ANSI/HI 2.4-2008

American National Standard for

Rotodynamic (Vertical) Pumps

for Manuals Describing Installation, Operation, and Maintenance

ANSI/HI 2.4-2008

Hydraulic Institute

6 Campus Drive
First Floor North
Parsippany, New Jersey
07054-4406
www.Pumps.org

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Sponsor

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Approved December 4, 2008

American National Standards Institute, Inc.

American National Standard

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Foreword (Not part of Standard)

Scope

The purpose and aims of the Institute are to promote the continued growth of pump knowledge for the interest of pump manufacturers and to 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 Hydraulic Institute. It will direct all such questions to the appropriate technical committee for provision of a suitable answer.

If a dispute arises regarding contents of an Institute publication or an answer provided by the Institute to a question such as indicated above, the point in question shall be referred to the Executive Committee of the Hydraulic Institute, which then shall act as a Board of Appeals.

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 using the ANSI canvass procedure.

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 for this Standard was achieved by use of the Canvass Method

The following organizations, recognized as having an interest in the standardization of vertical pumps, 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.

Bantrel
City of Atlanta
GIW Industries, Inc.
Grundfos Pumps Corporation
Healy Engineering
J.A.S. Solutions Ltd.
John Crane Inc.
Malcolm Pirnie North America
Marathon Petroleum Company LLC
Peerless Pump Company
Pentair Water
Sulzer Pumps (US) Inc.
Weir Floway, Inc.
Weir Minerals North America

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 the standard was approved, the committee had the following members:

Chair – Fred Walker, Weir Floway, Inc.
Vice-chair – Roger Turley, Flowserve Pump Division

Committee Members	Company
Edward Allis	Peerless Pump Company
James Bonifas	Emerson Motors / US Motors
Michael Derr	Afton Pumps
Ralph Gabriel	John Crane, Inc.
Richard O'Donnell	ITT - Industrial Process
John Phillips	Fairbanks Morse Pump Corporation
Aleksander Roudnev	Weir Minerals North America
Arnold Sdano	Fairbanks Morse Pump Corporation
Constantino Senon	MWH Americas, Inc.

Other Contributors	Company
William Beekman	Weir Floway, Inc.
Randal Ferman	Flowserve Pump Division
Allen Hobratschk	National Pump Company, LLC
Al Iseppon	Pentair Water
Peter Noll	Peerless Pump Company
Kees van der Sluijs	Flowserve Pump Division

2.4 Manuals describing installation, operation, and maintenance

2.4.1 Introduction

The normative portion of this Standard is prescriptive in nature and thereby mandatory for compliance to this Standard; it includes a standard outline for manufacturers' installation, operation, and maintenance (IOM) manuals.

Appendix A, a collection of IOM reference information arranged per the new standard outline, is informative and not mandatory for compliance to this Standard. Pump users should refer to the manufacturers' IOM manuals for IOM information specific to their equipment.

The objective of this Standard was to establish a standard outline for IOM manuals in order to help pump users locate IOM information.

2.4.2 Scope

This Standard applies to IOM manuals for rotodynamic (vertical) pumps including the following:

a) Vertical, diffuser, deep well (VS1).

b) Vertical, diffuser, short set (VS1 and VS3).

c) Vertical, diffuser, can-mounted (VS6).

d) Vertical, diffuser, submersible, deep well (VS0).

e) Vertical, diffuser, submersible, short set (VS0).

f) Vertical, diffuser, double casing, in-line, floor mounted (VS8).

g) Vertical, volute, double suction, wet pit (VS2).

h) Vertical, volute, double suction, can type (VS7).

i) Vertical, volute, multistage axial split, can type (VS7a).

The standard outline shall be used when writing IOM manuals. The subtopics within each section shall be addressed when appropriate for the specific pump.

Installation, operation, and maintenance manuals shall be comprised of 10 sections. Each section must appear in the IOM manual and in the sequence shown. The topics that appear under each section may be combined and/or arranged to meet the specific needs of the product being addressed. Not all of the topics listed are applicable for all products and therefore, need not be included in every IOM manual for all products.

2.4.3 Standard outline for IOM manuals

A.1 Introduction and safety

A.1.1 Marking and approvals (CE[1], ATEX[2], etc.)
A.1.2 Safety
A.1.2.1 Explanation of designations (safety terminology and symbols)
A.1.2.2 General guidelines
A.1.2.3 Safety labels

[1] Conformité Européenne (European health and safety product label).
[2] ATmosphere EXplosibles.

A.1.2.4 Material safety data sheets (MSDSs)
A.1.2.5 Noise level data
A.1.2.6 Rigging and lifting

A.2. Transport and storage
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A.2.2 Rigging and lifting
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A.2.4 Unpacking
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A.3.2 Nomenclature
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A.4.3.1 Construction
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A.4.5.2 Grouting
A.4.6 Piping and connections
A.4.6.1 Piping general guidelines
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A.4.6.3 Check valves
A.4.6.4 Strainers
A.4.7 Clearance setting
A.4.8 Alignment
A.4.8.1 Auxiliary (driver, coupling, etc.)
A.4.8.2 Hot alignment considerations (prealignment and realignment)
A.4.9 Lubrication, priming, and cooling systems
A.4.10 Electrical
A.4.11 Control, monitoring, and alarm equipment (hardware)

A.5. Commissioning, start-up, operation, and shut-down
A.5.1 Lubrication
A.5.2 Rotation
A.5.3 Guarding
A.5.4 Checklist – start-up
A.5.4.1 System flushing
A.5.4.2 Priming by ejector or exhauster
A.5.4.3 Priming by vacuum pumps
A.5.4.4 Shaft sealing settings and adjustments (mechanical seals, packing, etc.)
A.5.5 Start-up, operation, and shut-down
A.5.5.1 Minimum continuous flow
A.5.5.2 Minimum thermal flow
A.5.5.3 Lubrication system settings

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Appendix A

Installation, Operation, and Maintenance Manual Reference Information

This appendix is not part of this Standard, but is presented to help the user with factors referenced in the Standard.

A.1 Introduction and safety

Vertical pumps, when properly installed and operated, and when given reasonable care and maintenance, will operate satisfactorily for a long period of time. The following paragraphs outline the general principles that should be considered to ensure trouble-free pump operation.

Vertical pumps are built in a wide variety of designs and for many different services. The manufacturer's instruction book should be studied carefully and followed, as there may be specific requirements for a particular machine or application that cannot be covered in a general discussion.

The installation and service manual and/or special instructions included in the shipment should be read thoroughly before installing or operating the equipment. All instructions regarding maintenance should be retained for reference.

A.1.1 Marking and approvals (CE, ATEX, etc.)

It is a legal requirement that machinery and equipment put into service within certain regions of the world shall conform to the applicable CE marking directives covering machinery and, where applicable, low-voltage equipment, Electromagnetic Compatibility (EMC), Pressure Equipment Directive (PED), and equipment for potentially explosive atmospheres (ATEX).

Where applicable the directives and any additional approvals cover important safety aspects relating to machinery and equipment and the satisfactory provision of technical documents and safety instructions. Where applicable this document incorporates information relevant to these directives and approvals. To confirm the approvals applying and if the product is CE marked, check the serial number plate markings and the certification (see Section A.9).

A.1.2 Safety

Legal requirements and local regulations may differ substantially with regard to particular safety requirements and may be regularly modified by relevant authorities without notice. As a consequence, applicable laws and regulations should be consulted to ensure compliance. The following cannot be guaranteed as to its completeness or continuing accuracy.

A.1.2.1 Explanation of designations (safety terminology and symbols)

These user instructions contain specific safety markings where nonobservance of an instruction would cause hazards. The specific safety markings are:

 DANGER — This symbol indicates electrical safety instructions where noncompliance will involve a high risk to personal safety or the loss of life.

 This symbol indicates safety instructions where noncompliance would affect personal safety and could result in loss of life.

This symbol indicates "hazardous and toxic fluid" safety instructions where noncompliance would affect personal safety and could result in loss of life.

CAUTION This symbol indicates safety instructions where noncompliance will involve some risk to safe operation and personal safety and/or would damage the equipment or property.

This symbol indicates explosive atmosphere zone marking according to ATEX. It is used in safety instructions where noncompliance in the hazardous area would cause the risk of an explosion.

Note: This sign is not a safety symbol but indicates an important instruction in the assembly process.

A.1.2.2 General guidelines

These instructions must always be kept close to the product's operating location or directly with the product.

Products are designed, developed, and manufactured with state-of-the-art technologies in modern facilities. The unit is produced with great care and commitment to continuous quality control, utilizing sophisticated quality techniques and safety requirements.

The manufacturer is committed to continuous quality improvements and being of service for any further information about the product in its installation and operation or about its support products, repair, and diagnostic services.

These instructions are intended to facilitate familiarization with the product and its permitted use. Operating the product in compliance with these instructions is important to help ensure reliability in service and avoid risks. The instructions may not reflect all current legal requirements and local regulations; ensure that such requirements and regulations are observed by all, including those installing the product. Always coordinate repair activity with operations personnel, and follow all plant safety requirements and applicable safety and health laws/regulations.

These instructions should be read prior to installing, operating, using, and maintaining the equipment in any region worldwide. The equipment must not be put into service until all the conditions relating to safety noted in the instructions have been met.

Information in these user instructions is believed to be reliable. In spite of all the efforts to provide sound and necessary information, the content of this manual may appear insufficient and is not guaranteed as to its completeness or accuracy.

Products are manufactured to exacting international quality management system standards as certified and audited by external quality assurance organizations. Genuine parts and accessories have been designed, tested, and incorporated into the products to help ensure their continued product quality and performance in use. Incorrect incorporation of substitute parts from other suppliers and accessories may adversely affect the performance and safety features of the products. The failure to properly select, install, or use authorized parts and accessories is considered misuse. Damage or failure caused by misuse is not covered by the warranty. In addition, modification of products or removal of original components may impair the safety of these products in their use.

The product must not be operated beyond the parameters specified for the application. If there is any doubt as to the suitability of the product for the application intended, contact the manufacturer for advice, quoting the serial number.

If the agreed on conditions of service are going to be changed (for example, liquid pumped, temperature, or duty), it is recommended that the user seek the manufacturer's written agreement before start-up.

A.1.2.3 Safety labels

A.1.2.3.1 Personnel qualification and training

All personnel involved in the operation, installation, inspection, and maintenance of the unit must be qualified to carry out the work involved. If the personnel in question do not already possess the necessary knowledge and skill, appropriate training and instruction must be provided.

If required, the operator may commission the manufacturer/supplier to provide applicable training.

Always coordinate repair activity with operations and health and safety personnel, and follow all plant safety requirements and applicable safety and health laws and regulations.

A.1.2.3.2 Safety action

This is a summary of conditions and actions to prevent injury to personnel and damage to the environment and to equipment.

⚠ DANGER NEVER DO MAINTENANCE WORK WHEN THE UNIT IS CONNECTED TO POWER

⚠ GUARDS MUST NOT BE REMOVED WHILE THE PUMP IS OPERATIONAL

⚠ DRAIN THE PUMP AND ISOLATE PIPEWORK BEFORE DISMANTLING THE PUMP
The appropriate safety precautions should be taken where the pumped liquids are hazardous.

⚠ FLUORO-ELASTOMERS (When fitted.)
When a pump is subjected to temperatures over 250 °C (482 °F), partial decomposition of fluoro-elastomers (for example, Viton) will occur. In this condition, these are extremely dangerous and skin contact must be avoided.

⚠ HANDLING COMPONENTS
Many precision parts have sharp corners, thus wearing appropriate safety gloves and equipment is required when handling these components. To lift heavy pieces above 25 kg (55 lb), use a crane appropriate for the mass and in accordance with current local regulations.

⚠ THERMAL SHOCK
Rapid changes in the temperature of the liquid within the pump can cause thermal shock that can result in damage or breakage of components and should be avoided.

⚠ APPLYING HEAT TO DISASSEMBLE A PUMP

If heat is used to disassemble a pump, then it must be applied with great care. For example, there may be occasions when the impeller has either been shrunk to fit onto the pump shaft or has become difficult to remove due to corrosive products. Before applying heat to remove an impeller, ensure any residual hazardous liquid trapped between the impeller and pump shaft is thoroughly drained out through the impeller keyway to prevent an explosion or emission of toxic vapor.

Because impeller design varies, so does temperature, location, and duration of heat application. Contact the manufacturer for help.

UNDER NO CIRCUMSTANCE SHOULD HEAT BE USED TO EXPAND OR CUT A THREADED IMPELLER FROM THE SHAFT. Personal injury and damage to equipment could occur as a result of an explosion. A shaft wrench may be provided to assist with impeller removal. A release collar may also be provided to assist with impeller removal.

A release collar will typically be provided for larger pumps with impeller thread sized 125 mm (5 in) and greater.

⚠ HOT (and COLD) PARTS

If hot or freezing components or auxiliary heating supplies can present a danger to operators and persons entering the immediate area, then action must be taken to avoid accidental contact. If complete protection is not possible, the machine access must be limited to maintenance staff only, with clear visual warnings and indicators to those entering the immediate area. Note: Bearing housings must not be insulated and drive motors and bearings may be hot.

If the temperature is greater than 68 °C (154 °F) or below 5 °C (41 °F) in a restricted zone, or exceeds local regulations, action as above shall be taken.

HAZARDOUS LIQUIDS

When the pump is handling hazardous liquids, care must be taken to avoid exposure to the liquid by appropriate setting of the pump, limiting personnel access, and by operator training. If the liquid is flammable and/or explosive, strict safety procedures must be applied.

Gland packing must not be used when pumping hazardous liquids.

⚠ CAUTION PREVENT EXCESSIVE EXTERNAL PIPE LOAD

Do not use pump as a support for piping. Do not mount expansion joints, unless allowed by the manufacturer in writing, so that their force, due to internal pressure, acts on the pump flange.

⚠ CAUTION ENSURE CORRECT LUBRICATION

(See Section A.5, Commissioning, start-up, operation, and shut-down.)

⚠ CAUTION START THE PUMP AT REDUCED SPEED OR WITH THE OUTLET VALVE PARTLY OPENED

(Unless otherwise instructed at a specific point in the user instructions.)

This is recommended to minimize the risk of overloading and damaging the pump motor at full or zero flow. Pumps may be started with the valve further open only on installations where this situation cannot occur. The pump outlet control valve may need to be adjusted to comply with the duty following the run-up process. (See Section A.5, Commissioning, start-up, operation, and shut-down.)

⚠ CAUTION NEVER RUN THE PUMP DRY

⚠ CAUTION INLET VALVES TO BE FULLY OPEN WHEN PUMP IS RUNNING

Running the pump at a flow rate below the manufacturer's recommended minimum flow rate will cause damage.

CAUTION DO NOT RUN THE PUMP CONTINUOUSLY OUTSIDE THE ALLOWABLE OPERATING REGION
Operating at a flow rate higher than normal or at a flow rate with no backpressure on the pump may overload the motor and cause cavitation. Low flow rates may cause a reduction in pump/bearing life, overheating of the pump, instability, and cavitation/vibration.

A.1.2.3.2.1 Products used in potentially explosive atmospheres

Measures are required to:

- Avoid excess temperature
- Prevent buildup of explosive mixtures
- Prevent the generation of sparks
- Prevent leakages
- Maintain the pump to avoid hazard

The following instructions for pumps and pump units, when installed in potentially explosive atmospheres, must be followed to help ensure explosion protection. Both electrical and nonelectrical equipment must meet the requirements of European Directive 94/9/EC.

A.1.2.3.2.2 Scope of compliance

Use equipment only in the zone for which it is appropriate. Always check that the driver, drive coupling assembly, seal, and pump equipment are suitably rated and/or certified for the classification of the specific atmosphere in which they are to be installed.

Where the manufacturer has supplied only the bare shaft pump, the Ex rating applies only to the pump. The party responsible for assembling the pump set shall select the coupling, driver, and any additional equipment, with the necessary CE Certificate/Declaration of Conformity establishing it is suitable for the area in which it is to be installed.

The output from a variable frequency drive (VFD) can cause additional heating effects in the motor, and the ATEX Certification for the motor must state that it covers the situation in which electrical supply is from the VFD. This particular requirement still applies even if the VFD is in a safe area.

A.1.2.3.2.3 Marking

An example of ATEX equipment marking is shown below. The actual classification of the pump will be engraved on the nameplate.

II 2 GD c IIC 135°T (T4)

Equipment Group
I = Mining
II = Nonmining

Category
2 or M2 = High level protection
3 = Normal level of protection

Gas and/or Dust
G = Gas
D = Dust

c = Constructional safety
(in accordance with EN 13463-5)

Gas Group (Equipment Category 2 only)
IIA – Propane (typical)
IIB – Ethylene (typical)
IIC – Hydrogen (typical)

A.1.2.3.2.4 Avoiding excessive surface temperatures

ENSURE THE EQUIPMENT TEMPERATURE CLASS IS SUITABLE FOR THE HAZARD ZONE
Pumps have a temperature class as stated in the Ex rating on the nameplate. These are based on a maximum ambient temperature of 40 °C (104 °F). Refer to the manufacturer for higher ambient temperatures.

The surface temperature on the pump is influenced by the liquid handled. The maximum permissible liquid temperature depends on the temperature class and must not exceed the values in the table that follows. The temperature rise at the seals and bearings due to the minimum permitted flow rate is taken into account in the temperatures stated.

Surface temperatures above 54 °C (130 °F) can cause irreversible skin damage and, therefore, require insulation to protect personnel.

Temperature class (reference NEC[a], CEC[b], IEC[c], CENELEC[d])	Maximum surface temperature permitted	Temperature limit of liquid handled (depending on material and construction variant – check which is lower)
T6	85 °C (185 °F)	Consult manufacturer
T5	100 °C (212 °F)	Consult manufacturer
T4	135 °C (275 °F)	115 °C (239 °F)
T3	200 °C (392 °F)	180 °C (356 °F)
T2	300 °C (572 °F)	275 °C (527 °F)
T1	450 °C (842 °F)	400 °C (752 °F)

[a] National Electrical Code.

[b] Commission of the European Communities.

[c] International Electrotechnical Commission.

[d] Comité Européen de Normalisation Électrotechnique (European Committee for Electrotechnical Standardization).

The responsibility for compliance with the specified maximum liquid temperature is with the plant operator.

Note: Temperature classification *Tx* is used when the liquid temperature varies and the pump could be installed in different hazardous atmospheres. In this case the user is responsible for ensuring that the pump surface temperature does not exceed that permitted in the particular hazardous atmosphere.

If an explosive atmosphere exists during the installation, then do not attempt to check the direction of rotation by starting the pump unfilled. Even a short run time may give a high temperature resulting from contact between rotating and stationary components.

Where there is any risk of the pump being run against a closed valve generating high liquid and casing external surface temperatures, it is recommended that users fit an external surface temperature protection device.

Avoid mechanical, hydraulic, or electrical overload by using motor overload trips, temperature monitor, or a power monitor. Make routine vibration measurements. In dirty or dusty environments, regular checks must be made and dirt removed from areas around close clearances, bearing housings, and motors.

A.1.2.3.2.5 Preventing the buildup of explosive mixtures

ENSURE THE PUMP IS PROPERLY FILLED AND VENTED AND DOES NOT RUN DRY
Ensure the pump and relevant suction and discharge pipeline system is completely filled with liquid at all times during the pump operation, so that an explosive atmosphere is prevented. In addition, it is essential to make sure that seal chambers, auxiliary shaft seal systems, and any heating and cooling systems are properly filled.

If the operation of the system does not allow for this condition, then it is recommended to fit an appropriate dry-run protection device (for example, liquid detection or a power monitor).

The surrounding area must be well ventilated to avoid potential hazards from fugitive emissions of vapor or gas to the atmosphere.

A.1.2.3.2.6 Preventing sparks

To prevent a potential hazard from mechanical contact, the coupling guard must be nonsparking and antistatic for Category 2 (see Section A.1.2.3.2.3).

To avoid the potential hazard from random induced current generating a spark, the ground contact on the baseplate must be used.

Avoid electrostatic charge: Do not rub nonmetallic surfaces with a dry cloth; ensure cloth is damp.

The coupling must be selected to comply with 94/9/EC and correct alignment must be maintained.

A.1.2.3.2.7 Preventing leakage

The pump must only be used to handle liquids for which it has been approved to have the correct corrosion resistance.

Avoid entrapment of liquid in the pump and associated piping due to closing of suction and discharge valves, which could cause dangerous excessive pressures to occur if there is heat input to the liquid. This can occur if the pump is stationary or running.

Bursting of liquid-containing parts due to freezing must be avoided by draining or protecting the pump and auxiliary systems.

Where there is the potential hazard of a loss of a seal barrier fluid or external flush, the fluid must be monitored.

If leakage of liquid to atmosphere can result in a hazard, then the installation of a liquid detection device is recommended.

A.1.2.3.2.8 Maintenance to avoid the hazard

PROPER MAINTENANCE IS REQUIRED TO AVOID POTENTIAL HAZARDS THAT HAVE A RISK OF EXPLOSION

The responsibility for compliance with maintenance instructions is with the plant operator.

To avoid potential explosion hazards during maintenance, the tools, cleaning, and painting materials used must not give rise to sparking or adversely affect the ambient conditions. Where there is a risk from such tools or materials, maintenance must be conducted in a safe area.

It is recommended that a maintenance plan and schedule be adopted and include the following (see Section A.6, Maintenance):

a) Any auxiliary systems installed must be monitored to ensure they function correctly.

b) Gland packings must be adjusted correctly to give visible leakage and concentric alignment of the gland follower to prevent excessive temperature of the packing or the follower.

c) Check for any leaks from gaskets and seals. The correct functioning of the shaft seal must be checked regularly.

d) Check bearing lubricant level, and verify if the hours run show a lubricant change is required.

e) Check and verify that the duty condition is in the safe operating range for the pump.

f) Check vibration, noise level, and surface temperature at the bearings to confirm satisfactory operation.

g) Check that dirt and dust are removed from areas around close clearances, bearing housings, and motors.

h) Check coupling alignment and realign if necessary.

A.1.2.4 Material safety data sheet (MSDS)

Note: As a matter of general practice, material safety data sheets are not supplied with the pumps. If the contract requires them, they will be placed in Section 10 (Other relevant documentation and manuals) of the IOM manual.

A.1.2.5 Noise level data

CAUTION Whenever pump noise level exceeds 85 dBA, attention must be given to the prevailing health and safety laws and regulations for the location to limit the exposure of plant operating personnel to the noise. The typical safety level requires limiting the sound level to 90 dBA for 8 hours of exposure. Thereafter, the allowable dBA value increases 5 dBA for each halving of exposure time. The usual approach is to control exposure time to the noise or to enclose the machine to reduce emitted sound.

You may have already specified a limiting noise level when the equipment was ordered; however, if no noise requirements were defined, then machines above a certain power level will exceed 85 dBA. In such situations, consideration must be given to the fitting of an acoustic enclosure to meet local regulations. Pump noise level is dependent on a number of factors, including the type of driver fitted, the operating capacity, pipework design, and acoustics of the building.

A.1.2.6 Rigging and lifting

DANGER See Section A.2.2 for proper instructions for safely rigging and lifting the equipment.

A.2 Transport and storage

Where applicable and appropriate for the pump types, unless specifically noted:

A.2.1 Transport and handling requirements

The pump has been prepared for shipment at the factory in such a way as to minimize potential damage due to handling and transport. The equipment should not be subjected to excessive g-forces during the handling or transport.

A.2.2 Rigging and lifting (for lineshaft-style pumps types VS1, VS2, VS3, VS6, and VS7)

The following instructions are for the safe handling of the pump. When shipment is received, extreme care should be exercised during unloading. Heavy parts should be skidded to the ground if lifting equipment is not available. It is recommended a forklift or crane be used to unload equipment. Do not drop the unit, or any parts, as damage may result that makes proper assembly or operation of the unit impossible. Particular care and close adherence to the manufacturer's recommendations are required when unloading long, slender components, such as shafting. Improper placements of slings or chains can result in deformation or other serious damage.

For a relatively short pump, it may be convenient to install the column and shaft sections directly from the transporting vehicle. This might be true, for example, for a pump whose overall length is 9 m (30 ft) or less.

For pumps that will be installed in a vertical position, all the parts should be located close to the location where the pump will be installed. Clear a large area around the well or sump as a working space for laying out the pump parts to prepare them for installation. Arrange timbers parallel on the ground in the cleared area to support the pump column and shafts.

Prior to installation, take inventory (see Section A.2.3 Inspection and damage reporting below) of the shipment to ensure that the parts received match the list of parts on your order. If the shaft sections were shipped crated, one end of the crate may be opened for a count. Leave the rest of the crate intact to protect the shaft sections during unloading.

It is strongly recommended that pump parts too heavy to be lifted by hand be lifted from the transporting vehicle with a suitable hoist. If this is impossible, they may be unloaded by *slowly* and *carefully* skidding them down an incline. Lifting chains or cables should not be allowed to contact machined surfaces. If the shaft sections were shipped crated, they should be unloaded from the vehicle in the crate and not be uncrated until ready for installation.

Parts provided with lifting lugs, lifting ears, or eyebolts should be lifted by these points only.

Column, tube, and shaft sections should be handled with extreme care. These parts are machined to achieve precision alignment. If dropped, bent, or otherwise mistreated, misalignment and pump malfunction will occur. Shafts are especially sensitive to abuse. Bent or dropped shafts should not be used; they are certain to cause pump failure.

Certain extra-long, relatively small-diameter bowl units may be shipped attached to skids bearing a special notation such as:

⚠ CAUTION DO NOT REMOVE THIS PROTECTIVE SKID UNTIL THE BOWL UNIT IS IN A VERTICAL POSITION, READY TO BE INSTALLED IN THE WELL OR SUMP. RETAIN THIS SKID FOR USE WHEN REMOVING THE BOWL UNIT FROM THE WELL OR SUMP.

Basket strainers may be shipped loose from the suction manifold to avoid damage to the strainer when lifting the pump.

A.2.3 Receipt, inspection, and damage reporting

Vertical turbine pumps are normally shipped without the driver attached. The pump itself may be shipped assembled (typically 9 m [30 ft] or less in length) or as a bowl assembly, column and shafting, discharge head, and driver. It is important that all the components for a pump unit be identified and properly stored until installation is to be done. There may be many small parts (such as lineshaft couplings) that are best left in their shipping container until installation.

On receipt of the pump, immediately check for shortages of parts and damages. Prompt reporting to the carrier's agent, with notations made on the freight bill, will expedite satisfactory adjustment by the carrier.

Immediately on receipt of the pump equipment, check carefully to see that all items have been received and are in undamaged condition. Report any shortage or damage to the transport company handling the shipment and to the equipment manufacturer, noting the extent of damage or shortage on the freight bill and bill of lading. This should be done at once. Do not unpack any more than required to verify that the equipment is complete and undamaged unless installation is to be done immediately. Do not leave the pump unit or any accessories exposed to weather or construction hazards, which may cause damage to the equipment. (See Storage below.)

A.2.4 Unpacking

As stated above, do not unpack any more than required to verify that the equipment is complete and undamaged unless installation is to be done immediately. Check all packing material that is to be discarded to verify that no parts or instructions are being accidentally discarded as well. It is best to leave small parts in their shipping container until installation so they do not get lost. Make certain that accessories with a pump unit are clearly marked showing which pump unit they are to be used with. Clean all parts of all dirt, packing materials, and other foreign matter. Clean all noncoated machined surfaces. If the pump is to be installed immediately, then clean all coated machined surfaces too. Remove any rust spots found on the machined surfaces with a fine emery cloth. Clean all threaded connections and any accessory equipment.

A.2.5 Storage

The standard packaging is suitable for protection during shipment and during covered storage at the jobsite for a short period between installation and start-up. The preservatives applied at the factory have an effective life of two to three months from date of shipment, depending on the severity of the environment in which the equipment is stored.

A.2.5.1 Recommended storage environment

- Equipment should be protected from flooding and harmful chemical vapors.

- Whether indoors or out, the area of storage should be free from ambient vibration. Excessive vibration can cause bearing damage.

- Precautions should be taken to prevent rodents, snakes, birds, or other small animals from nesting inside the equipment. In areas where they are prevalent, precautions should also be taken to prevent insects, such as mud dauber and wasps, from gaining access to the interior of the equipment.

- Controlled storage facilities should be maintained with the ambient temperature 5.5 °C (10 °F) above the dew point temperature, relative humidity less than 50%, and little or no dust. If these requirements cannot be met, the pump is to be considered in uncontrolled storage.

- For uncontrolled storage periods of six months or less, the equipment is to be inspected weekly to ensure that all preservatives are intact and internals are protected.

- Periodically inspect and recoat the equipment with water-displacement rust inhibitors (Rust-Ban 392 or equal), crusting grease (Rust-Ban 326 or equal), vapor phase inhibitor (Shell VPI-260 or equal), or rust-preventative coating (Rust-Ban 373 or equal).

A.2.5.2 Uncontrolled storage moisture protection

- All pipe threads and flanged pipe covers are to be sealed with tape. In addition, 4.5 kg (10 lb) of moisture-absorbing desiccant or 2.3 kg (5 lb) of vapor phase inhibitor crystals should be placed near the center of pump.

- If the pump is assembled, then place an additional 0.5 kg (1 lb) (securely fastened) in the discharge of the pump.

- Also install a moisture indicator near the perimeter of the pump.

- Cover the equipment with 0.15-mm (0.006-in) minimum thickness black polyethylene or equal and seal it with tape. Provide a small ventilation hole approximately 12.7 mm (0.5 in) in diameter.

- Provide a roof or shed shelter for protection from direct exposure to the elements.

- If equipped, connect space heaters on equipment such as motors, engines, or controls.

A.2.5.3 Short-term storage

The pump and equipment, as shipped, have adequate protection for short-term (up to three months) storage in a covered, dry, and ventilated location at the jobsite prior to installation.

- Remove and discard stuffing-box packing, if pump is packed type. Fill the stuffing box with a crusting grease (Rust-Ban 326 or equal), then pack the end of the stuffing box with rolled vapor phase inhibitor paper and seal with weatherproof tape.

- Dry pump internals and spray the liquid end with a water-displacement rust inhibitor (Rust-Ban 392, Crown 6011, Arma 245, Ensis fluid 254, Sunkote 1303, or equal).

- Enclose vapor inhibitor in pump internals (Shell VPI 260 or equal).

- Apply a film of compatible lube oil over the water-displacement rust preventative. A compatible lube oil is Rust-Ban 632 or equivalent.

- After the pump has been thoroughly drained, cover the pump suction and discharge flanges with full gasket material and blank off these openings with metal blank flanges and a minimum of four full-sized bolts. Cover the pump stuffing-box opening with a nonhygroscopic tape. If packed-type pump, the packing gland may be left on the pump shaft, but should be wired or otherwise securely fastened in position. If mechanical seals have been used, then the annular opening between gland plate and shaft should be closed by a removable sealing ring supplied by the pump original equipment manufacturer (OEM) to exclude airborne dust. Additionally, all connections in the seal cartridge must be plugged or sealed.

- All exposed machined surfaces should be thoroughly coated with a firm film rust-preventative material (Rust-Ban 373, CRC-SP-350, Enis fluid 264, Protec 612801, or equal) that is readily removable with a petroleum distillate product.

- All exposed painted surfaces should be dry, clean, and free of grease and other contaminates.

- The pump should be covered with a weather-resistant cover of waterproof paper or plastic to prohibit the buildup of dirt and dust accumulations.

- The pump should be inspected at regular periods during storage, and the pump shaft should be rotated by hand at intervals of approximately four to six weeks.

- To place the pump in operation, all protective coverings and coatings should be properly removed. If packed-type pump, then repack with the proper number of packing rings in each stuffing box in accordance with normal repair and maintenance instructions furnished with the pump.

- Rotate pump shaft several revolutions at least once per week to coat the bearing with lubricant and to retard oxidation and corrosion, flat spots, and staining.

- Long-term storage procedures should be followed as detailed by the OEM when the start-up of equipment is made over three months from the date of shipment from the factory.

A.2.5.4 Long-term storage

If the equipment will be subject to extended (more than three months) storage prior to installation and commissioning, then the standard warranty of the equipment may be affected. At the time of pump specification and/or order placement, the equipment manufacturer should be advised about the extended storage duration so that special long-term storage protection can be provided for the equipment prior to shipping to the jobsite. Periodic rotation of the pump and driver shaft is recommended during long-term storage (consult the equipment manufacturer as to the frequency), and inspection of the equipment by a factory representative prior to start-up is normally required to ensure equipment integrity and compliance with warranty requirements.

A.2.6 Disposal of packaging materials

Most of the materials supplied in the pump unit are suitable for recycling. Please conserve our natural resources and recycle these materials.

A.3 Product description

A.3.1 Configuration

There is an identification plate on each pump. The pump rating plate gives identification and rating information. See Figure A.1 for an example. Permanent records for this pump are kept by the serial number, which should be referenced with all correspondence and spare parts orders.

When a driver is supplied, it will also have an identification plate. When requesting information on the driver, both the driver serial number and the pump serial number will be required.

A.3.2 Nomenclature

A.3.2.1 Nameplate information

Information on the nameplate may include the following:

- Pump manufacturer and location
- Pump size/model
- Serial number
- Rated flow
- Rated head
- Rated rpm
- Impeller diameter

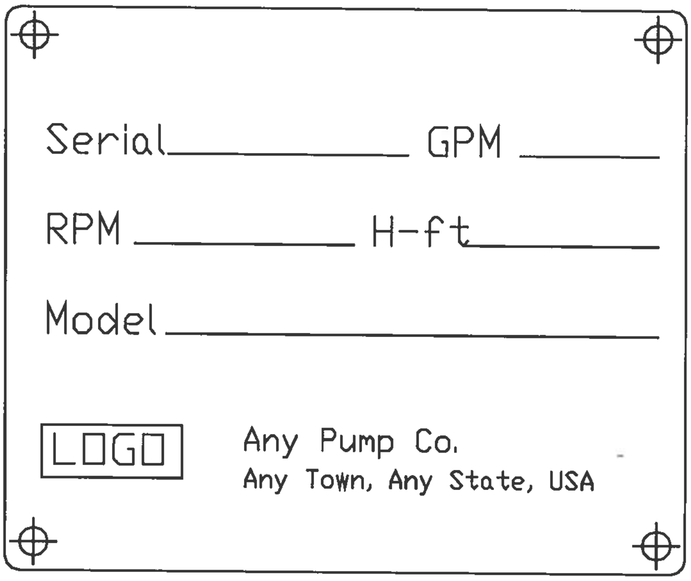


Figure A.1 — Identification plate

A.3.2.2 Pump

The pump size/model can be given in many different formats by different manufacturers. One style is to identify the size/model with a number and letter(s), followed by a number, for example, 14A-4. These would represent the nominal bowl diameter or well size the bowl assembly would go into, the series of pump, and the number of stages. Another style would include letters to signify other features, such as nominal bowl diameter, impeller type, bowl type, and number of stages. An example is 12EJH-3. Still others may add to that the column and head size and the lineshaft diameter. An example would be an M 12 x 8 VTMC-3-1.0, where M is medium capacity, 12 is nominal bowl diameter, 8 is column and head size, VT is vertical turbine, M is medium capacity impeller, C is closed-type impeller, 3 is number of stages, and 1.0 is lineshaft diameter.

A.3.2.3 Parts

Refer to Section A.8 for a parts listing and cross-sectional drawing.

A.3.3 Auxiliaries

(The manufacturer will include information in this section regarding auxiliary equipment supplied with the pump unit.)

A.3.4 Support systems

(The manufacturer will include information in this section regarding any support systems supplied with the pump unit.)

A.4 Installation

A.4.1 Factory support requirements

It is recommended that the services of a manufacturer's erecting engineer be employed for supervising installation and start-up of the pumping equipment when such equipment is custom-engineered or of a costly, high-precision type. This is to ensure that the machinery is properly installed. The purchaser then also has the opportunity to review and see implemented factory-recommended instructions.

A.4.2 Location

For pumps that require assembly on site, a clean, drained area should be provided next to the point of installation, of adequate size for placing the pump components and driver in the sequence in which they will be installed. Protective covers should be left on all pump openings until the time of actual installation to prevent dirt and foreign objects from entering the pump. Protective coatings should likewise be left on machined surfaces to prevent rusting. For outdoor installations, the components should be covered with rainproof tarps during the period of installation for protection against the elements. This is particularly important during freezing conditions to prevent water from collecting in pump cavities and perhaps causing freezing damage.

All pumps require regular maintenance. It is therefore important to locate pump discharge piping (and suction piping when applicable), as well as auxiliary equipment and control and starting panels in such a manner that adequate access is provided for maintenance. Adequate floor space and working room should also be provided for repair, including parts placement.

To minimize frictional head loss, locate the pump so that it can be installed with a short and direct discharge pipe and with the least number of elbows and fittings. If practical, it should be placed so that it will be accessible for inspection during operation. The equipment selected should be compatible with the environment. Pumps and drivers, other than submersible types, and controls should be protected against flooding.

A.4.2.1 Checking wells

NOTE: This section applies to pump types VS0, VS1, VS2, and VS3.

When vertical pumps, either of the lineshaft or submersible type, are to be installed in wells, consideration should be given to the well before application and installation (see Figure A.2).

Installing a unit in a crooked well may bind and distort the pump column or pump-motor assembly and could result in malfunction. Well straightness should be in accordance with AWWA-A100. If straightness is in doubt, the well should be "gauged" prior to installation by lowering a dummy assembly, slightly longer and larger in diameter than the actual pump or pump-motor assembly, on a cable. Gauging is also important when a stepped well casing is used, with the lower part of the well casing having a smaller inside diameter.

Wells that have not been properly constructed or developed, or which produce sand, can be detrimental to a pump. If a well is suspected of producing an excessive amount of sand, a unit other than the production pump should be used to clear the well.

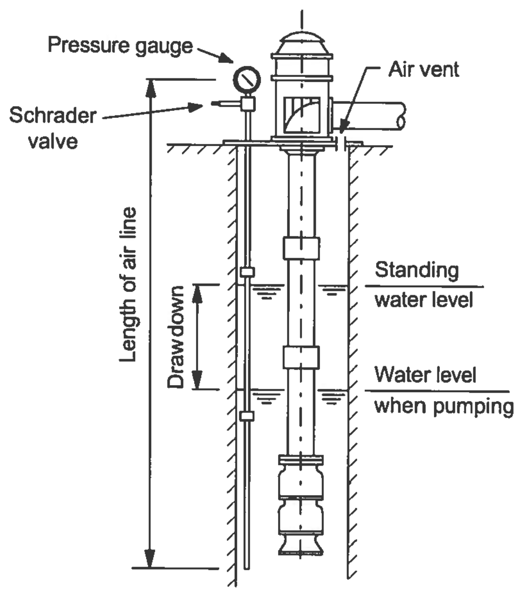


Figure A.2 — Typical deep well type installation

A.4.2.2 Checking wet pits

NOTE: This section applies to pump types VS0, VS1, VS2, and VS3.

Before starting the installation of pumps in an open pit, there are several checks that can be made. The configuration of the intake structure is now fixed and should be in conformance with the general guidelines provided in ANSI/HI 9.8, *Pump Intake Design*. Dimensional checks should be made as follows to preclude installation and servicing problems.

a) Length of pump versus depth of sump.

b) Correct fit of anchor bolts to soleplate and of the soleplate to the pump mounting base.

c) Satisfactory angular location of anchor bolts or correct lineup of discharge head to discharge piping.

d) Proper conduit location provided for driver.

e) Sufficient head room for handling.

A.4.3 Foundation

The mass of the foundation should be sufficient, preferably five times that of the pumping equipment, to form a permanent and rigid support for the baseplate. This is equally important whether the pump is installed over a pit or over a well. Baseplate and foundation bolt sizing is critical, particularly on high-pressure pumps, to adequately restrain reaction forces such as from directional flow change, system transients, and sudden valve closure. Foundation bolts should be selected for appropriate loading. Foundation bolts should be embedded in the concrete and located by a drawing or template. A pipe sleeve larger than the bolt should be used to allow movement for final positioning of the bolts. (See Figure A.3).

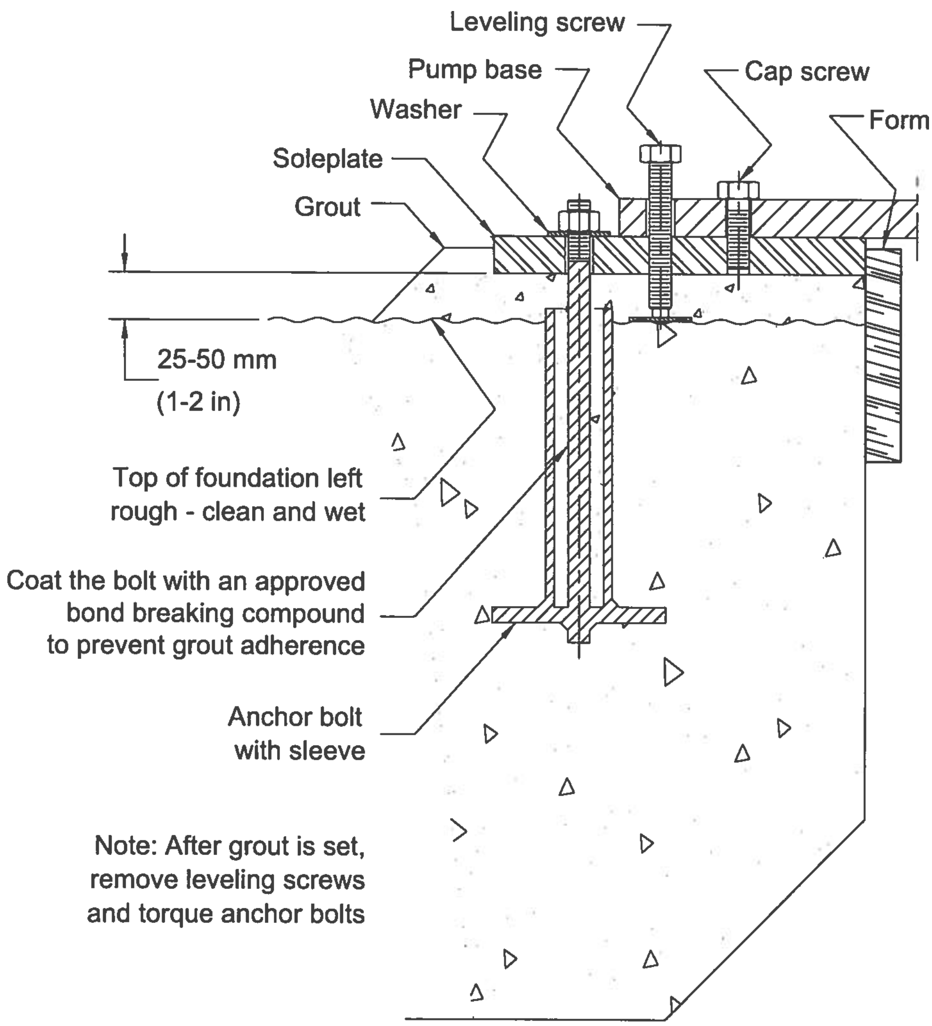


Figure A.3 — Typical foundation bolt, leveling screw, and grout details

CAUTION: Steel support structures may not be stiff enough even if their mass exceeds five times that of the pumping equipment. A civil engineer should review and approve a steel support structure before pump installation.

Vertical pumps (types VS1, VS2, VS3, VS6, VS7, and VS8) should be mounted to ensure they rest on a flat surface without distortion and to minimize any potential pipe strain.

Submersible pumps (type VS0) do not require special alignment at the foundation. However, solid support should be provided for the surface plate from which the unit is suspended, and a watertight seal may also be required to prevent well contamination.

Submersible turbine pumps (VS0) require a mounting method sufficient to support the weight of the pump, motor, and drop pipe.

A.4.3.1 Seismic analysis

When pumps are located in seismically active areas and for certain critical installations, such as nuclear power plants, the pumps, supports, and accessories should be earthquake-resistant. The design specifications to achieve earthquake resistance vary, depending on geographical area, class of the equipment (defining how critical the survival of the equipment is), and the characteristics (acceleration response) of the structure or foundation supporting the pump.

Complete specifications for earthquake-resistance requirements should be supplied by the customer. These include:

- The seismic criteria, such as acceleration, magnitudes, frequency spectrum, location, and direction relative to pump
- The qualification procedure required, i.e., analysis, testing, or a combination of these and requirements for operability during and/or after test

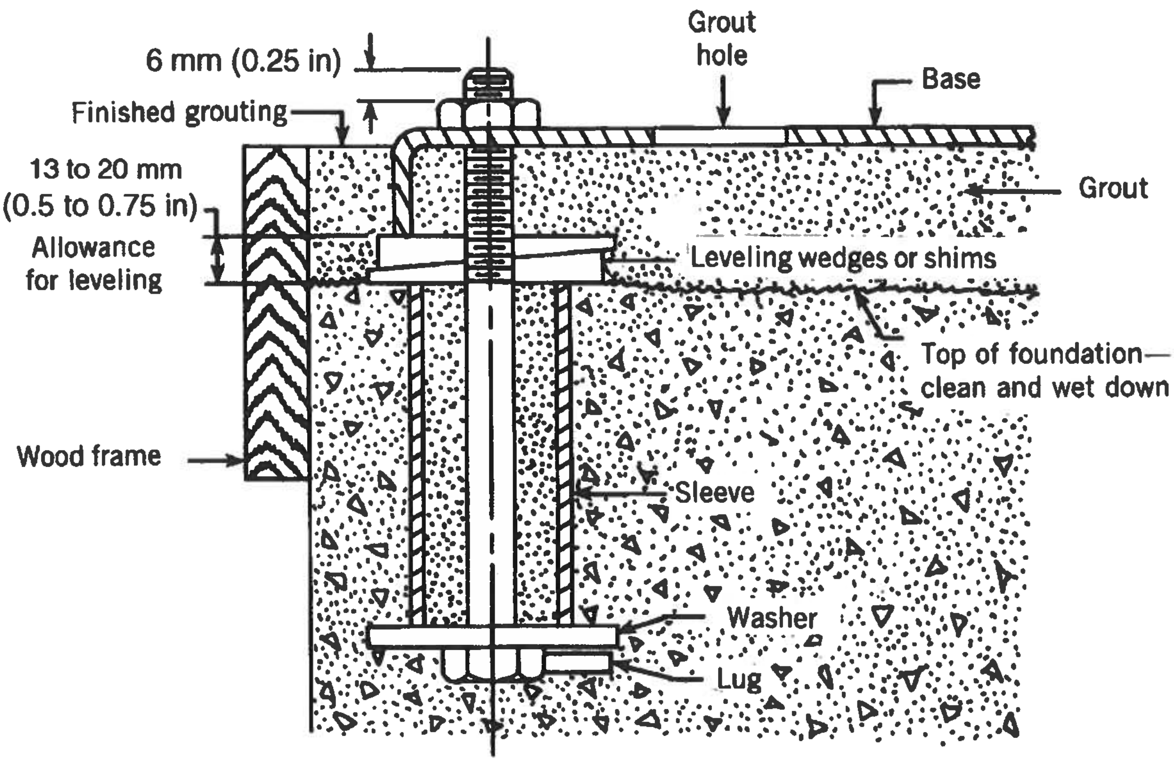


Figure A.4 — Alternate method for leveling with wedges or shims

A.4.4 Rigging and lifting

For typical installations, suitable overhead lifting equipment of adequate capacity to lift the driver, the entire pump (without driver), or the heaviest subassembly of the pump should be available at the jobsite when installing or removing the pump.

Adequate headroom should be provided to accommodate the longest section of the pump to be handled, including rigging.

Motor lifting lugs are designed for lifting motors only and should not be used to lift a motor attached to a pump.

Properly sized slings, chains, and shackles should be available for attachment to the equipment lifting lugs. Eyebolts are required for handling pump sections when lifting lugs are not provided.

I-beams for supporting pump subassemblies at the foundation should be available when it is necessary to install the pump in sections. Common millwright's tools are used for this type of work, including a machinist level to ensure proper leveling of the foundation plate.

A.4.5 Baseplate

A.4.5.1 Leveling

As shown in Figure A.3, baseplates may be mounted on a soleplate or sub-base grouted to a concrete foundation.

Baseplates that might capture air during grouting should be vented to prevent voids between the baseplate and the grout.

When the baseplate has been correctly leveled using the leveling screws, it will be supported on rectangular metal blocks and the leveling screws. Shims and metal wedges are not recommended and seldom used for leveling because they are difficult to remove before or after grouting (see Figure A.3). If shims are used, forms should be placed to isolate them from the initial application of grout. After the initial grout has cured, the forms and shims may be removed and the void filled with a second application of grout.

On large units, small leveling screws made of cap screws and nuts under the soleplate may be used.

The leveling screw threads should be covered with a nonbinding material, such as grease, putty, or tape, before grouting, to facilitate their removal.

A gap of about 25 to 50 mm (1 to 2 in) should be allowed between the baseplate and the foundation for grouting.

Some well pump installations (types VS1, VS2, and VS3) may require a slightly tilted baseplate for correct positioning of the pump in the well. See Section A.4.2. Consult the manufacturer for recommendations and acceptance criteria.

A.4.5.2 Grouting

The grout material that supports the baseplate is a critical element of the pump support structure and should be carefully selected. If the grout cracks or fails, the structure will be compromised. It is not recommended to grout leveling pieces, shims, or wedges in place because they introduce discontinuities and stress concentrations that may cause the grout to crack. Foundation bolts should not be fully tightened until the grout is hardened, usually about 48 to 72 hours after pouring. Leveling screws should be removed after the grout has hardened and the holes filled with an appropriate sealing material.

CAUTION: Do not distort the soleplate by overtightening the foundation bolts.

A.4.6 Piping and connections

A.4.6.1 Piping, general guidelines

A.4.6.1.1 Pipe supports/anchors/joints

Suction and discharge piping should be anchored, supported, and restrained near the pump to avoid application of forces and moments to the pump in excess of those permitted by the pump manufacturer. See ANSI/HI 9.6.6, *Rotodynamic Pumps for Pump Piping*, and ANSI/HI 9.6.2, *Rotodynamic (Centrifugal and Vertical) Pumps – Allowable Nozzle Loads.*

In calculating forces and moments, the weights of the pipe, internal thrust, contained fluid and insulation, as well as thermal expansion and contraction, should be considered.

If an expansion joint is installed in the piping between the pump and the nearest anchor in the piping, a force equal to the area of the maximum inside diameter (ID) of the expansion joint, times the pressure in the pipe, will be transmitted to the pump. Pipe couplings that are not axially rigid have the same effect. This force may be larger than can be safely absorbed by the pump or its support system. The Fluid Sealing Association's *Technical Handbook, Non-Metallic Expansion Joints and Flexible Pipe Connectors* presents information on the design of expansion joints and the calculation of thrust.

Expansion joints or flexible connection provided at the pump suction and discharge may be restrained to prevent transmitting the load to the pump.

The allowable thrust values that various compliant pump types can withstand are found in ANSI/HI 9.6.2, *Rotodynamic (Centrifugal and Vertical) Pumps – Allowable Nozzle Loads.*

If it is necessary to use an expansion joint or nonrigid coupling, then it is recommended that a pipe anchor be located between it and the pump. Note that an anchor provides axial restraint, whereas a pipe support or guide does not.

If a pipe anchor cannot be used, acceptable installations can also be obtained using tie rods across the expansion joint or flexible pipe coupling, provided careful attention is given to the design of the tie rods. The total axial elongation of the tie rod and pipe assembly should not exceed the pump manufacturer's recommendation. The total axial rigidity of the tie rods, including their supporting brackets, should equal that of the pipe, or as an alternate, limit axial deflection to 0.125 mm (0.005 in) when subjected to the maximum working pressure in the system. Many standard tie rod designs are inadequate for use near pumps because they are based on maximum allowable stress only, and do not consider deflection. In fact, some standard tie rod designs result in very high deflection values due to the use of high-strength steel in the tie rods, which allow high stress values. Since deflection is proportional to stress, these high allowable stresses result in high deflections.

A.4.6.1.2 Suction piping requirements

A vertical pump in a suction barrel (types VS6, VS7, and VS7a) or a vertical multistage pump (type VS8) performs properly only if it is supplied with a steady flow of liquid with a uniform velocity profile and with sufficient pressure to provide adequate net positive suction head available (NPSHA).

Failure of the suction piping to deliver the liquid to the pump in this condition can lead to noisy operation, swirling of liquid around the suspended pump assembly, premature bearing failure, and cavitation damage to the impeller and inlet portions of the casing.

For pumps operating with suction pressure below atmospheric pressure, or handling fluids near their vapor pressure, the suction line should slope constantly upwards toward the pump to avoid trapping vapor using eccentric reducers where necessary (see Figure A.5).

In systems where the suction line is not always kept full of liquid, there is a possibility that a large slug of air or vapor may be swept into the pump during a restart, causing a partial or complete loss of pump prime. Any high point in a suction line will accumulate gas with similar results.

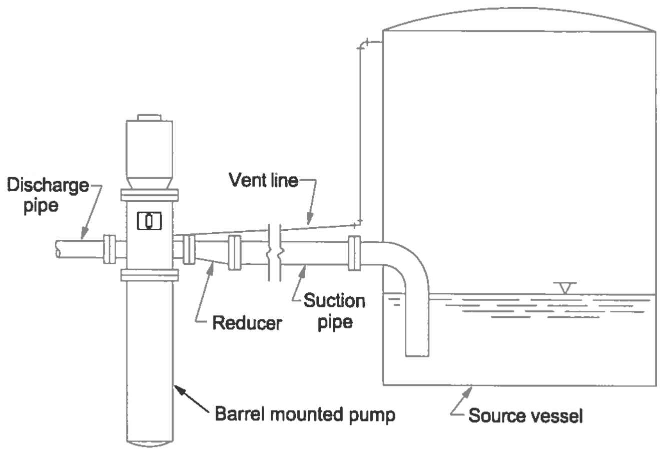


Figure A.5 — Pump system with eccentric reducer in suction pipe

Entrained air reduces pump total head and rate of flow, with amounts as small as 1% by volume affecting radial flow pumps, and 3% to 5% affecting axial flow pumps. Cascading water causing air entrainment should therefore be avoided. For well pumps, the perforated casing should be located below the pump suction. Return lines into sumps or tanks should terminate a minimum of two pipe diameters below the low liquid level. Undersized or partially blocked intake screens and trash racks result in similar problems, caused by excess pit velocity. Adequate provisions for cleaning rotating screens and trash racks should be made.

If it is required to prime the pump before start-up, then the priming connections should be at the high point of the pump suction chamber.

A permanent vent line back to the suction source at this point may also be desired for pumps operating in a closed system.

See ANSI/HI 9.8, *Pump Intake Design*, for more information.

A.4.6.1.3 Pipe reducers

Reducers are installed just ahead of the pump suction when the pipe is larger than the pump nozzle. Reducers used at the pump suction should be of the conical type and sufficiently long to prevent liquid turbulence.

With the liquid source below the pump, the reducer should be eccentric and installed with the level side up (see Figure A.5).

Eccentric or concentric reducers may be used when the liquid source is above the pump and the suction piping is sloping upward towards the source.

A.4.6.1.4 Suction valves and manifolds

Block valves should be installed to isolate the pump for safe maintenance.

Foot valves are specially designed check valves sometimes used at the inlet-to-bowl assemblies for well pumps to keep the column water filled and to prevent backspin and well disturbance caused by rapidly draining water.

A.4.6.1.5 Flow inducers

All submersible motors require a minimum flow of liquid past the motor surface to ensure proper cooling and to maintain acceptable motor winding temperatures. The minimum flow may be critical to ensure reliable performance. Some operating conditions may reduce the flow past the motor. Here are some examples:

Flow may be inadequate if the motor is installed in a large body of water or in a casing much larger in diameter than the motor, and the resulting rate of flow is very low.

Cascading (top feeding) wells can feed the water directly into the pump without providing adequate flow past the motor. This may result when the well is not cased above the motor or the water entry areas are above the motor. Sand and mud may accumulate around the motor.

A suction shroud or flow inducer sleeve is a tube placed over the motor and closed off above the pump intake and may be critical to ensure reliable performance. It extends to the bottom of the motor to direct water flow to the pump and past the motor. Thus, all pumped water will pass between the sleeve and the motor. This device also prevents accumulations around the motor.

A.4.6.1.6 Elbow at pump suction

When a straight run of pipe at the pump suction cannot be provided, certain arrangements of fittings should be avoided for vertical pumps installed in suction barrels and for vertical multistage pumps (VS8). When liquid flows through an elbow, or makes a turn through a tee, the exit velocity will be strongly nonuniform. Elbows with a plane perpendicular to the pump shaft should therefore not be used, since a strong vortex motion can be set up in the liquid in the pump barrel. This could lead to a swirling motion in the suspended pump and result in bearing failure, noisy operation, and cavitation damage in the first stage of the pump assembly. Splitters inside the pump barrel can be used to break up the liquid swirl.

Ninety-degree suction elbows should be designed to include guide vanes.

A.4.6.1.7 Suction tanks

In many process applications, a suction line may be taken off the side or bottom of a process or storage vessel. When this is done, it is necessary to ensure that the submergence level over the inlet to the suction pipe is adequate to prevent vortices. ANSI/HI 9.8, *Pump Intake Design*, indicates recommended minimum values of submergence over the inlet as a function of outlet velocity. If operating levels of liquid in the vessel cannot provide the required submergence at the planned line velocities, then the size of the inlet should be increased as necessary to reduce the velocity to the point where the submergence is adequate.

A.4.6.1.8 Discharge valves

A check valve and an isolation valve should be installed in the discharge line. The check valve serves to protect the pump from reverse flow and excessive backpressure. The isolation valve is used in priming, starting, and when shutting down the pump. Except on axial flow and mixed flow pumps, it is advisable to close the isolation valve before stopping or starting the pump. Operating pumps of specific speed over 100 (5000) at shut-off may cause a dangerous increase in pressure or power. If increasers are used on the discharge side of the pump to increase the size of piping, they should be placed between the check valve and the pump. If expansion joints are used, they should be placed between the pipe anchor and the check valve. (See Figure A.6.)

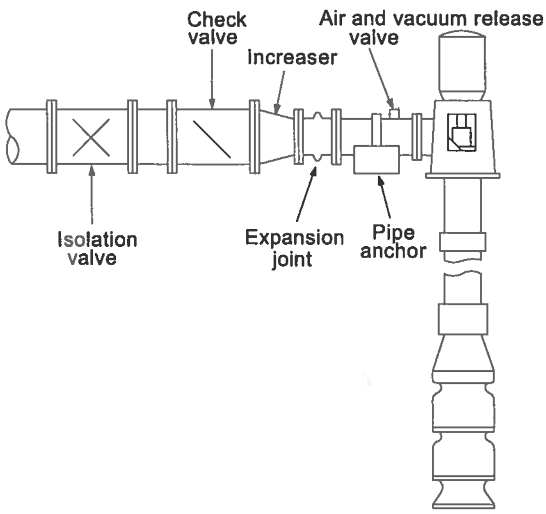


Figure A.6 — Pump system with expansion joint in discharge pipe

A.4.6.1.9 Air and vacuum release valves for wet pit and well pumps

For medium- and large-size vertical wet pit pumps discharging into a pressurized system, an automatic air and vacuum release valve is recommended. The valve should be located on the pump discharge nozzle or between the pump discharge nozzle and the discharge valve or check valve, whichever is closest.

The release valve prevents a large volume of air from being compressed, and then setting up a severe shock wave when suddenly released, with potential for serious equipment damage. The air release valve also prevents air from entering the pressurized system.

The valve also relieves the vacuum that might otherwise be generated in the discharge during shut-down when the liquid recedes in the column pipe to the sump or well standing level. Vacuum release valves may be critically important to prevent equipment damage on restarting flow into an evacuated column.

A.4.6.1.10 Siphons

When a siphon is used in the pump discharge line, for the purpose of reducing the head requirement for applications such as pumping over a levee, additional equipment requirements are imposed for the system to function satisfactorily.

To clear the siphon of air and make it operational, either a vacuum pump or an air ejector should be provided, or the pump and driver should be suitable for handling the higher head with adequate flow until the siphon is cleared. For high specific-speed pumps, this may result in a significant increase in required brake horsepower. Additionally, if the height of the siphon above the discharge water level is substantial, then the flow from the pump at the increased head requirement may not be sufficient to clear the siphon, and a vacuum pump assist is required.

A siphon breaker should be mounted at the high point of the siphon to prevent backflow when the pump is stopped.

A.4.6.2 Nozzle loads

The piping should be aligned with the pump nozzles to minimize pump nozzle loads. See ANSI/HI 9.6.2, *Rotodynamic (Centrifugal and Vertical) Pumps – Allowable Nozzle Loads.*

A.4.6.3 Check valves

Check valves may be located in the discharge to prevent backflow but should not be used in the suction line. They are sometimes used in series-parallel connections to reduce the number of valves that should be operated when changing from one type of operation to the other. In some applications, check valves may be provided with dashpots to mitigate the slamming effect of the valve during closing.

Pump backspin and hydraulic shock can cause severe damage to pump and motor. Install at least one check valve to help prevent this. Install check valve in discharge pipe, not more than 8 m (25 ft) above pump. For 150-mm (6-in) and larger submersible pumps installed more than 183 m (600 ft) deep, install a second check valve at the pipe joint nearest to the halfway point between pump and ground level.

NOTICE: To avoid water hammer and pipe breakage, distance from first check valve to second check valve should not equal distance from second check valve to ground level.

All submersible pumps (type VS0) should be equipped with a check valve. Some units have check valves built into the top of the pump, which also serve as the discharge adapter. Alternately, a line check valve may be threaded directly into the discharge of the pump or within 8 m (25 ft) of the pump. Special male-by-female threaded check valves or female-by-female threaded check valves are commonly used.

When selecting a submersible check valve, be sure the valve is sized properly to flow and pressure conditions for the particular pump installation. Before installing a check valve, be sure the spring-loaded check mechanism of the valve is operating freely. Always install check valves with the arrow pointing in the direction of flow.

A.4.6.3.1 Reasons to install check valves

With no check valve, or with an improperly placed check valve, severe damage can occur to the rotating elements of the pump, the supporting motor thrust bearing, surface piping, and other pump system components for these reasons:

a) The column of water supported by the running pump will drain back through the pump when it stops. This causes the rotating elements of the pump and motor to backspin. If the pump is restarted during backspin, the resultant torque could shear the pump shaft or coupling or cause pump thrust bearing damage.

b) With an empty discharge pipe, the pump will start each cycle with no head. Many pumps will exert an upward thrust on the impeller stack at low heads, which can lift the rotor of the motor for a short period until the water column rises sufficiently to create a downward thrust in the pump. This repeated upthrust at each start could cause excessive wear in the motor upthrust bearings.

c) In a deep well submersible installation with a check valve only on the surface, with no provision allowing air to enter the column pipe when the pump is stopped and the water is drained back, a vacuum is created in the drop pipe below the check valve. When the pump is restarted, water pumped at a relatively high velocity fills this vacuum, striking the closed check valve and the stationary water in the pipe downstream. This impact causes hydraulic shock and water hammer, which in some cases can be transmitted back to the pump impellers and motor thrust bearing, causing severe damage.

A.4.6.4 Strainers

To keep unwanted solids out of the pump, strainers may be installed at the suction bell or in the pump suction piping. The strainer itself usually introduces only a moderate pressure drop, but as debris accumulates, the pressure drop will increase. It is therefore recommended that pipe-mounted strainers be installed with upstream and downstream pressure taps and that the pressure drop be monitored.

Suction bell strainers typically clear themselves by backflow in the pump column when the unit is stopped. For large pumps, trash racks and screens are typically part of the intake structure.

A.4.7 Clearance setting

For deep-setting well pumps or high thrust load pumps where shaft elongation and accumulation of column shaft joint tolerances could affect the clearance between the impeller and the bowl, it is important that an accurate estimate of shaft stretch be determined to prevent interference during pump operation.

The rotating element in vertical turbine pumps (types VS1, VS2, VS3, and VS6) should be raised axially before start-up. An adjustable head shaft nut or pump-to-driver shaft coupling is provided for this purpose, and the pump shaft should be raised per the manufacturer's instructions. Vertical multistage pumps (VS8) require rotor running height alignments to ensure proper operation.

A.4.8 Alignment

Vertical lineshaft and submersible pumps are automatically aligned through registered fits between mating parts. However, on lineshaft pumps, it is recommended to check the alignment of the head shaft to the driver at the time the latter is mounted.

After the grout has set and the foundation bolts have been properly tightened, the unit alignment should be checked. After the suction and discharge piping of the unit have been connected, the alignment should be checked again. Alignment may be checked by mounting a dial indicator to measure shaft movement before and after tightening flange bolts. If the unit does not stay in alignment after being properly installed, the following are possible causes:

a) Setting, seasoning, or springing of the foundation.

b) Excessive pipe strain distorting or shifting the machine.

A.4.8.1 Auxiliary (driver, coupling, etc.)

Motors mounted to either submersible turbines (VS0) or vertical multistage pumps (VS8) assemble into machined fits and typically do not require alignment.

A.4.8.1.1 Vertical solid shaft drivers

Before mounting the driver on the discharge head/driver stand, check the register fit, if furnished, and the mounting face on the driver for acceptable tolerance on runout and perpendicularity, respectively, using a dial indicator mounted on the driver shaft. See ANSI/NEMA MG-1, *Motors and Generators*. Next, check the perpendicularity of the face of the driver coupling half, mounted on the shaft with a tight fit and seated against a split ring, using a dial indicator on a firm base.

With the driver bolted to the discharge head, mount a dial indicator on the driver shaft above the coupling half and sweep the bore of the stuffing box. If excess runout exists, some adjustment can be made at the driver mounting fit and the stuffing-box mounting fit. Before installing any additional coupling parts, check the driver for correct rotation, as given in the manufacturer's installation instructions. Next, mount the pump half coupling, shaft adjusting nut, and coupling spacer if applicable, and raise the impeller in accordance with the manufacturer's instructions. Then secure the coupling bolts. Make a final check of the shaft runout below the pump half coupling with a dial indicator. If the runout is within acceptable tolerances, check the tightness of the driver hold-down bolts. If dowels are used to secure the driver location, then it should be noted that redoweling is required after disassembly/reassembly, since tolerance buildup in the multiple vertical joints results in alignment variation.

A.4.8.1.2 Vertical hollow shaft drivers

Remove the clutch or coupling from the top of the hollow shaft, and mount the driver on top of the discharge head/driver stand. For designs requiring the pump head shaft to be installed prior to mounting the driver, lower the hollow shaft driver with care over the head shaft to be sure the latter is not damaged. Check the driver for correct rotation, as given in the manufacturer's installation instructions. Install the head shaft, if not already done, and check it for centering in the hollow shaft. If off-center, check for runout in head shaft, misalignment from discharge head to driver, or out-of-plumbness of the suspended pump. Shims can be placed under the discharge head to center the head shaft, but shims should not be placed between the motor and the discharge head unless recommended by the manufacturer.

The head shaft should be centered within the motor hollow shaft by using a close-fitting steady bushing. This bushing is pressed into or is fastened to the hollow shaft and rotates with the hollow shaft and head shaft. Steady bushings should be installed by the motor manufacturer.

For motors with lower oil-lubricated bearings, the motor manufacturer should install the steady bushing. This is because the steady bushing will usually be located well up inside of the hollow shaft above the stationary oil sleeve. On the grease-lubricated lower motor bearing designs, the steady bushing is usually located at the bottom of the hollow shaft, which is more accessible.

Install the driver coupling or clutch, and check the anti-reverse rotation device for operability, if furnished. Install the coupling gib key and the adjusting nut, and raise the shaft assembly with the impeller(s) to the correct running position in accordance with the manufacturer's instructions. Secure the adjusting nut to the clutch, and double-check the driver hold-down bolts for tightness.

Most hollow shaft drivers have register fits. Further centering of these drivers is, therefore, normally not required, nor are dowels recommended.

A.4.8.1.3 Special driver considerations for submersible units (type VS0)

While it is important to comply with the manufacturer's installation instructions for all equipment, this is imperative for submersible pumps in order to avoid start-up failure, since the unit cannot be observed at this stage. Submersible motors vary greatly in basic construction, so only a few general guidelines can be provided.

For storage prior to installation, the manufacturer will specify whether the motor should be kept in a horizontal or vertical position.

For motors filled with either oil or other special fluid, check for leakage at the shaft seal prior to installation. Check the fluid level in the motor and refill with the manufacturer's recommended fluid per the instructions, if required.

If the power cable is to be connected to the motor terminal box in the field, make sure the connection is dry and the gaskets undamaged before bolting up the joint.

Keep the reel with the power cable close to the wellhead so that the cable insulation does not become damaged by being dragged over the ground or over the well casing flange when the unit is lowered into the well. Similarly, clamps for securing the cable to the discharge pipe should not have sharp edges.

The couplings for the discharge pipe joints should be tightened securely to prevent the motor's induced starting torque from either loosening or further tightening the joints. This would cause the power cable to spiral around the pipe and could cause cable or terminal failure. When the unit has been completely installed, a meg-ohm reading should be taken on the cable/motor per the manufacturer's instructions to verify complete electrical integrity. If the meg-ohm reading is below the manufacturer's recommended minimum, the problem should be identified and corrected before the unit is started.

Electrical splices and connections must be waterproof. Make a strong mechanical bond between the motor leads and the cable to avoid high electrical resistance at the connection. A poor mechanical connection or a poorly wrapped splice can cause motor problems and motor failure.

The necessary electrical controls should be provided in the starting panel. A time-delay relay is recommended by most manufacturers to provide for time delay between stops and starts.

A.4.8.1.3.1 Submersible motor selection

Selecting the best submersible motor for a particular pump application requires careful consideration of several factors. The motor should match the pump in mounting dimensions, and should have adequate horsepower (hp) load rating and thrust rating to support the pump over its entire operating range. Most motors up to 203 mm (8 in) in size are built to National Electrical Manufacturers Association (NEMA) Standards, which define their physical dimensions, electrical ratings, and thrust ratings. The motor should be capable of operation at the water temperature and velocity presented by the installation.

Most motor nameplates and/or the manufacturer's literature specify the maximum water temperature and minimum required velocity past the motor. Motor operation in water that exceeds the rated temperature may be allowable at reduced loading, depending on the particular motor. NEMA Standards are based on 25 °C (77 °F) maximum ambient water temperature. Some motors, however, may be rated for full output at 30 °C (86 °F) or higher. If the installation does not ensure the specified velocity past the motor – because of well diameter, water inflow above the pump, or other reasons – a sleeve over the motor should be used to induce the required velocity.

A plot of speed versus torque requirements during the starting phase of a pump can be checked against the speed versus torque curve of the driving motor. The driver should be capable of supplying more torque at each speed than required by the pump in order to accelerate the pump up to rated speed. This condition is usually easily attainable with standard induction or synchronous motors, but under certain conditions, such as high specific-speed pumps over 100 (5000) or reduced voltage starting, a motor with high pull-in torque may be required. For additional information on speed versus torque requirements, see ANSI/HI 2.3, *Rotodynamic (Vertical) Pumps for Design and Application*.

A.4.8.1.3.2 Types of cable for submersible motors

Several manufacturers produce cable designed for use with submersible motors. The exact type of cable to be used is usually specified by the pump manufacturer or selected by the installer.

Cable may be three individual conductors twisted, three conductors molded side-by-side in one flat cable, or three conductors sealed within a round overall jacket. The insulation around the conductor should be type RW, RUW, TW, or the equivalent, and specifically suited for use under water. The use of stranded or solid conductor cable is optional. The use of copper cable is preferred.

A.4.8.1.3.3 Lightning and surge protection for submersible motors

While submersible motors are more vulnerable to damage by lightning or voltage surges than any other pump motors, lightning arrestors – when properly selected and installed – can provide inexpensive protection. The need for arrestors is greater in pump installations that are distant from the primary power circuit and in areas where thunderstorms occur frequently. Power lines are subject to extremely high voltage surges caused by switching loads and electrical storms. Surges also may be induced by charged clouds passing over the lines or by generator fluctuations. A properly selected and installed surge arrestor can provide protection against motor damage.

A.4.8.2 Hot alignment considerations

(Manufacturer will include information in this section regarding hot alignment considerations.)

A.4.9 Lubrication, priming, and cooling systems

(Manufacturer will include information in this section regarding lubrication, priming, and cooling systems.)

A.4.10 Electrical

Electrical conduit and boxes should be located to avoid obstruction of the windows of the discharge head. Electrical conduit and boxes should be sized to manufacturers' recommendations along with all appropriate standards and local statutes.

To achieve a smooth start for the pumping equipment, autotransformers may be connected to the starting panel or solid-state starters used. These provide a gradual increase in voltage up to rated voltage, ensuring even acceleration.

A.4.11 Control, monitoring, and alarm equipment

All control and alarm systems, which may be electrical, hydraulic, or pneumatic, should be checked for correct installation and functioning in accordance with the manufacturer's instructions. All alarm point settings should be verified.

Once pumping starts, the water level in the well will draw down. However, excessive drawdown may cause the unit, either lineshaft or submersible, to break suction, with resulting potential pump damage. Installation of undercurrent relays in the power supply lines will normally provide protection against this occurrence.

A pressure gauge is recommended on the pump discharge to monitor pump operation.

A.4.11.1 Stopping unit/reverse runaway speed

A sudden power and/or discharge valve failure during pump operation against a static head will result in a flow reversal, and the pump will operate as a hydraulic turbine in a direction opposite to that of normal pump operation. Vertical pump drivers can be equipped with anti-reverse rotation devices to prevent reverse rotation. However, their application is not always desirable and a review should always be made with the manufacturer.

If the pump is driven by a prime mover offering little resistance while running backwards, the reverse speed may approach its maximum for the applicable specific speed. This speed is called *runaway speed*. If the head under which such operation may occur is equal or greater than that developed by the pump during normal operation, then the runaway speed may exceed that corresponding to normal pump operation. This excess speed may impose high mechanical stresses on the rotating parts of both the pump and prime mover, thus knowledge of this speed is essential to safeguard the equipment from possible damage.

The ratio of reverse runaway operation speed (n_{ro}) to normal operation speed (n_{no}) for pumps varies with specific speed. This relationship is shown in Figures A.7 and A.8. The data shown should be used as a guide, recognizing that variations may be experienced with individual designs.

It should be pointed out that transient conditions, during which runaway speed may take place, often result in considerable head variations due to surging in the pressure line. Since most pumping units have relatively little inertia, surging can cause rapid speed fluctuations. The runaway speed may, in such a case, be consistent with the highest head resulting from surging. Therefore, knowledge of the surging characteristics of the pipeline is essential for determining the runaway speed. This is particularly important in case of long lines.

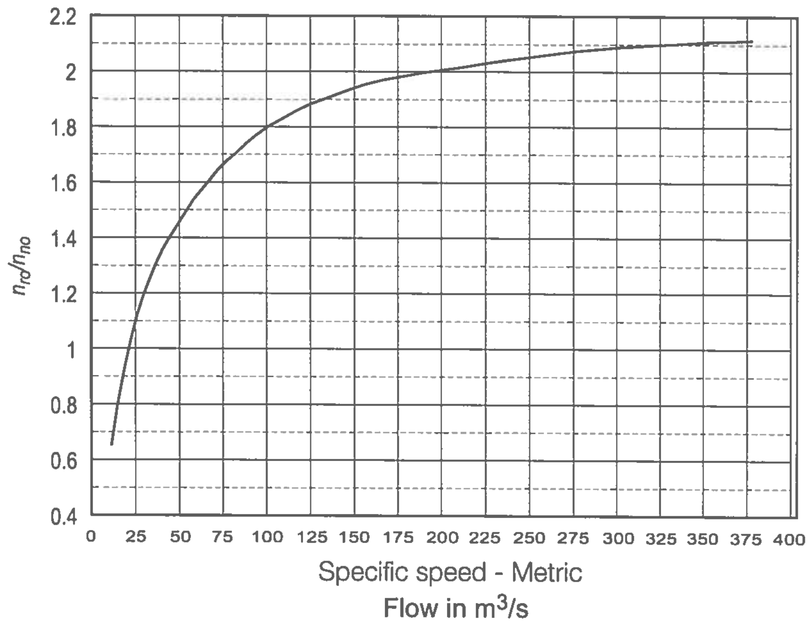


Figure A.7 — Reverse runaway speed ratio versus specific speed (metric)

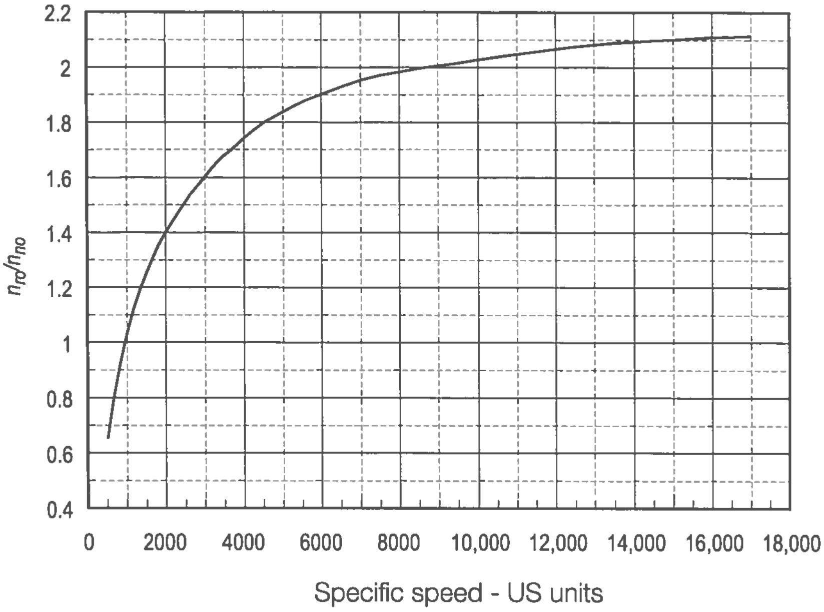


Figure A.8 — Reverse runaway speed ratio versus specific speed (US customary units)

A.5 Commissioning, start-up, operation, and shut-down

A.5.1 Lubrication

(Manufacturer will include information in this section regarding lubrication requirements.)

A.5.2 Rotation

Anti-reverse rotation devices are furnished as an integral part of the motor or right-angle gear when reverse rotation from backflow in the pump may cause damage. While the motor or gear is still disconnected from the pump, rotate the motor or gear by hand in both directions to check proper functioning of the ratchet. The rotation of the complete drivetrain should also be checked at this time.

Before starting the pump, check the direction of rotation. The proper direction is usually indicated by a direction arrow on the discharge head or on the driver stand when the discharge is located below the mounting level. When electric motors are used as drivers, the rotation should be checked with the motor disconnected from the pump.

The rotation of submersible units can normally be checked by comparing the pump output against the guaranteed performance curve. Check the manufacturer's start-up instructions.

A.5.3 Guarding

All guards must be in place and secure per the manufacturer's instructions prior to start-up.

A.5.4 Check list – start-up

A.5.4.1 System flushing

When the pump is installed in the completed piping system, it is recommended that the system be back-flushed to remove debris such as stubs of welding rod, welding slag, and loose scale. The pump and other sensitive equipment should be protected with start-up strainers, which should in turn be removed upon completion of the flushing cycle. For barrel-mounted pumps, it is recommended to remove the pump and let the barrel become the receptacle for the debris for subsequent cleanout.

Before starting the pump, adequate submergence should be provided for lineshaft pumps and submersible pumps, and the barrel and suction line should be filled with liquid for barrel-mounted pumps (can pumps). Minimum required submergence to prevent vortices is specified by the manufacturer. See also ANSI/HI 9.8, *Pump Intake Design*, and ANSI/HI 2.3, *Rotodynamic (Vertical) Pumps for Design and Application*.

The pump should not be run unless it is completely filled with liquid or is provided with the minimum required submergence, as there is danger of damaging some of the pump components. Typically, bowl and impeller rings and internal sleeve bearings depend on liquid for their lubrication and may seize if the pump is run dry.

For pumps mounted in a suction barrel or can, typically for critical NPSH applications, a continuous vent line should be provided from the highest point in the barrel to the vapor phase of the suction source. This prevents inadvertent vapor locking and dry-running of the pump. The vent line should be continuously rising to preclude liquid traps, and be fully airtight.

When the required submergence is provided, all submersible units, and most vertical turbine pumps, can be started without concern for the nonsubmerged part of the pump. However, for vertical lineshaft pumps, this depends on the column length and bearing construction, such as metallic and nonmetallic material.

Most vertical pumps have the first stage below the liquid level. Therefore, they are automatically primed by proper venting. When required, as for barrel pumps, priming may be accomplished by ejector/exhauster or vacuum pump.

For VS8-style pumps, a vent valve is usually installed in the motor bracket and can be used for positive suction applications. A fill port or connection for a priming device is also provided. Starting a VS8-style pump not properly primed can cause serious mechanical seal damage.

A.5.4.2 Priming by ejector or exhauster

When steam, high-pressure water, or compressed air is available, the pump may be primed by attaching an air ejector to the highest point on the discharge nozzle or discharge pipe, close to the discharge valve. This will remove the air from the pump and suction can for barrel-mounted pumps, provided the discharge valve forms a tight seal. Prime is obtained when a steady stream of fluid flows from the ejector or discharge vent connection. The pump can then be started. A foot valve is unnecessary when this kind of device is used. Note that when the pump discharge nozzle is located above the suction source, and a foot valve is not used, the discharge valve should not be opened until the driver has been started, since this may result in loss of prime.

A.5.4.3 Priming by vacuum pumps

When neither of the above methods are practicable, the pump may be primed by the use of a vacuum pump to exhaust the air from the pump and suction can, if applicable. A wet vacuum pump is preferable, as it will not be damaged if water enters. When a dry vacuum pump is used, the arrangement should preclude liquid from being drawn into the air pump. The manufacturer's instructions should be followed.

A.5.4.4 Shaft sealing settings and adjustments (mechanical seals, packing, etc.)

A.5.4.4.1 Packed stuffing box (types VS1, VS2, VS3, VS6, and VS7)

The stuffing box may or may not be filled with packing before shipment. If the stuffing box is not packed, it should be carefully cleaned and packed once the motor is mounted and connected to the head. Instructions may be found with the box of packing. If not, the following may be used as a guide.

The stuffing box should be carefully cleaned. Make sure the packing rings are of proper cross section and length. When installed, the rings should butt tightly but not overlap at the joints. The joints should be staggered 90° apart.

Packing rings should be tamped down individually, but not too tightly, as this may result in burning the packing and scoring of the shaft of the shaft sleeve. Where compatible, lightly lubricate the packing ID and OD with a suitable lubricant. When a lantern ring is required, be sure that sufficient packing is placed in below the lantern ring so that the liquid for sealing is brought in at the lantern ring and not at the packing.

The pipe supplying the sealing liquid should be fitted tightly so that no air enters. This is particularly important for vertical barrel pumps mounted in a system where a vacuum must be maintained (see Figure A.9). If the liquid to be pumped is dirty or gritty, clean sealing liquid should be piped to the stuffing box to prevent damage to the packing and shaft sleeves. Clear sealing liquid is also required if the stuffing-box materials are not completely compatible with the pumpage. Sealing liquid should be at a pressure sufficient to ensure flow of clean liquid into the pump, but not so high as to require excessive tightening of the packing.

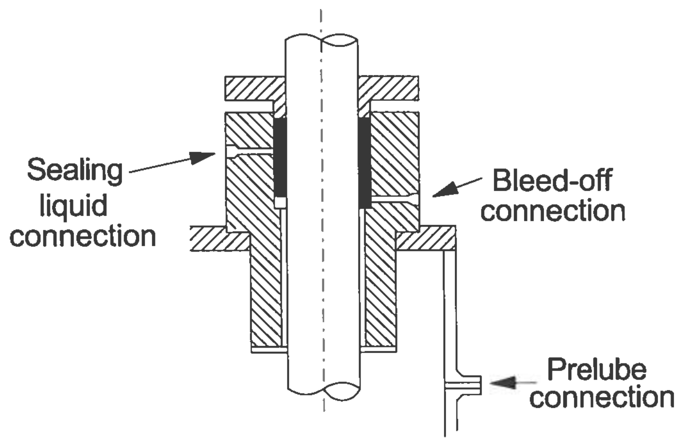


Figure A.9 — Packed-type stuffing box

When a pump is first put into operation, the packing should be left quite loose. After the pump has been found to operate properly, the stuffing-box gland may be tightened very slowly if the leakage is excessive. A leakage of about 8 to 10 drops per minute per 25 mm (1 in) of shaft diameter from the stuffing box is necessary to provide lubrication and cooling. When the leakage can no longer be controlled by adjusting the gland, all rings of packing should be replaced. The addition of a single ring to restore gland adjustment is not recommended.

If the pump is to be left idle for a long period, it is recommended that the packing be replaced prior to starting up the pump.

A.5.4.4.2 Mechanical seals

Pumps handling hazardous or expensive liquids, or where normal leakage from the stuffing box is objectionable, are often furnished with mechanical seals.

A mechanical seal consists of a rotating element and a stationary element. The sealing faces are highly lapped surfaces on materials selected for their low coefficient of friction and their resistance to corrosion by the liquid being pumped. The faces run with a very thin film of liquid between them. In addition, there must be a means of loading the seal. This is accomplished either with a spring (or springs) or with an elastomeric or metallic flexible member.

Mechanical seals for vertical pumps are of two basic types, depending on whether mounting is to be external or internal. Externally mounted seals are easily adjusted for correct positioning after the impeller(s) is set for correct running clearance. Mechanical seals mounted internally in the stuffing box, unless of the cartridge type, must be mounted on a shaft sleeve and the sleeve correctly positioned and locked to the shaft after the impeller(s) is lifted for proper running clearance. For vertical pumps equipped with a mechanical seal and a vertical hollow shaft (VHS) motor, it is recommended that a steady bushing be installed in the motor.

There are two features that can simplify change-out of worn seals. The first is the use of a spacer coupling in the head shaft of the pump. This allows removal of the seal/sleeve assembly without removing the driver. The second is use of an axially split mechanical seal. Change-out of this design does not require any disassembly of the pump.

Because mechanical seals are made in a wide variety of designs, the instructions for the specific seal must be carefully studied and followed. A mechanical seal is a precision device and must be treated accordingly. Mechanical seals normally require no adjustment during operation. Except for possible slight initial leakage, the seal should operate with negligible leakage. They should not be run dry. Seals may require a continuous supply of flush and/or cooling fluid. Where seal damage due to system uncleanliness is expected, it may be advisable to operate the pump with packing or temporary seals and sleeves until the system is clean and start-up problems are resolved. Packing or temporary seals are normally used on systems where the start-up pumpage is different from the final process pumpage, and are replaced once the process pumpage is introduced.

All VS8-style pumps are equipped with mechanical seals. Mechanical seals on vertical multistage pumps (VS8) are typically factory installed. Some configurations will require alignment and are clearly marked.

A.5.5 Start-up, operation, and shut-down

A.5.5.1 Minimum continuous flow

See ANSI/HI 9.6.3, *Centrifugal and Vertical Pumps for Allowable Operating Region*.

A.5.5.2 Minimum thermal flow

See ANSI/HI 9.6.3, *Centrifugal and Vertical Pumps for Allowable Operating Region*.

A.5.5.3 Lubrication system settings

A.5.5.3.1 Primary and secondary drivers

Before running the driver, either separately or connected to the pump, check lubrication requirements in the manufacturer's instruction manual. Inspect and make sure that:

- Grease-lubricated bearings have been properly greased with the manufacturer's recommended grade
- Oil-lubricated bearings on drivers and gears, as well as oil sumps on gears, have been filled to the required level with the recommended oil
- All automatic oilers are functioning properly

A.5.5.3.2 Pumps

Vertical pumps are either furnished with product-lubricated, oil-lubricated, or grease-lubricated sleeve bearings. The following provisions should be made for the respective bearings:

a) For product-lubricated bearings (bearings lubricated by the pumped liquid), prelubrication with clean water should be provided for all pump bearings above static water level when the distance from the mounting floor to the minimum water level exceeds 15 m (50 ft), or as recommended by the manufacturer. The manufacturer may permit a greater distance without prelubrication for bearings made of self-lubricating materials.

b) For pumps with oil-lubricated bearings, it is recommended to pour one or more quarts of oil, depending on pump setting, down the shaft enclosing tube prior to start-up. Next, make sure that the oil reservoir is filled and, if a solenoid valve is supplied, that it is functioning properly with the correct amount of oil being gravity-fed into the shaft enclosing tube.

c) For pumps with grease-lubricated bearings, make sure the correct grade of grease is available. For manual grease injection, make sure the grease nipples are properly connected, clean, and accessible. Inject per the manufacturer's instructions.

For motorized grease injection, make sure the grease lines are all securely fastened to the reservoir. Fill the reservoir with grease, energize the grease pump, and check the functioning per the manufacturer's instructions. Proceed in accordance with the pump manufacturer's instruction manual.

A.5.5.3.3 Type of lube filtration

When required to inject water, either for flushing or lubrication of pump components, clean filtered water should be provided. If such quality water is not available at the site, then process water may be filtered, using either a cyclone separator, a mechanical filter, or a tank with a filter bed. When liquids other than water are handled, such liquids can similarly be filtered and used for injection. The pressure drop across the filter should be monitored to ensure that the required injection pressure is available, and filter maintenance should be performed when required. Additional bearing protection can be provided by installing a flow switch in the injection line, set for the minimum flow requirement.

A.5.5.4 Drive system settings

(Manufacturer will include information in this section regarding drive system settings.)

A.5.5.5 Valve settings and operation (timing)

A.5.5.5.1 Across-the-line start

When squirrel cage induction motors having line starting controls are used, it is permissible to have the discharge valve open when the pump is being started. However, the length of time of the high starting current may be shortened if the discharge valve remains closed until the pump comes up to full speed.

A.5.5.5.2 Reduced voltage start

Except for axial flow and mixed flow pumps, pumps using squirrel cage induction motors with reduced voltage starting control should always be started with the discharge valve closed or partially opened.

A.5.5.5.3 Warning against closed valve operation

⚠ CAUTION

The pump should not be operated with the discharge valve closed. The fluid in the pump may boil, with risk of explosion and steam burns to anyone near. If there is any danger of the pump running against a closed discharge valve, install a pressure relief or bypass valve in the discharge pipe to allow for minimum liquid flow through the pump. Minimum liquid flow through the pump is needed for cooling and lubrication of the pump. Run the bypass/relief valve and discharge pipe to a floor drain or a tank for collection.

Brief shut-off operation of most vertical pumps may be necessary. The necessity may arise from system start-up or shut-down requirements and is normally met by closure of the discharge valve for the minimum possible time. Prolonged operation of the pump under this condition may prove harmful to the structural integrity of the pump because of:

- Increased vibration levels affecting the stuffing boxes, mechanical seals, and areas with close running fits
- Increased axial thrust and resultant stresses in the shafts and bearings
- Heat buildup resulting in a dangerous temperature rise of the liquid being handled and pump components in contact with it
- Damage resulting from internal recirculation and flow separation

When a pump has been started against a closed discharge valve, it should be opened slowly as soon as pressure develops at the pump side of the valve. Abrupt valve opening can result in surges damaging to the pump and piping.

Pumps with specific speed over 100 (5000) often have high zero flow horsepower. Running such a pump with the discharge valve closed can result in serious mechanical overloads as well as motor overload.

Operation of a pump with the suction valve closed may cause serious damage and should not be attempted. Operation with both valves closed for even brief periods of time is an unacceptable and dangerous practice. It can rapidly lead to a violent pump failure.

A.5.5.5.4 Water (hydraulic) hammer

Water hammer is an increase in pressure due to rapid changes in the velocity of a liquid flowing through a pipeline.

Water hammer may be controlled by regulating valve closure time, using relief valves or surge chambers, and certain other means. See ANSI/HI 2.3, *Rotodynamic (Vertical) Pumps for Design and Application.*

It is recommended that specialized engineering services be engaged for water hammer analysis.

A.5.5.5.5 Parallel and series operation

Pumps should not be operated in series or in parallel unless specifically designed for this purpose, since serious equipment damage may occur.

For parallel operation, the pumps should have approximately matching shut-off heads. Otherwise, the system operating head may exceed the shut-off head of one or more pumps, resulting in the pump(s) operating with zero output flow. This would have the same effect as operating against a closed discharge valve. Mismatched shut-off heads could also cause one pump to operate below the allowable operating region.

For series operation, the pumps should have approximately the same rate-of-flow characteristics. Because each pump takes suction from the preceding pumps, the stuffing boxes and all pressure-containing components should be designed for the corresponding pressure, and the thrust bearing requirements may also change. The discharge pressure of the first pump must be sufficient to provide adequate net positive suction head available (NPSHA) to the suction of the second pump.

A.5.5.5.6 Valve setting at start-up

A.5.5.5.6.1 Position of discharge valve on starting, high or medium head pumps

Normally, pumps with specific speed below 100 (5000), when primed and operated at full speed with the discharge valve closed, require less power input than when operated at the rated flow rate and head with the discharge valve open. For this reason, it is advantageous to have the discharge valve closed when starting the pump. Note, however, that with pumps of 100 (5000) specific speed and higher, closing of the discharge valve at starting leads to an increased horsepower requirement.

A.5.5.5.6.2 Position of discharge valve on starting, mixed or axial flow pumps

Pumps of the mixed flow type usually require greater input power with the discharge valve closed than open. Axial flow type pumps nearly always require substantially more power and produce more pressure at shut-off than at rating and should be started with the discharge valve open or with the opening of the valve sequenced with starting of the pump. Flap valves are commonly used for these purposes. The manufacturer's instructions should be consulted for the characteristics of such pumps.

A.5.5.5.6.3 Reduced flow/minimum flow discharge bypass

When operating at reduced flow, noise and vibration levels typically increase. This may lead to reduced bearing life and mechanical seal life as well as potential damage to other components.

If it becomes necessary to operate a pump for prolonged periods at flows below the rate specified by the manufacturer as permissible continuous minimum flow, then a bypass line should be installed from the pump discharge to the suction source. See ANSI/HI 9.6.3, *Centrifugal and Vertical Pumps for Allowable Operating Region*. The bypass line should be sized so that the system flow plus the bypass flow is equal to or larger than the manufacturer's specified minimum.

A.5.5.6 Condition monitoring

See ANSI/HI 9.6.5, *Rotodynamic (Centrifugal and Vertical) Pumps for Condition Monitoring.*

A.5.5.7 Vibration (alarms and trip points)

See ANSI/HI 9.6.4, *Rotodynamic Pumps for Vibration Measurements and Allowable Values.*

A.5.5.7.1 Noise in pumping machinery

Sound is energy and may be produced by movement within machinery. This is also true for pumps. Sound is produced by liquid flowing within the pump, the bearings within the pumping unit, the coupling, and the unit driver. Some sound is expected during normal operation. Sound may be transmitted in three ways:

a) Airborne within the machinery room.

b) Liquidborne by the liquid being pumped.

c) Structureborne through the attached piping and support system.

Two of the most important factors in minimizing sound in pump installations are the correct selection of the pump type for the operating conditions and the equipment installation. To ensure minimum sound, the pump should be chosen for operation near the point of best efficiency and proper suction conditions should be provided.

The prevention of excessive noise is greatly dependent upon the pump installation. Proper alignment of the pump and the driver is essential, as well as the support of the suction and discharge piping. The manner in which the pump is installed and in which the piping is supported may contribute to objectionable noise and vibration. A greater degree of noise prevention may be obtained when the pumping unit is supported free of building structures by the use of vibration isolators and flexible piping and conduit connectors. Noise emanating from the motion of high-velocity liquids within the piping system, particularly from partly opened valves, should not mistakenly be attributed to the pumping unit. Further discussion of noise and sound is contained in ANSI/HI 9.1-9.5, *Pumps – General Guidelines.*

A.5.5.7.2 Hydraulic resonance in piping

Severe vibration problems are often caused by a resonant condition within the pump/piping system that amplifies normal pump-induced pulsations. Such a condition is referred to as a *hydraulic resonance.*

Hydraulic resonance is defined as a condition of pulse reinforcement in which pulses reflected by the piping system are repeatedly added in phase to the source pulse, producing large pulsation amplitudes. Hydraulic resonance in piping may result in unacceptable noise or vibration, or, if uncorrected, can ultimately result in mechanical fatigue failures in either the piping or pump components.

In cases where the existence of a hydraulic resonance is known to be a problem, experience has shown that the following solutions aimed at alleviating the resonant condition may prove effective:

a) Alter the resonant piping.

b) Change the pump speed.

c) Change the internal design characteristics of the pump.

d) Insert a pulsation damper on the pump/piping system.

Modifications to the pump or piping, including the supporting structures, which do not change the pulsation response of the pump/piping system, will not affect the resonant condition and therefore will not be effective.

A.5.5.8 Performance testing/verification

Once the unit is energized, check operating speed, rate of flow, suction and discharge pressure, and power input. While it may not be possible to exactly repeat the factory performance, initial field-test data become a valuable baseline for future checking to determine possible wear and need to perform maintenance. Vibration levels should be checked for the same reason. Auxiliary piping and gasketed joints should be checked for leaks and proper makeup.

A.5.5.9 Bearing temperature

See Section A.7.2.2.

A.6 Maintenance

A.6.1 Schedule

To ensure satisfactory operation of the pumping equipment, frequent inspection and periodic maintenance are required. An inspection and maintenance log should be kept and the inspector is to immediately report any problems. A suggested guide for preventative maintenance for normal applications is given below. Unusual applications with abnormal heat, moisture, dust, etc., may require more frequent inspection and service.

Item	Action Required	Frequency
Packing, Packing box	Inspect for excessive leakage Adjust gland and replace packing	150 hours of operation As necessary
Pump/Motor alignment	Check for change in alignment	Annually
Vibration	Check for change in vibration	Refer to ANSI/HI 9.6.5, *Condition Monitoring*
Bearings	Lubricate (grease)	Every 2000 h or at least annually
Bolting	Check for loose bolting	Annually

A.6.1.1 Cold weather maintenance

When handling water, care should be taken to prevent the pump from freezing during cold weather when the pump is not in operation. It may be necessary to drain the pump casing on dry pit applications during shutdown periods by removing the bottom drain plug. In some pumps, draining the suction line is sufficient. For vertical wet pit pumps, removal of the unit is required.

A.6.1.2 Wear/parts replacements

Wear rings are commonly fitted in the bowls (bowl rings) and if specified, on the impeller (impeller rings). These wear rings provide a close-running, renewable clearance, to reduce the quantity of liquid leaking from the high-pressure side to the suction side. These rings depend on the liquid in the pump for lubrication. They will eventually wear so that the clearance becomes greater and more liquid passes into the suction. This rate of wear depends on the character of the liquid pumped. Badly worn wear rings will result in severe degradation of pump head and rate of flow, particularly on small pumps. Examination of wear patterns can provide valuable information in diagnosing pump problems and determining their origin.

It is not possible to recommend minimum spares to cover all conditions. However, the following may be taken as a guide:

a) For intermittent service:

- Stuffing-box packing or mechanical seal
- Gaskets and O-rings (complete set)
- Packing gland and studs or gland bolts

b) For continuous service (in addition to above):

- Stuffing-box sleeve bearing
- Headshaft (if used)
- Lineshaft (one set)
- Lineshaft coupling (one set)
- Sleeve bearings, both lineshaft and bowlshaft
- Pump shaft
- Impeller lock collets (one set)
- Bowl and/or impeller wear rings (one set)

A.6.2 Recommended spare parts

The list of recommended spare parts will depend on factors such as normal supplier lead time when ordering parts, whether pumping equipment is for use as normal duty or severe duty, and whether or not there is backup pumping while a unit is down for maintenance and component parts replacement. Below is a suggested list of spare parts for pumping units.

For Normal Duty	For Severe Duty
Packing or mechanical seal	Impeller
Shaft sleeve	Shaft
Wear rings or wear plates	
Set of bearings	
Gaskets, O-rings, seals	

For VS8-style pumps, a replacement impeller stack and mechanical seal may be kept on hand.

A.6.3 Consumables

Items normally used in the maintenance of pumping equipment may include the following, but depending on the type of unit, some items may vary.

- Replacement packing, if used
- Lubricant (grease or oil)

- Cleaning materials
- Touch-up coating

A.6.4 Required tools and fixtures

Most preventive maintenance work requires only the use of standard hand tools. Removal of packing is aided by the use of a packing removal tool with a hook or threaded end.

Tools and fixtures for pump disassembly and rebuilding, in addition to the above, may include:

- Lifting devices (crane, hoist, lifting chains or straps)
- Impeller puller (to remove pressed-on impeller from shaft)
- Lock collet hammer (to remove colleted impeller from shaft)
- Bearing puller (to remove pressed-on bearings from shaft)
- Torch (to heat parts to aid in removal)
- Die grinder (to cut out wear rings or remove shaft sleeves, if needed)
- Work table or fixture for holding pump
- Measuring equipment (feeler gauges, dial indicator, etc.)
- Hot oil bath (or method to heat bearings and coupling hubs for installation)

A.6.5 Fastener torques, rotation direction, and sequence

Proper tightening of bolting is very important. These values will vary depending on the size and grade of bolting used. Refer to the installation, operation, and maintenance (IOM) manual provided with the specific pumping unit for proper torque values for specific fasteners.

Most fasteners are standard right-hand threads; however, some units may have fasteners with left-hand threads. Consult the IOM manual provided with the specific pumping unit for designation of rotation.

When reassembling a pumping unit, it is important to follow the tightening sequence stated by the pump manufacturer in the IOM manual. Failure to properly tighten the bolting in sequence (usually going from one side to the other, then back) may result in misalignment, binding, and leakage.

A.6.6 Pump decontamination

Before disassembling a pumping unit, it is very important to ensure that the unit is thoroughly cleaned and there are no residual contaminants that could cause injury or illness. This is particularly true with pumps used for pumping chemicals and sewage handling.

The method of cleaning pumps will vary with the design and construction of the pump. In general, the pump needs to be properly drained, flushed out, and any evidence of contamination removed. Contents of the pump, cleaning materials, and wash-down materials should be properly disposed. In addition to thorough cleaning, disinfecting all surfaces for protection from injury and illness is recommended. During the decontamination and disassembly work to the pump, workers are required to wear protective clothing and equipment to protect them from exposure to potentially harmful materials.

When decontaminating a pump, it is important to use a fluid or compound that will not damage (e.g., corrode or swell) pump components. Often the pump materials of construction are suitable for limited corrosive service with pumpage liquids, such as potable water. Limited contact time with the pump is recommended. Before disinfection or decontamination of a pumping unit, careful consideration must be given to the following items: mixing concentration prior to entering the pump, method of dosage, and pumping operation, e.g., limiting flow, throttling, and limiting retention time. Pump components particularly sensitive to disinfection fluids or compounds include pump shafting, bearing journals, and elastomeric sleeve-type bearings. It is recommended to always contact the pump manufacturer prior to disinfecting or decontaminating a pump.

A.6.7 Disassembly

Pump disassembly should be performed as outlined in the IOM manuals provided by the equipment manufacturer. In most cases, the pumps are removed from their installed locations and disassembly is performed in a well-equipped repair facility.

A.6.8 Inspection

Once the pumping unit is disassembled, component parts should be inspected to determine their condition. Worn parts should be reconditioned to like-new condition or replaced.

A.6.8.1 Acceptance criteria and dimensions

The operation and maintenance manual for the subject pump lists the dimensional criteria, such as wear-ring clearance. If this clearance is no longer attainable because of wear, then the wear rings should be replaced. Likewise if any dimension or tolerance deviates from the allowable amount as shown in the operation and maintenance manual, then it requires correction.

A.6.8.2 Shaft straightening

Refer to the manufacturer for acceptable limits and correction techniques. If a pump shaft is bent beyond acceptable limits, then it requires replacement or straightening. The shaft may be checked for straightness by setting the shaft between two rollers and checking runout by use of a dial indicator. The shaft may be straightened by either the heating and cooling technique or bending it back to straight by use of a press.

A.6.9 Assembly

Following disassembly, cleaning, inspection, and replacement or repair of the component parts, the pump may be reassembled. Follow the assembly procedures listed in the operation and maintenance manual as provided by the pump manufacturer. During the assembly procedure, take care not to damage any of the component parts and avoid contamination (dirt, debris, moisture, etc.) to the unit.

A.6.9.1 Clearances

Proper clearances are shown in the operation and maintenance manual for the pump in question. Following assembly of the pump, be sure it turns freely without binding or rubbing.

A.6.10 Auxiliary equipment – see separate documentation

(Manufacturer will include information in this section regarding auxiliary equipment.)

A.7 Troubleshooting guide

When investigating pump trouble at the jobsite, every effort should first be made to eliminate all outside influences. If the performance is suspect, the correct use and accuracy of instruments should first be checked. In addition, note that pump performance is substantially affected by such liquid characteristics as temperature, specific gravity, and viscosity.

A.7.1 Hydraulic performance

A.7.1.1 Pressure

Insufficient pressure from a pump may be caused by any of the following conditions:

a) Speed too low.

NOTE: When direct-connected to an electric motor, determine if the motor is across the line and receives full voltage. When direct-connected to a steam turbine, make sure the turbine receives full steam pressure.

b) System head less than anticipated.

c) Air or gas in liquid.

d) Impeller rings worn.

e) Impeller damaged.

f) Impeller diameter too small.

g) Impeller for wrong direction of rotation.

h) Wrong direction of rotation.

i) Excessive clearance adjustment on semi-open impellers.

j) Leaking joints.

k) Failed to remove protective caps for shipment from suction and discharge openings.

l) Rotating internal stack (VS8)

m) Check valve (on the pump's discharge line) operating improperly due to trash or a mechanical problem.

Loss of suction under these conditions may be caused by any of the following conditions:

a) Suction line drawing air.

b) Suction lift too high or insufficient NPSHA.

c) Air or gas in liquid.

d) Bowl gasket defective.

e) Clogging of strainer.

f) Excessive well drawdown.

g) High liquid temperature.

A.7.1.2 Flow

Lack of discharge from a pump may be caused by any of the following conditions:

a) Pump not primed.

b) Speed too low.

NOTE: When direct-connected to an electric motor, determine if the motor is across the line and receives full voltage. When direct-connected to a steam turbine, make sure the turbine receives full steam pressure.

c) System head exceeds shut-off head.

d) Suction lift higher than that for which pump is designed.

e) Impeller completely plugged.

f) Impeller installed backwards.

g) Wrong direction of rotation.

h) Air leak in the suction line.

i) Well drawdown below minimum submergence.

j) Pump damaged during installation.

k) Broken lineshaft or coupling.

l) Impeller(s) loose on shaft.

m) Closed suction valve.

n) Failed to remove protective caps for shipment from suction and discharge openings.

o) Check valve (on the pump's discharge line) operating improperly due to trash or a mechanical problem.

Insufficient discharge from a pump may be caused by any of the following conditions:

a) Air leaks in suction line (can pumps).

b) Speed too low.

NOTE: When direct-connected to an electric motor, determine if the motor is across the line and receives full voltage. When direct-connected to a steam turbine, make sure the turbine receives full steam pressure.

c) System head higher than anticipated.

d) Insufficient NPSHA: Suction lift too high.

e) Clogged suction line or screen.

f) Not enough suction head for hot or volatile liquids.

g) Foot valve too small.

h) Impeller partially plugged.

i) Rings worn.

j) Impeller damaged.

k) Impeller(s) loose on shaft.

l) Excessive clearance adjustment on semi-open impeller.

m) Suction valve partially closed.

n) Leaking joints.

o) Foot valve of suction opening not submerged enough.

p) Impeller installed backwards.

q) Wrong direction of rotation.

r) Check valve (on the pump's discharge line) operating improperly due to trash or a mechanical problem.

A.7.1.3 Power

High power consumption may be caused by any of the following conditions:

a) Speed too high.

b) System head lower than rating, pumps too much liquid (radial and mixed flow pumps).

c) System head higher than rating, pumps too little liquid (axial and mixed flow pumps).

d) Specific gravity or viscosity of liquid pumped is too high.

e) Shaft bent.

f) Rotating element binds.

g) Stuffing boxes too tight.

h) Impeller rings worn.

i) Electrical or mechanical defect in motor.

j) Undersized submersible cable or poor connections.

k) Incorrect lubrication of driver.

l) Lubricant in shaft enclosing tube too viscous.

A.7.2 Mechanical

A.7.2.1 Vibration

Refer to ANSI/HI 9.6.4, *Rotodynamic Pumps for Vibration Measurements and Allowable Values.*

A.7.2.2 Bearing temperature

The temperature of the bearings within a vertical pump is not measured. When bearing temperature is measured, it is usually either at the driver bearings or independent thrust bearing mounted below the driver. (Manufacturer will include information in this section regarding values for allowable bearing temperatures.)

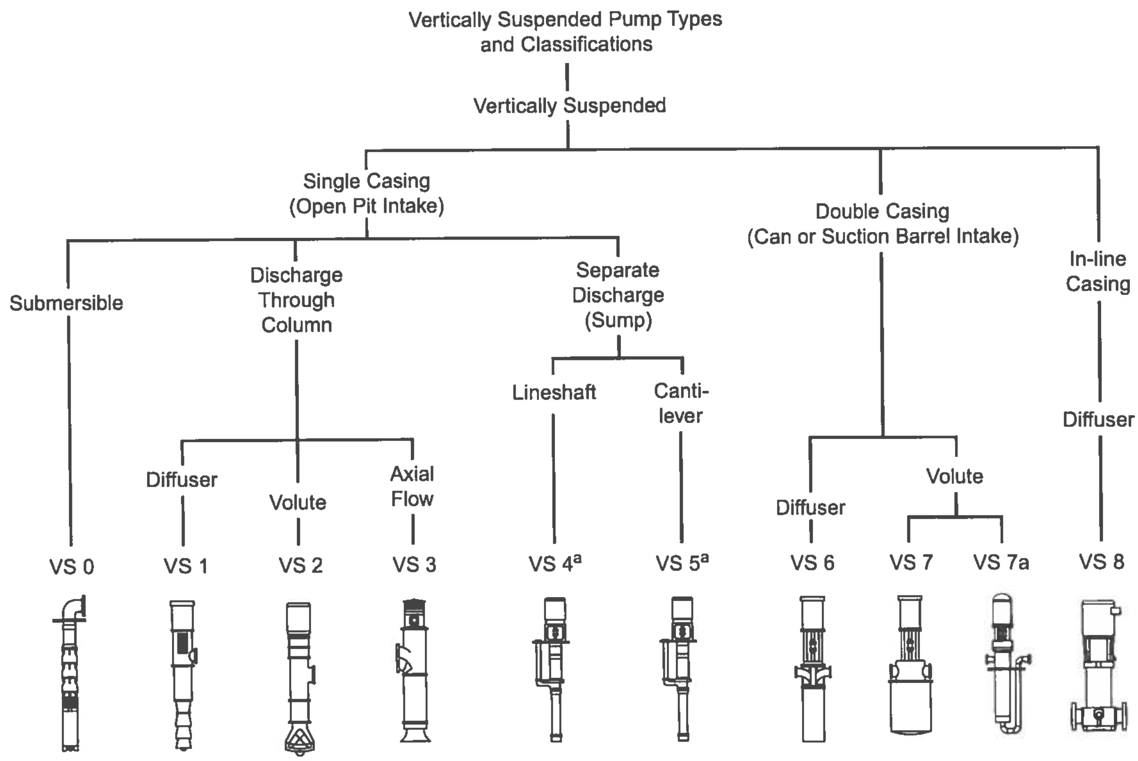
A.7.2.3 Noise

The sound generated within a vertical pump is discussed in ANSI/HI 2.3, *Rotodynamic (Vertical) Pumps for Design and Application*. The sound pressure level for vertical pumps is usually less than the sound generated by the driver.

A.7.3 Electrical

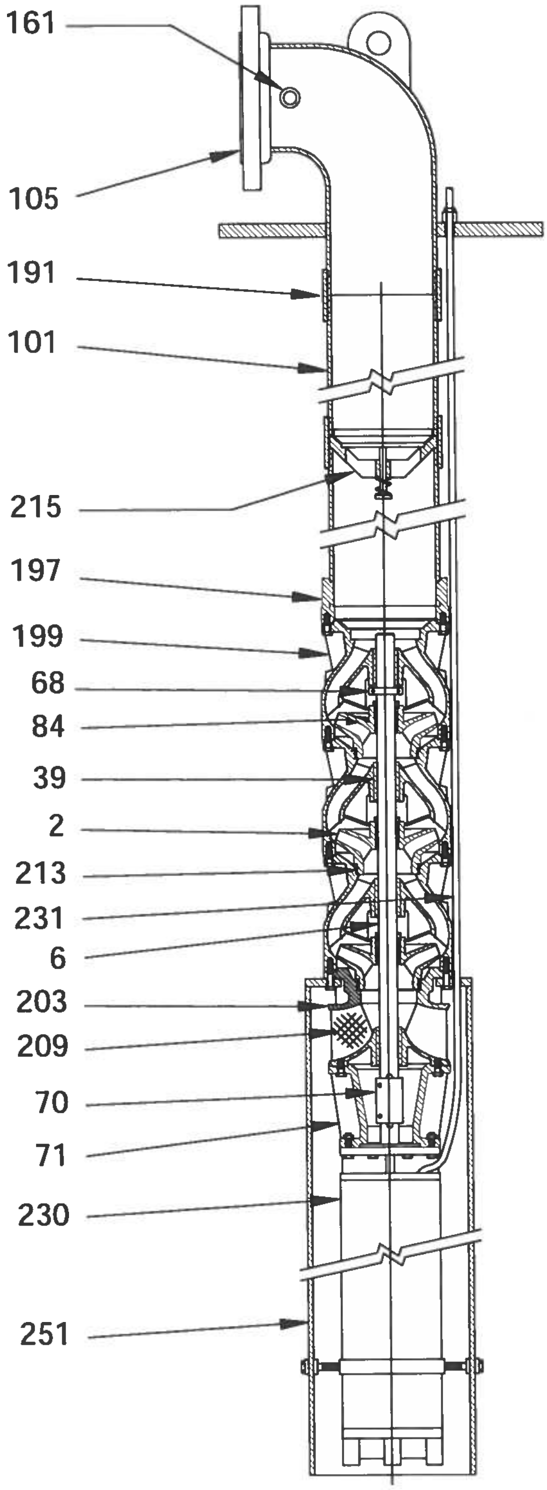
(Manufacturer will include information in this section regarding electrical troubleshooting.)

A.8 Parts listing and cross-sectional drawings



[a] See ANSI/HI 1.4, *Centrifugal Pumps for Installation, Operation and Maintenance.*

Figure A.10 — Vertical pump types – single and multistage



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)

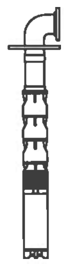
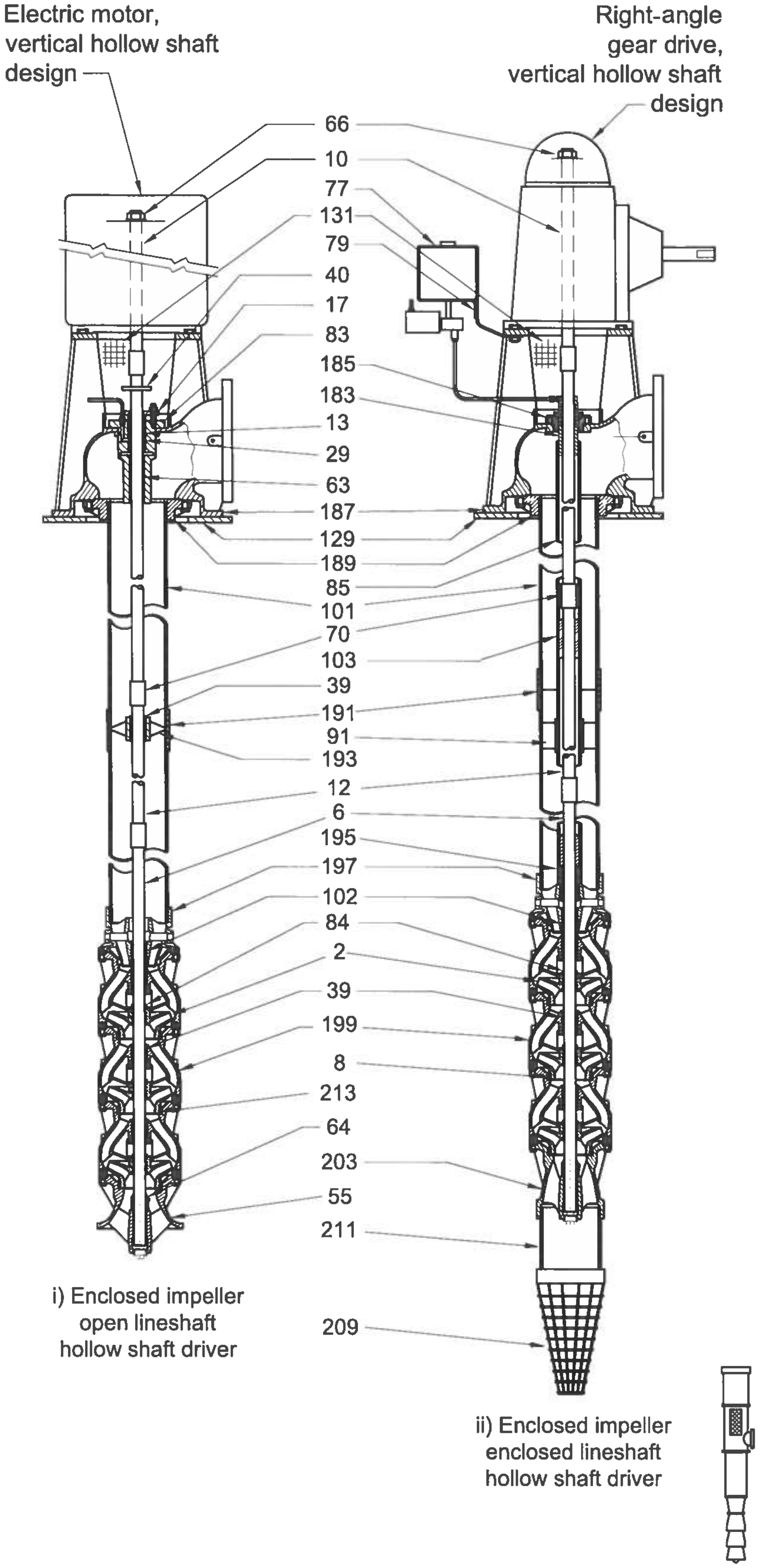


Figure A.11 — Vertical, multistage, submersible pump (VSO)

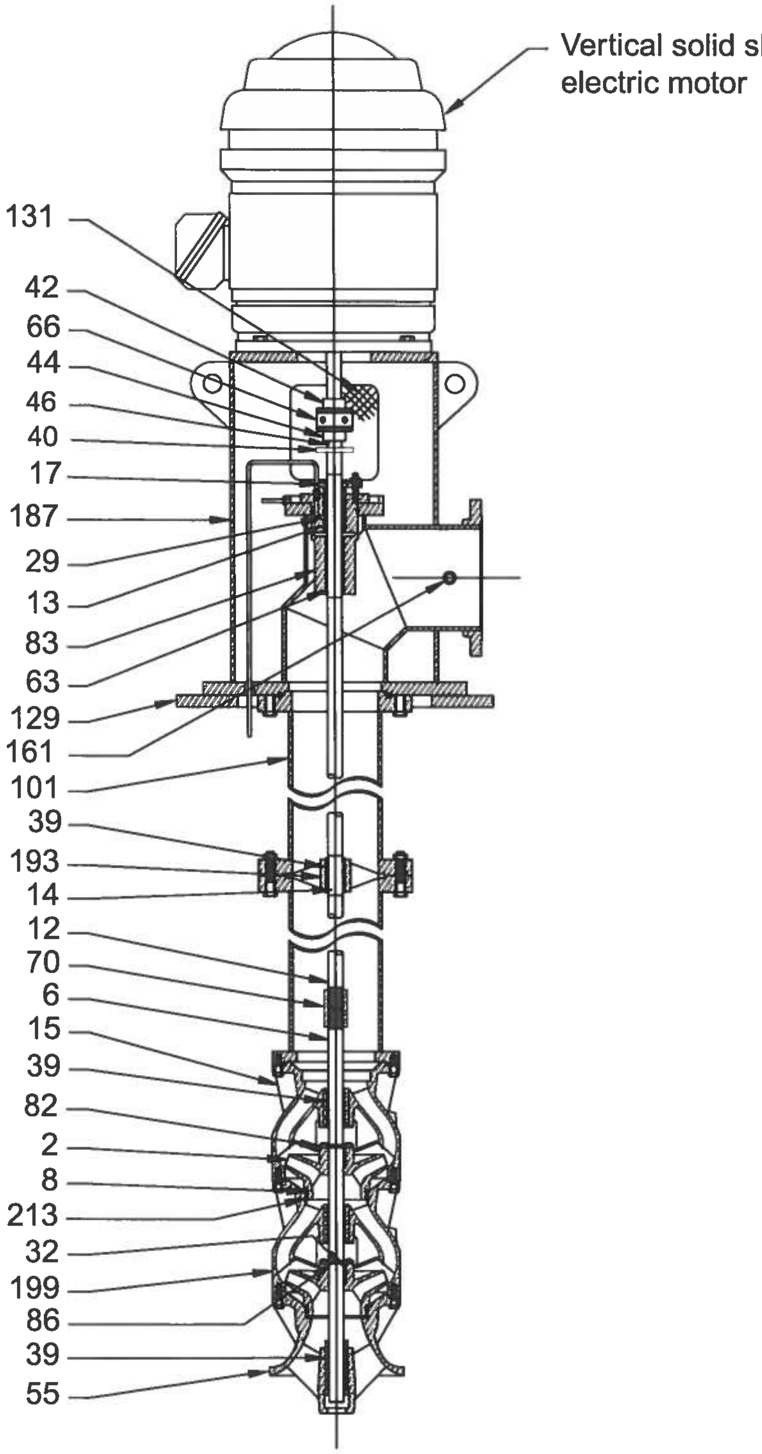
2	Impeller
6	Shaft, pump
8	Ring, impeller
10	Shaft, head
12	Shaft, line
13	Packing
17	Gland
29	Ring, lantern
39	Bearing, sleeve
40	Deflector
55	Bell, suction
63	Bushing, stuffing box
64	Collar, protecting
66	Nut, shaft-adjusting
70	Coupling, shaft
77	Lubricator
79	Bracket, lubricator
83	Stuffing box
84	Collet, impeller lock
85	Tube, shaft-enclosing
91	Stabilizer, tube
101	Pipe, column
102	Bearing, throttle
103	Bearing, lineshaft, enclosing
129	Sole plate
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 lineshaft
195	Adapter, tube
197	Case, discharge
199	Bowl, intermediate
203	Case, suction
209	Strainer (optional)
211	Pipe, suction (optional)
213	Ring, bowl



i) Enclosed impeller open lineshaft hollow shaft driver

ii) Enclosed impeller enclosed lineshaft hollow shaft driver

Figure A.12 — 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 lineshaft
199	Bowl, intermediate
213	Ring, bowl

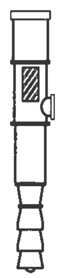
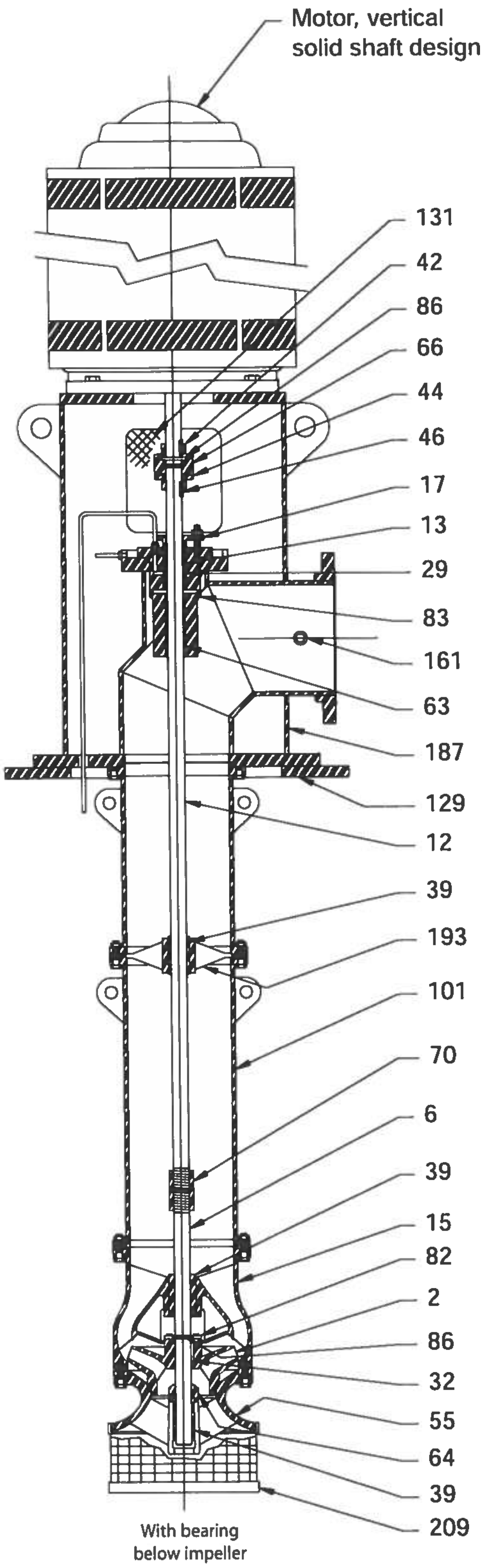


Figure A.13 — Vertical single or multistage, short setting, open lineshaft (VS1)



2 Impeller
6 Shaft, pump
12 Shaft, line
13 Packing
15 Bowl, discharge
17 Gland
24 Nut, impeller
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, protecting
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 lineshaft
209 Strainer (optional)

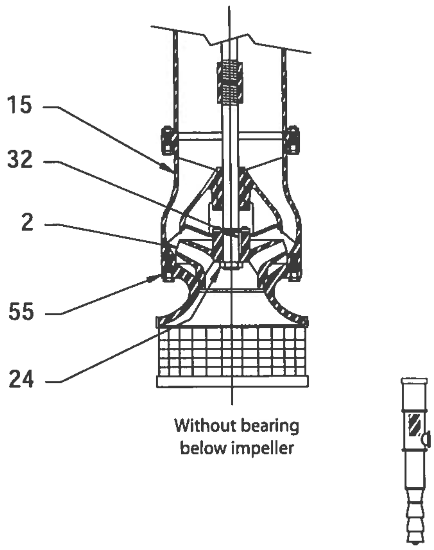
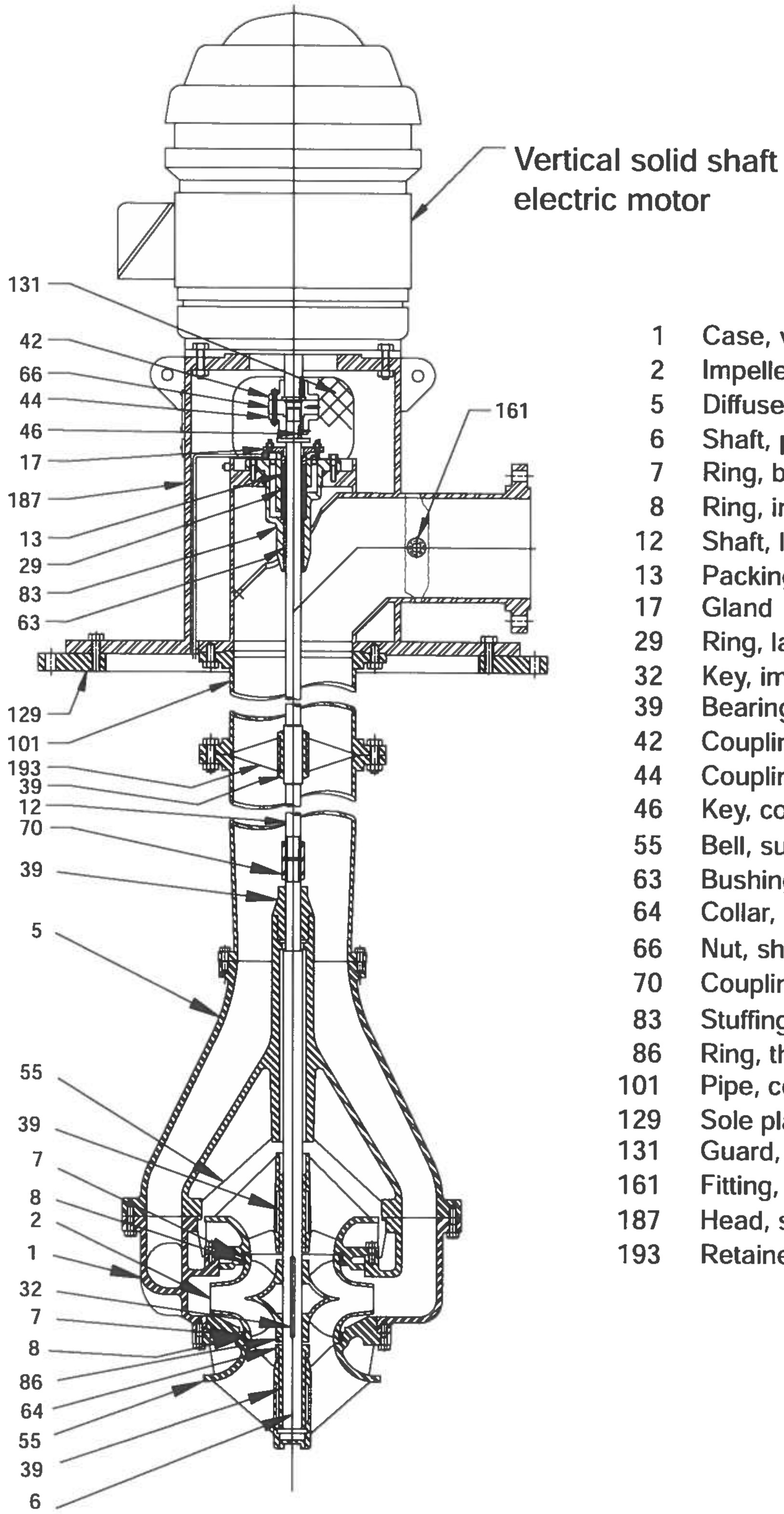


Figure A.14 — Mixed flow vertical, open lineshaft (VS1)



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, protecting
66	Nut, shaft adjusting
70	Coupling, shaft
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

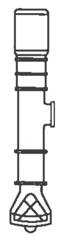
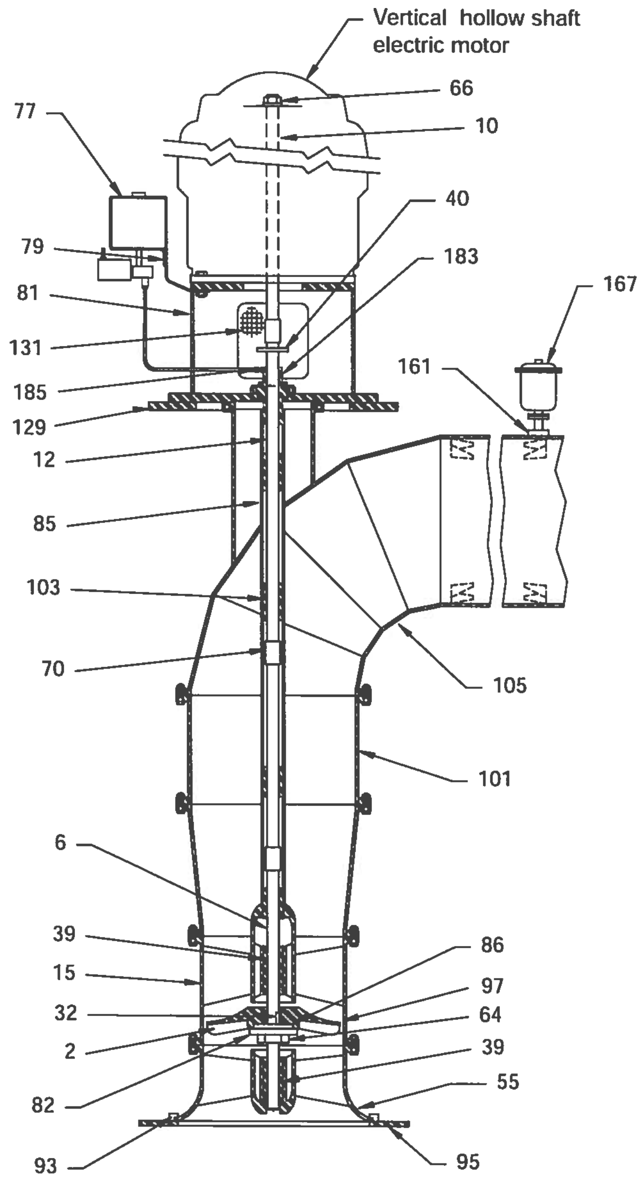


Figure A.15 — Vertical double suction, short setting, open lineshaft (VS2)



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, lineshaft, 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

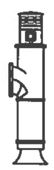
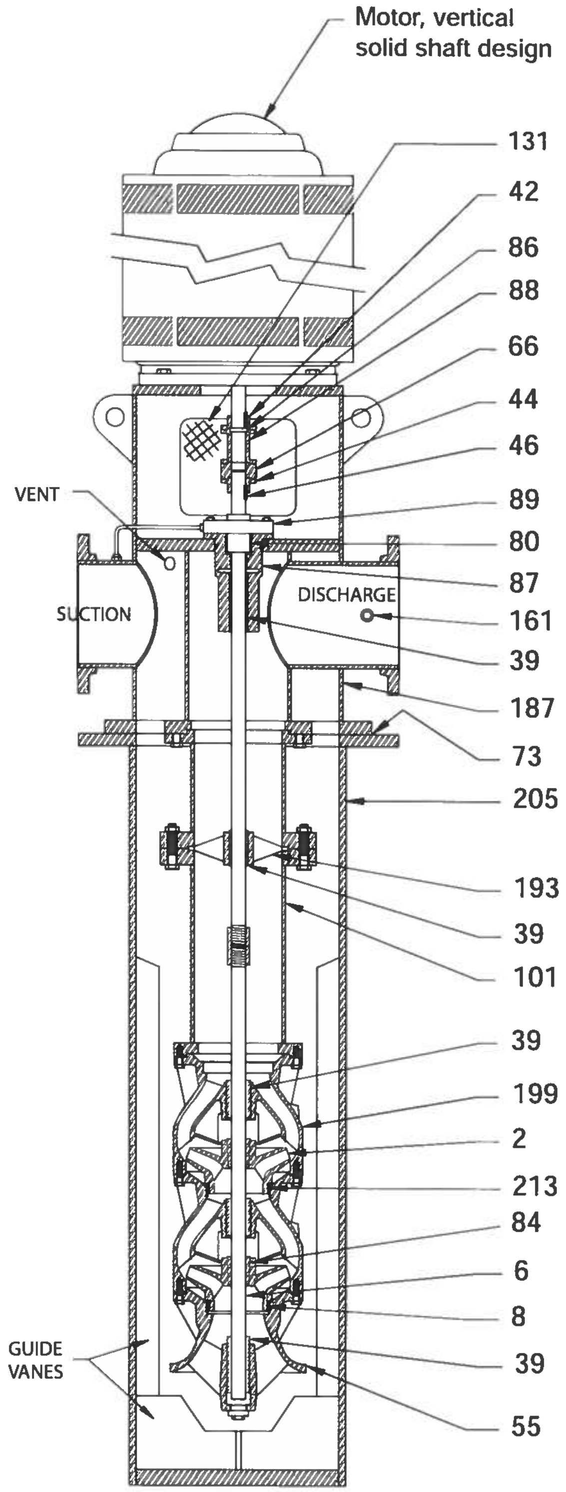
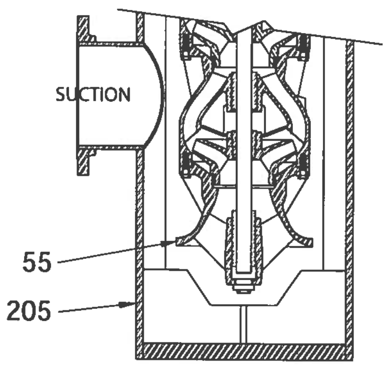


Figure A.16 — Vertical, axial flow impellar (propeller) type (enclosed lineshaft) below floor discharge configuration (VS3)



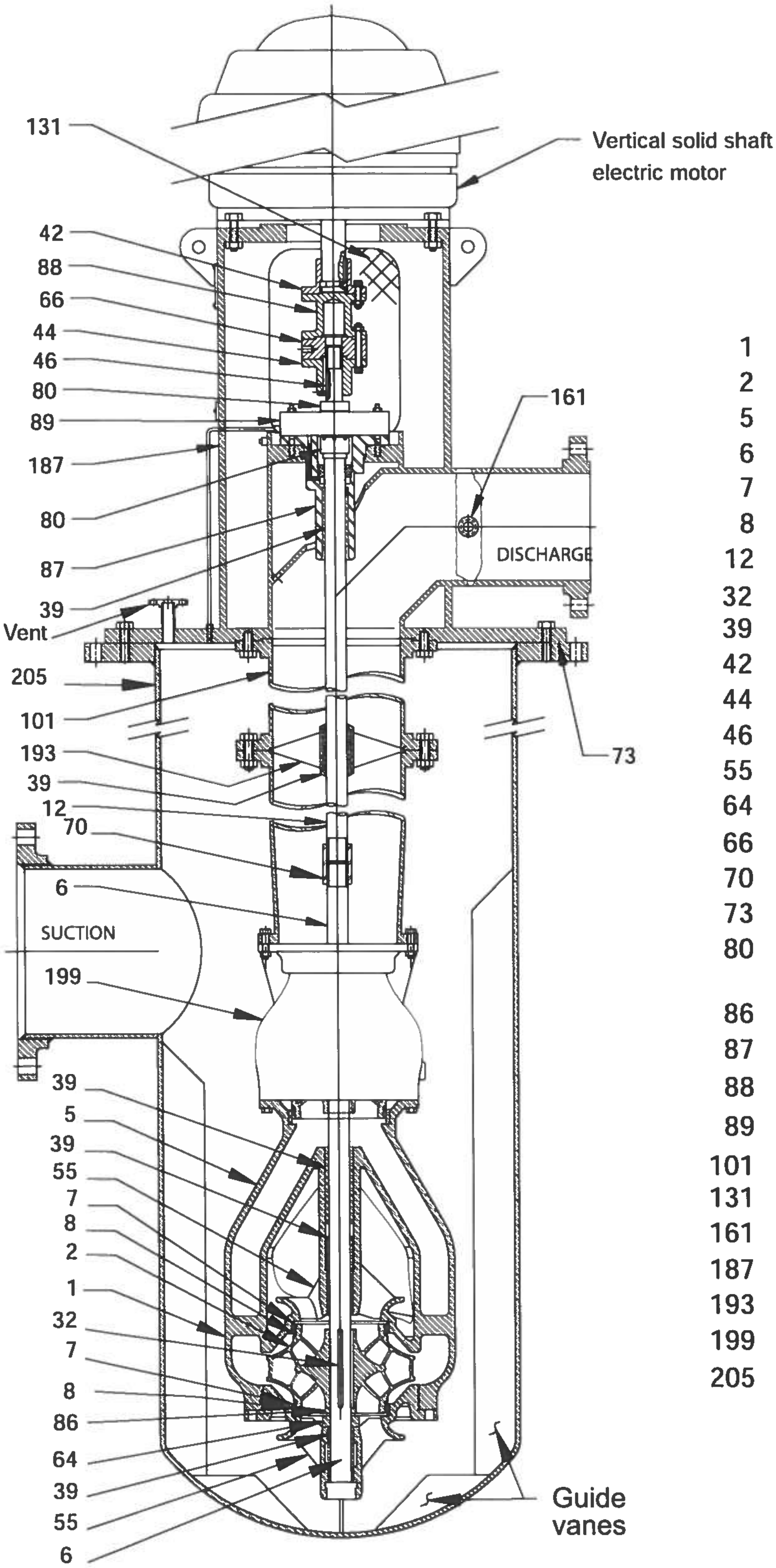
Suction nozzle in discharge head

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 lineshaft
199 Bowl, intermediate
205 Barrel or can suction
213 Ring, bowl



Suction nozzle in barrel

Figure A.17 — Vertical single or multistage 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, protecting
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

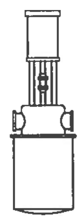
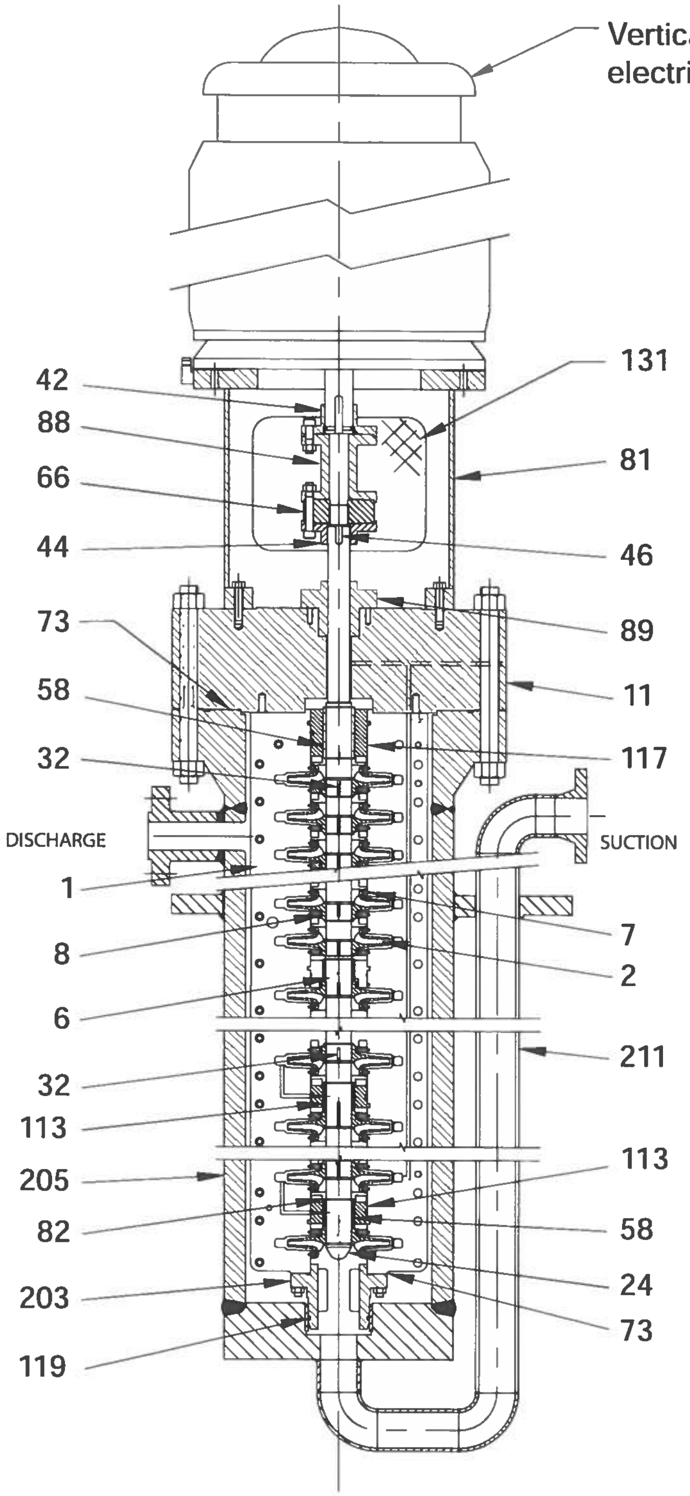


Figure A.18 — Vertical double suction, multistage barrel or can pump (VS7)



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

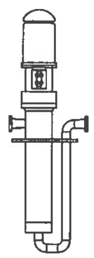
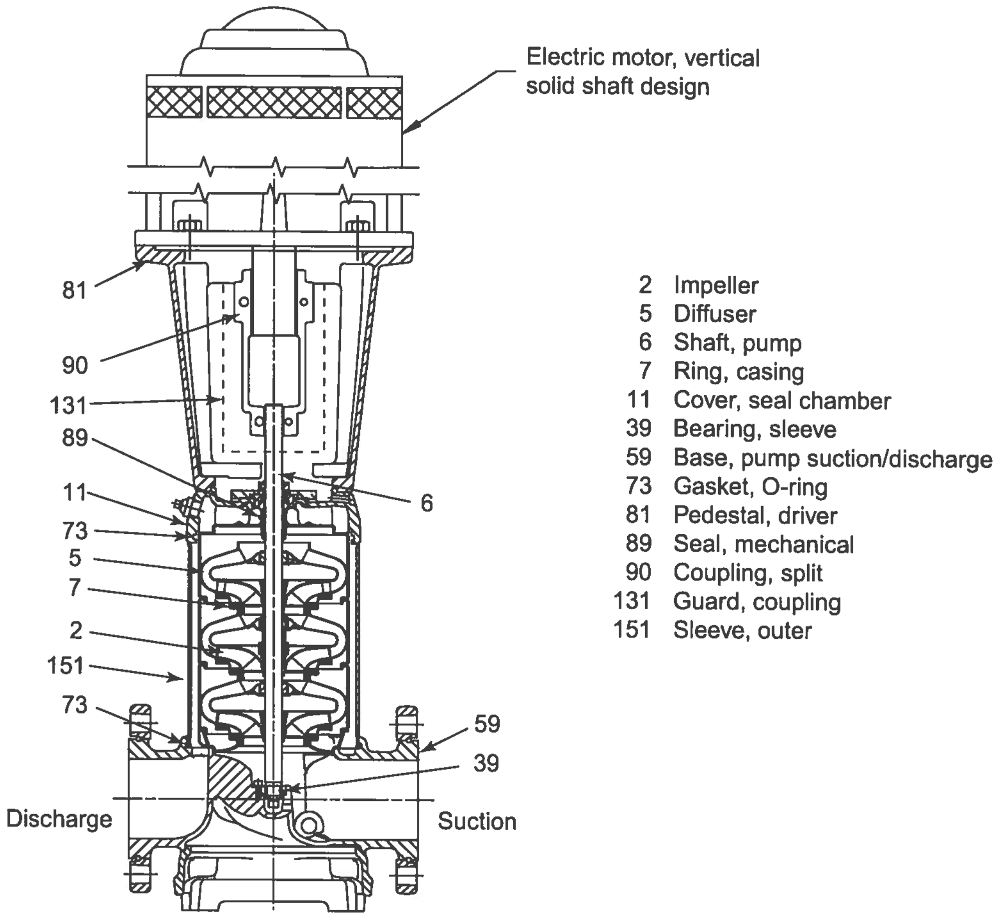


Figure A.19 — Vertical volute multistage double casing pump (VS7a)



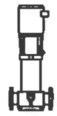


Figure A.20 — Vertically floor-mounted, in-line casing diffuser pump (VS8)

A.9 Certification

Although many retailers, consumers, distributors, installers, and regulatory officials today require that certification marks appear on products, there may still be some confusion about what certification marks mean, who is qualified to perform product testing and certification and issue the marks, and how product safety testing and performance certification organizations can assist in protecting purchasers from products that do not meet accepted standards for safety and/or performance. To help clarify these issues, a guide to understanding how the process works follows.

A.9.1 Why product certification matters

Product certification marks offer peace of mind to well drillers, pump installers, product specifiers, regulators, retailers, and consumers alike. Certification marks such as UL and CSA-US provide credible evidence that a product has been independently tested and certified to meet recognized standards for safety or performance.

In some jurisdictions, such as New York City, Los Angeles (city and county), Chicago, Washington, Oregon, and North Carolina, certification marks are mandatory; in other jurisdictions these marks are voluntary. But in either case it makes good sense to look for a reputable certification mark on the products you buy, sell, and specify, especially in today's business environment where independent verification and product liability litigation are increasing concerns.

Certification marks demonstrate responsible corporate citizenship, and shows commitment to customer satisfaction and safety. It means greater consumer confidence. Certification demonstrates that products will work together safely, such as a pump and motor assembly, and various control box combinations.

A.9.2 UL and CSA-US acceptance

For over 100 years, products have been tested and listed by independent testing laboratories for use in North America to ensure public safety. Product certification marks are the result of an independent, accredited third-party testing and certification process. Today, the three largest product-safety testing and certification laboratories in North America are Underwriters Laboratory Inc (UL), Canadian Standards Association (CSA), and Intertek (ITS [ETL]).

Today, it makes no difference which recognized laboratory tests and certifies a product. This is a direct result of the North American Free Trade Agreement (NAFTA) as applied to third-party conformity assessment procedures recognized by the Occupational Safety and Health Administration (OSHA).

Products displaying the CSA marks are accepted by, and found on the shelves of, leading retail chains and carried by leading wholesalers and distributors.

For additional information on the various certification marks, their meaning, interchangeability, and other related topics, visit UL at www.ul.com and CSA at www.csa-international.org.

A.9.3 Authorized testing locations

There are two considerations to ensure testing compliance:

- The standard to which a product is tested and the independent testing
- The certification laboratory that tests the product and certifies its compliance, authorizing the manufacturer to apply its certification mark

All similar listed products in the United States are tested to the same standard, regardless of whether or not they are tested, certified by, and carry either a UL or CSA-US mark. Hence, UL and CSA-US marks are interchangeable and are normally equally accepted today.

Because multiple laboratories have attained national accreditation/recognition as a Nationally Recognized Testing Laboratory (NRTL) through OSHA to test and certify various types of product, a competitive open testing and certification marketplace has been created. These different competing laboratories can then test and evaluate similar products against the same standards, offering choices in laboratories and certification marks that are not solely based on who did the testing and evaluation.

To receive OSHA recognition, a laboratory should submit application materials to OSHA. OSHA then performs an application review and an assessment review of the laboratory's organization, programs, and test facilities to prove that it has the necessary competence, capabilities, calibration and control programs, independence, and reporting and compliant handling procedures. If the findings are successful, the laboratory is considered approved as an NRTL. All NRTLs test products against the same set of standards regardless of who wrote or published them. The organizations that are covered to test the same products are then considered equally qualified to perform the testing covered by their OSHA recognitions.

The certification mark provides visual evidence that the product was tested and certified to meet the applicable standard. All listed products for the US market are tested to the same standard, regardless of whether they carry a

UL or CSA-US mark. Hence, the following UL and CSA marks are interchangeable and are usually equally accepted today.

A.9.3.1 Underwriters Laboratories, Inc

UL listing mark

This is one of the most common UL marks. If a product carries this mark, it means UL found that representative samples of this complete product met UL's safety requirements. These requirements are primarily based on UL's own published Standards for Safety. Testing and certification is performed by UL.

C US LISTED **C-UL US listing mark**

UL introduced this new listing mark in early 1998. It indicates compliance with both Canadian and US requirements. The Canada/US UL mark is optional. UL encourages those manufacturers with products certified for both countries to use this new, combined mark, but they may continue using separate UL marks for the United States and Canada. Testing and certification is performed by UL.

Recognized Component mark and Canadian Recognized Component mark

These are marks consumers rarely see because they are specifically used on component parts that are part of a larger product or system, such as motors and their controls, which are then assembled together in combination with a pump. These components may have restrictions on their performance or may be incomplete in construction. Products intended for Canada carry the Recognized Component mark "C." Testing and certification is performed by UL.

CLASSIFIED WATER QUALITY CLASSIFIED EPH **Water Quality mark**

The UL Water Quality mark appears on drinking water products evaluated to drinking water standards. The UL Water Quality mark can be found on drinking water treatment additives; drinking water treatment/filtration units; drinking water system components and materials, such as submersible well pumps and their motors; water storage tanks; and distribution and plumbing products. Until the UL Water Quality mark is fully implemented in 2010, the UL EPH (upside-down triangle) may also appear on drinking water products. Testing and certification is performed by UL.

A.9.3.2 Canadian Standards Association

US NRTL **Certification marks for the United States**

For the United States: A CSA mark with the indicator "US" or "NRTL" means that the product is certified for the US market to the applicable US standards. Testing and certification is performed by CSA.

For the United States and Canada: A CSA mark with the indicators "C" and "US" or "NRTL/C" means that the product is certified for both the US and Canadian markets, to the applicable US and Canadian standards. Testing and certification is performed by CSA.

For the United States: A CSA mark with the indicator "NSF/ANSI 61" means that the product is certified for the US market to the requirements of the ANSI/NSF 61 standard *Drinking Water System Components – Health Effects.* Testing and certification is performed by CSA.

A.10 Other relevant documentation and manuals

(Manufacturer will include other relevant documentation or manuals, such as motor manuals, in this section.)

Appendix B

Index

This appendix is not part of this standard, but is presented to help the user with factors referenced in the standard.

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

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