

A-2.9 *Specific yield*: The rate of flow being pumped for a well divided by the total drawdown as measured during the metered flow rate. It is expressed in US gallons per minute per foot of drawdown (litres per second per metre of drawdown).

A-2.10 *Pump capacity (Q)*: The volume rate of flow, expressed in gallons per minute (cubic metres per hour), produced by the pump, calculated for specified conditions.

A-2.11 *Pump speed of rotation (n)*: The rate of rotation of the pump shaft, expressed in revolutions per minute or revolutions per second.

A-2.12 *Head*: A quantity used to express the energy content of the liquid per unit weight of the liquid, referred to any arbitrary datum. In terms of foot-pounds (metre-kilograms) of energy per pound (kilogram) being pumped, all head quantities have the dimension of feet (metres) of liquid.

A-2.12.1 *Head below datum h_b* is the vertical distance, in feet (metres), between the datum and the pumping water level.

A-2.12.2 *Head above datum h_a* is the head measured above the datum, expressed in feet (metres) of liquid, plus the velocity head (Sec. A-2.12.3) at the point of measurement.

A-2.12.3 *Velocity head h_v* is the kinetic energy per unit weight of the liquid at a given section, expressed in feet (metres) of liquid. Velocity head is specifically defined by the expression

$$h_v = \frac{v^2}{2g} \quad (\text{Eq 1})$$

Where:

$$\begin{aligned} v &= \text{velocity, in feet per second (metres per second)} \\ g &= 32.17 \text{ ft/s}^2 \text{ (9.81 m/s}^2\text{)} \end{aligned}$$

A-2.12.4 *Suction head h_s* (closed system) is the algebraic sum of the pressure in feet (metres) of liquid (measured at the pump suction connection) and the velocity head at that point. Pump suction connection is the point at which the suction piping is attached to the pump bowl assembly or its enclosing vessel. Note that a negative suction head will add to the vertical distance from the datum, due to the algebraic subtraction of a negative quantity.

A-2.12.5 *Pump total head H* is the bowl assembly head (Sec. A-2.12.6) minus the column loss (Sec. A-2.12.7) and discharge head loss (Sec. A-2.12.8). This is the head generally called for in pump specifications.

A-2.12.5.1 *On open-suction installations*, pump total head is the sum of the head below datum and the head above datum.

A-2.12.5.2 *On closed-suction installations*, pump total head is the head above datum plus the vertical distance, in feet (metres), from the datum to the pump suction connection minus the suction head.

A-2.12.6 *Bowl assembly head h_1* is the energy imparted to the liquid by the pump bowl assembly, expressed in feet (metres) of liquid. It is the head developed at the discharge connection of the bowl assembly and is an integral multiple of the head per stage as shown on the catalog rating chart, depending on the number of stages in the bowl assembly.

A-2.12.7 *The column loss h_c* is the value of the head loss, expressed in feet (metres), caused by the flow friction in the column pipe.

A-2.12.8 *Discharge head loss h_e* is the value of the head loss, expressed in feet (metres), caused by the flow friction in the discharge head assembly.

A-2.13 *Line-shaft loss*: The power, expressed in horsepower (kilowatts), required to overcome the rotation friction of the line shaft. This value is added to the bowl assembly input (Sec. A-2.14.3) to predict the pump input (Sec. A-2.14.1).

A-2.14 *Power* is expressed in units of horsepower (kilowatts). One horsepower is equivalent to 550 ft-lb/s, 33,000 ft-lb/min, 2545 Btu/h, or 0.746 kW.

A-2.14.1 *Pump power input* is the power delivered to the top shaft by the driver, expressed in horsepower (kilowatts).

A-2.14.2 *Driver power input* is the power input to the driver, expressed in horsepower (kilowatts).

A-2.14.3 *Bowl assembly power input* is the power delivered to the bowl assembly shaft, expressed in horsepower (kilowatts).

A-2.15 *Pump power output*: For water having a specific weight of 62.4 lb/ft³, (relative density of 1.0), pump power output is defined as $QH/3960$. Pump power output is expressed in horsepower ($\text{hp} \times 0.746 = \text{kW}$) when Q is in gallons per minute and H is in feet of water.

A-2.16 *Bowl output*: For water having a specific weight of 62.4 lb/ft³ (relative density of 1.0), bowl output is defined as $Qh_1/3960$. Bowl output is expressed in horsepower ($\text{hp} \times 0.746 = \text{kW}$) when Q is in gallons per minute and h_1 is in feet of water.

A-2.17 *Pump efficiency (E_p)*: The ratio of pump power output to pump input, expressed in percent.

A-2.18 *Overall efficiency (E)*: The ratio of pump power output to prime mover power input, expressed in percent.

A-2.19 *Driver efficiency (E_g)*: The ratio of the driver power output to the driver power input, expressed in percent.

A-2.20 *Bowl assembly efficiency E_1* : The ratio of the bowl output to the bowl assembly input, expressed in percent. This is the efficiency that is usually shown on catalog rating charts.

SECTION A.3: GENERAL

Sec. A-3.1 Standard Nomenclature

Table 1 (page 8) lists the names of parts in vertical turbine pumps, the function of each part, the material or materials from which the part is typically made, and the ASTM* material designation. In the table, parts are listed by number; the part number refers to the numbers in Figures 1 and 2 (pages 6 and 7).

Sec. A-3.2 Order Form

A specification form recommended for use in purchasing vertical turbine pumps is given in Appendix B.

Sec. A-3.3 Inspection and Certification by Manufacturer

A-3.3.1 The manufacturer shall establish the necessary quality-control and inspection practices to ensure compliance with this standard.

A-3.3.2 The manufacturer shall, if required by the purchaser's supplemental specifications, furnish a sworn statement that the equipment furnished under the purchaser's order complies with all applicable requirements of this standard.

Sec. A-3.4 Information to Be Supplied by Bidder

The bidder shall submit, with its proposal, sufficient descriptive material or outline drawings to demonstrate compliance with this standard and the purchaser's supplemental specifications, and a performance curve showing pump total head, pump input power, and pump efficiency over the specified head range for the installed pump.

Sec. A-3.5 Sanitary Codes

The pump shall conform to the sanitary codes governing the installation. The purchaser shall furnish, as part of these specifications, all information necessary for the construction of the pump to meet these requirements.

SECTION A-4: SPECIFICATIONS

Sec. A-4.1 Pump Components

A-4.1.1 *Pump base.* A suitable base of cast iron or fabricated steel shall be provided for mounting the driver and supporting the pump column.

A-4.1.2 *Driver.* With electric power, the motor, unless specified otherwise by the purchaser, shall be of the full-voltage starting, vertical hollow-shaft squirrel-cage induction type, and shall comply with ANSI C50.10.† The connection to the top shaft shall be through a coupling or clutch in the motor head. The motor shall be of the

*American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

†ANSI C50.10—General Requirements for Synchronous Machines. Available from American National Standards Institute, 1430 Broadway, New York, NY 10018.

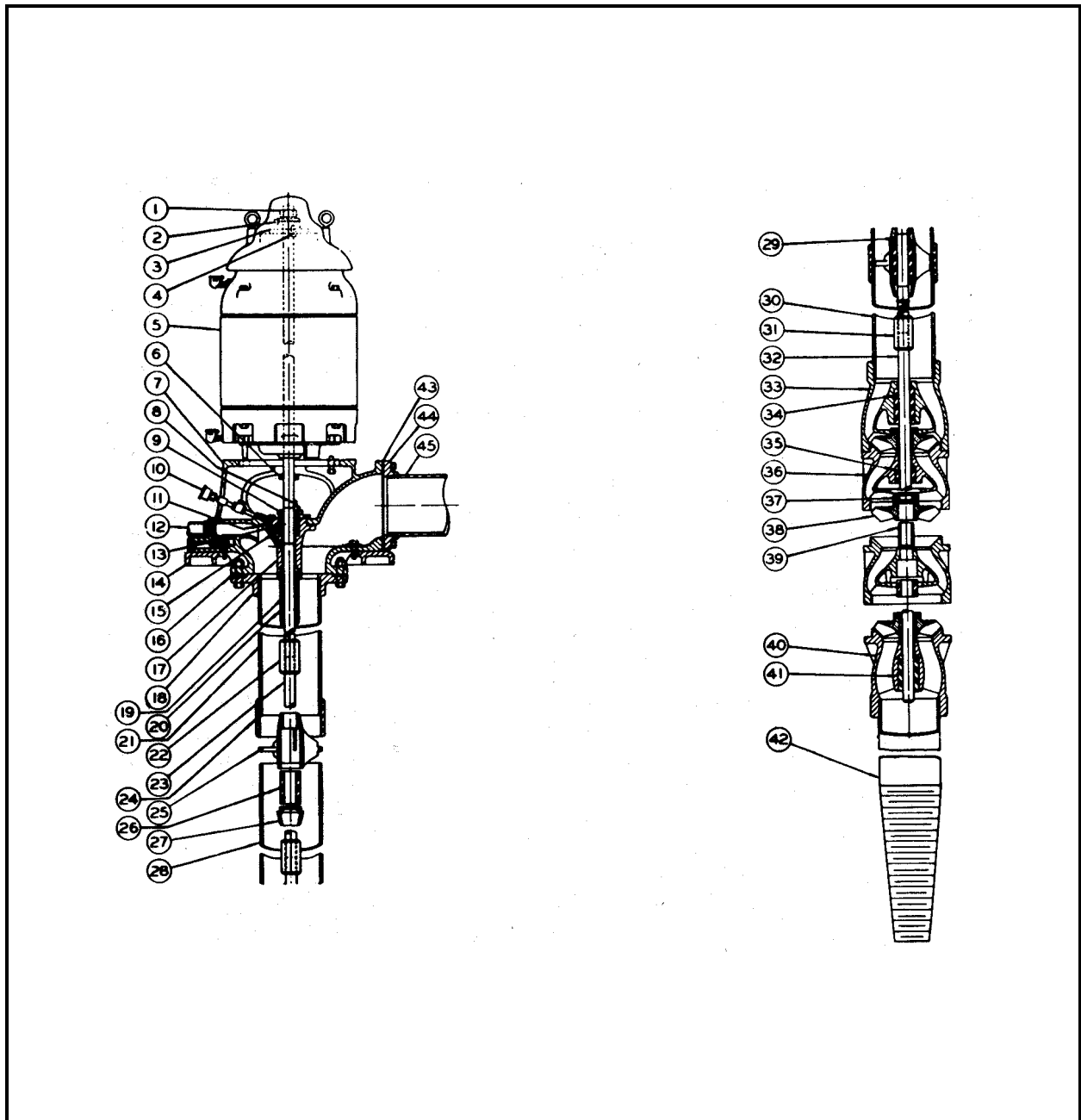


Figure 1 Open line-shaft pump (surface discharge, threaded column and bowls).

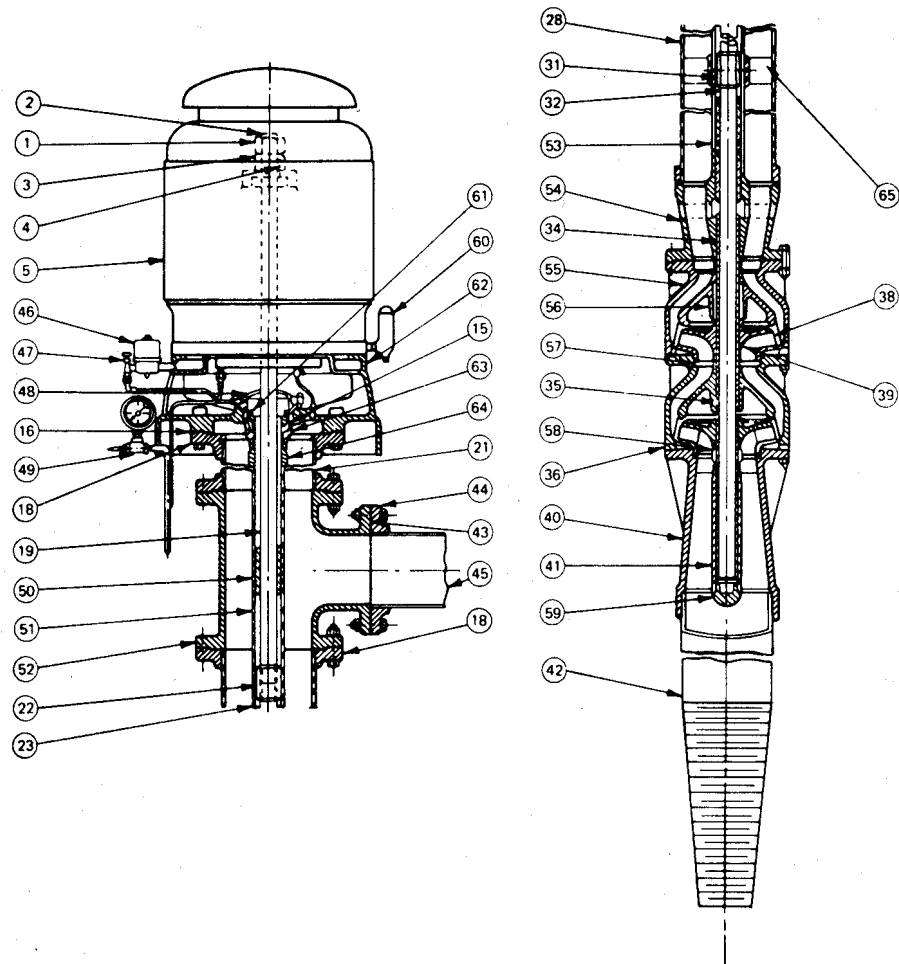


Figure 2 Enclosed line-shaft pump (discharge below base, threaded column and bowls).

Table 1 Standard Nomenclature—Line-Shaft Vertical Turbine Pumps

Part No.*	Name of Part	Typical Material	ASTM Designation	Function of Part
1	Top shaft adjusting nut	Bronze Steel Ductile iron	B505 or B584, ALY 836 A108 Gr B1113 A536 Gr 65-45-12	Means of adjusting impellers vertically by raising or lowering shaft
2	Adjusting nut lock screw or lock washer	Steel	A108 Gr 1018 Gr B1113 Gr 1213	Locks adjusting nut in place so that adjustment cannot change while pump is in operation
3	Top drive coupling	Part of motor	—	Couples top shaft with motor rotor
4	Key for top drive coupling	Steel	A108	Keys top shaft to top drive coupling
5	Motor	—	—	Drives pump
6	Water slinger	Steel Rubber	A108 Gr B1113	Keeps packing box leakage from shooting directly into hollow shaft of motor or driver unit
7	Surface discharge head	Cast iron Steel	A48 Class 30	Supports driver and pump column; discharges water from pump column
8	Stuffing-box studs and hexagonal nuts (cap screws)	Steel Brass Stainless steel	A307 Gr A or B B16 A193	Fastened in stuffing box to adjust stuffing-box gland
9	Stuffing-box gland	Bronze Cast iron	B584 ALY 836 A48 Class 30	Compresses and holds packing in place
10	Stuffing-box lubrication fittings	Steel Copper	— —	Conduct grease to packing and journal bearing
11	Stuffing-box gasket	Rubber Vellumoid	— —	Placed under seat of packing containers to prevent leakage
12	Prelubrication fittings	Commercial item	—	Conduct water to keep water-lubricated bearings wet during starting cycle
13	Top-shaft sleeve	Stainless steel	A276 Type 304 Type 410 Type 416	Sleeve operating within packed area in top shaft on open line-shaft pumps
14	Head base plate	Cast iron Steel	A48 Class 30 A36	Plate or casting that supports discharge head and may become permanent part of foundation after initial installation

15	Packing	Graphite impregnated	—	Flexible material that can be compressed by stuffing box to prevent leakage of fluid being pumped
16	Top column flange gasket	Rubber Vellumoid	— —	Seals joint between flange faces
17	Stuffing box	Bronze Cast iron	B584 ALY 836 A48 Class 30	Guides shaft and holds packing
18	Top column flange	Cast iron Steel	A48 Class 30 A36	Couples column to discharge head
19	Top shaft	Steel Stainless steel	O.L.†: A108 Gr 1045 W.L.‡: A276 Type 410 Type 416	Coupled to line shaft; connects latter to driver
20	Stilling tube§	Steel	A53 Gr A, A120	Suspended around top shaft from packing box to reduce flow of abrasive material into packing box
21	Top column pipe	Steel	A53 Gr A, A120	First section of column pipe below discharge
22	Line-shaft coupling	Steel	A108 Gr 1144 Gr1213	Used to join all sections of line shafting throughout unit
23	Line shaft	Steel	A108 Gr 1045	Those sections of line shafting between top shaft and pump shaft
24	Column-pipe coupling	Steel Cast iron	A108 Gr 1020 A48 Class 30	Couples sections of column pipe
25	Open line-shaft bearing retainer	Cast iron Bronze	A48 Class 30 B584 ALY 836 ALY844	Used to support line-shaft bearings; generally located at each end of each section of column pipe
26	Open line-shaft bearing	Rubber	—	Bearing held in bearing retainer to guide line shafting of pump
27	Open line-shaft retainer cap§	Bronze	B584 ALY 836 ALY 838 ALY 844 ALY 848	Locks bearing within bearing retainer
	Snap ring with thrust washer§	Stainless steel	A276 Gr 302	

*See Figures 1 and 2.

†O.L.—oil lubricated.

‡W.L.—water lubricated.

§Optional—these items are not furnished by all manufacturers.

Table continues on next page

Table 1—continued

Part No.*	Name of Part	Typical Material	ASTM Designation	Function of Part
28	Column pipe	Steel	A53 Gr A A120	Column pipe between top column and bottom column pipe; usually made of standard steel pipe
29	Open line-shaft sleeve§	Stainless steel	A276 Type 302 Type 304 Type 410 Type 416	Sleeve operating as journal for bearings
30	Bottom column pipe	Steel	A53 Gr A A120	First section of column immediately above discharge case or discharge bowl
31	Bowl-assembly shaft coupling	Steel	A108 Gr 1144 Gr 1213	Connects bottom shaft to bowl-assembly shaft; may be tapped with two different thread diameters
32	Bowl-assembly shaft	Stainless steel	A276 Type 410 Type 416	Supports impellers; coupled to line shaft
33	Discharge bowl	Cast iron	A48 Class 30	Receives flow from top impeller and guides it to pump column
34	Top bowl bearing	Rubber Bronze	— B505 or B584 ALY 836 ALY 838 ALY 844 ALY 848 ALY 932 ALY 935 ALY 937 ALY 938 ALY 943	Supports portion of bowl-assembly shaft
35	Intermediate bowl bearing	Rubber Bronze	— B505 or B584 ALY 836 ALY 838 ALY 844 ALY 848 ALY 932 ALY 935	Supports portion of bowl-assembly shaft

			ALY 937 ALY 938 ALY 943	
36	Intermediate bowl	Cast iron	A48 Class 30	Guides flow received from impeller to next impeller above
37	Impeller collet lock nut§	Steel	A108 Gr B1113	Used to pull impeller on collet; locks collet in place
38	Impeller	Cast iron Bronze	A48 Class 30 B584 ALY 836 ALY838 ALY844 ALY848 ALY875	Pumping element; receives water and impels it centrifugally to bowl passage
39	Impeller lock collet	Stainless steel Steel	A276 Type 416 A108 Gr B1113 Gr 1020 Gr 1213	Locks impeller to shaft
40	Suction case	Cast iron	A48 Class 30	Receives water from well; guides to first impeller
41	Suction-case bearing	Rubber Bronze	— B505 or B584 ALY 836 ALY 838 ALY 844 ALY 848 ALY 932 ALY 935 ALY 937 ALY 938 ALY 943	Supports bottom portion of pump shaft

*See Figures 1 and 2.

†O.L.—oil lubricated.

‡W.L.—water lubricated.

§Optional—these items are not furnished by all manufacturers.

Table continues on next page

Table 1—continued

Part No.*	Name of Part	Typical Material	ASTM Designation	Function of Part
42	Strainer	Steel Stainless steel	— —	Keeps large foreign material out of pumps
43	Discharge companion flange gasket	Commercial item	—	Seals joints between surface discharge head or underground elbow and companion flange
44	Discharge companion flange	Commercial item	—	Connects discharge pipe to integrally cast flanges on discharge head or underground discharge elbow
45	Discharge pipe	Commercial item	—	Conducts water away from pump
46	Solenoid oil valve	Commercial item	—	Starts oil flow to line-shaft bearings when motor is started
47	Sight-feed oil valve	Commercial item	—	Means of adjusting oil flow to line-shaft bearings
48	Tubing tension nut cap§	Bronze Cast iron	B145 A48 Class 30	Covers top of oil tube to prevent entrance of dust
49	Water-level indicator assembly	Commercial item	—	Determines water level in well
50	Enclosed line-shaft bearing	Bronze	B505, B584	Guides and supports shaft section; may couple connecting sections of enclosing tube
51	Shaft-enclosing tube	Steel	A53 Gr A A120	Encloses line shaft
52	Below-base discharge tee	Cast iron Steel	A48 Class 30 A120	Changes flow from vertical to horizontal when discharge is below surface; also forms part of column
53	Tubing adapter	Bronze	B505 or B584 ALY 836 ALY 838 ALY 844 ALY 848	Encloses shaft; adapts standard tube size to off-standard tube size
		Steel Cast iron	A120, A53 A48 Class 30	
54	Discharge case	Cast iron	A48 Class 30	Guides flow to pump column

55	Top bowl	Cast iron	A48 Class 30	Receives flow from top impeller and guides it to discharge case
56	Bypass seal§	Commercial item	—	Restricts leakage from bowls to oil tube; seals off passages from enclosing tube
57	Impeller seal ring§	Cast iron Bronze	A48 Class 30 B505 or B584 ALY 836 ALY 838 ALY 844 ALY 848 ALY 932 ALY 935 ALY 937 ALY 938 ALY 943 B148	Provides water seal at impeller
58	Suction-case sand collar§	Bronze	B505 or B584 ALY 836	Prevents sand from entering suction-case bearing
59	Suction-case plug	Malleable iron	A47	Plugs suction-case grease container
60	Oil-gauge assembly for motor bearings	Part of motor	—	Shows level of oil in motor-oil reservoir
61	Packing follower§	Cast iron	A48 Class 30	Tightens packing around enclosing tube
62	Below-base discharge head	Cast iron	A48 Class 30	Supports motor above foundation when discharge is below base
63	Tubing tension nut	Cast iron Bronze	A48 Class 30 B584 ALY 836 ALY 838 ALY 844 ALY 848	Maintains tension on shaft-enclosing tube
64	Lock nut for tubing tension nut	Cast iron	A48 Class 30	Locks tubing tension nut
65	Enclosing tube stabilizer	Rubber	—	Stabilizes shaft-enclosing tube

*See Figures 1 and 2.

†O.L.—oil lubricated.

‡W.L.—water lubricated.

§Optional—these items are not furnished by all manufacturers.

proper size to drive the pump continuously over the specified operating range without the load exceeding the nameplate rating of the motor. The motor shall be rated as drip proof with class B insulation and with a 1.15 service factor.

With an engine drive, the power shall be applied to the pump shaft through a right-angle gear drive. The connection to the vertical shaft shall be through a coupling or clutch in the gear head. The horizontal shaft shall rotate in the same direction as the engine drive, and shall be connected to the engine by a flexible shaft coupling.

An optional method of driving, for an engine or horizontal electric motor, shall be a belted drive—either a flat belt on a modified cylindrical pulley or a V-belt on a V-groove pulley.

Rotation of the vertical shaft shall be counterclockwise when viewed from above.

A thrust bearing of ample capacity to carry the weight of all rotating parts plus the hydraulic thrust at maximum operating conditions shall be incorporated into the driver. For antifriction bearings, the bearings shall be of such capacity that the AFBMA* calculated rating life (L_{10}) shall be no less than 8800 h. If the design and operating conditions are such that upthrust can occur, then proper provisions shall be made to accommodate the upthrust. This shall be done by the supplier.

A-4.1.3 Suction pipe and strainer. A strainer, if required, shall have a net inlet area equal to at least three times the suction pipe area. The maximum opening shall not be more than 75 percent of the minimum opening of the water passage through the bowl or impeller.

A-4.1.4 Shaft couplings. Line shafts shall be coupled with steel couplings that shall have a left-hand thread to tighten during pump operation. The maximum combined shear stress, determined by the following formula, shall not exceed 20 percent of the elastic limit in tension nor be more than 12 percent of the ultimate tensile strength of the shafting steel used.

$$S = \sqrt{\left[\frac{2F}{\pi (D^2 - d^2)} \right]^2 + \left[\frac{321,000P}{n (D^3 - d^3)} \right]^2} \quad (\text{Eq 2})$$

Where:

- S = combined shear stress, in pounds per square inch
- F = total axial thrust of the shaft, including hydraulic thrust plus the weight of the shaft and all rotating parts supported by it, in pounds
- D = outside diameter of the coupling, in inches
- d = inside diameter of the coupling at the root of the threads, in inches
- P = power transmitted by the shaft, in horsepower
- n = rotational speed of the shaft, in revolutions per minute

*Anti-Friction Bearing Manufacturers Association, 1101 Connecticut Ave. N.W., Suite 700, Washington, DC 20036.

NOTE: in. $\times$ 25.40 = mm; lb $\times$ 0.454 = kg; psi $\times$ 6.895 = kPa; hp $\times$ 0.746 = kW; rpm $\times$ 0.0167 = rps.

A-4.1.5 *Bowl assembly shaft.* The bowl assembly shaft shall have a surface finish not to exceed RMS-40 (ANSI B46.1*), and it shall be supported by bearings above and below each impeller. The minimum size of the shaft shall be determined by the following formula for steady loads of diffuser-type pumps with shaft in tension due to hydraulic thrust:

$$D^3 = \frac{16}{\pi S} \sqrt{\left(\frac{FD}{8}\right)^2 + \left(\frac{369,000P}{2\pi n}\right)^2} \quad (\text{Eq 3})$$

or

$$S = \sqrt{\left(\frac{2F}{\pi D^2}\right)^2 + \left(\frac{321,000P}{nD^3}\right)^2} \quad (\text{Eq 4})$$

or

$$P = \frac{nD^3}{321,000} \sqrt{S^2 - \left(\frac{2F}{\pi D^2}\right)^2} \quad (\text{Eq 5})$$

Where:

- D = shaft diameter at the root of the threads or the minimum diameter of any undercut, in inches
- S = combined shear stress, in pounds per square inch
- F = total axial thrust of the shaft, including hydraulic thrust plus the weight of the shaft and all rotating parts supported by it, in pounds
- P = power transmitted by the shaft, in horsepower
- n = rotational speed of the shaft, in revolutions per minute

NOTE: in. $\times$ 25.40 = mm; lb $\times$ 0.454 = kg; psi $\times$ 6.895 = kPa; hp $\times$ 0.746 = kW; rpm $\times$ 0.0167 = rps.

The maximum combined shear stress S shall not exceed 30 percent of the elastic limit in tension or be more than 18 percent of the ultimate tensile strength of the shafting steel used.

The straightness and machining tolerances shall be the same as those given in Sec. A-4.2.3 or Sec. A-4.3.3.

*ANSI B46.1—Surface Texture (Surface Roughness, Waviness, and Lay). Available from American National Standards Institute, 1430 Broadway, New York, NY 10018.