ANSI/HI 14.4-2018

Approved American National Standard
ANSI

American National Standard for

Rotodynamic Pumps

— for Installation, Operation, and Maintenance

HYDRAULIC INSTITUTE

ANSI/HI 14.4–2018

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— for Installation, Operation, and Maintenance

Sponsor
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www.Pumps.org

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American National Standard

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Foreword (Not part of Standard)

Purpose and aims of the Hydraulic Institute

The purpose and aims of the Hydraulic Institute (HI) are to promote the advancement of the pump manufacturing industry and further the interests of the public and to this end, among other things:

a) Develop and publish standards

b) Address pump systems

c) Expand knowledge and resources

d) Educate the marketplace

e) Advocate for the industry.

Purpose of Standards and Guidelines

a) HI Standards and Guidelines 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.

b) Use of HI Standards and Guidelines is completely voluntary. Existence of HI 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."

Definition of a Hydraulic Institute Guideline

An HI Guideline is not normative. The guideline is tutorial in nature to help the reader better understand the subject matter.

Comments from users

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

Revisions

American National Standards of the Hydraulic Institute (ANSI/HI) 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.

Disclaimer

This document was prepared by an HI committee and approved by following ANSI essential requirements. Neither HI, HI committees, nor any person acting on behalf of HI: 1) makes any warranty, expressed or implied, with respect to the use of any information, apparatus, method, or process disclosed in this document or guarantees that such may not infringe privately owned rights; 2) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this guideline. The Hydraulic

Institute is in no way responsible for any consequences to an owner, operator, user, or anyone else resulting from reference to the content of this document, its application, or use.

This document does not contain a complete statement of all requirements, analyses, and procedures necessary to ensure safe or appropriate selection, installation, testing, inspection, and operation of any pump or associated products. Each application, service, and selection is unique with process requirements that shall be determined by the owner, operator, or its designated representative.

Units of measurement

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

Consensus

Consensus for this American National Standard was achieved by use of the canvass method. The following organizations, recognized as having an interest in the standardization of 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.

Arizona Public Service/PVGS
Brown and Caldwell
Carollo Engineers Inc.
David McKinstry, Retired
GM BluePlan Engineering
JK Muir LLC
Kemet Inc.
Mechanical Solutions, Inc.
Outotec Canada Ltd.
Swiss Flow Solutions

Committee list

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

Chair – Paul Ruzicka, Xylem – Applied Water Systems
Vice Chair – Ernest Sturtz, CDM Smith – Water Services Group

Committee Members	**Company**
Lloyd Aanonsen	General Rubber Corporation
Jack Bagain	John Crane Inc.
Michael Coussens	Peerless Pump Company
Ryan Grimm (Alternate)	Sundyne LLC
Patrick Hogg	Nidec Motor Corporation
Lane Larsen	Weir Specialty Pumps
Patricia McCarthy	Xylem Inc. - Water Solutions
Michael Mueller (Alternate)	Flowserve Corporation
Maya Place (Alternate)	SULZER
Craig Redmond	Gorman-Rupp, Mansfield Division
Jan Schyberg (Alternate)	Xylem Inc. - Water Solutions
George Tey	MWH Americas, Inc.
Albert Ticknor, III, P.E.	National Pump Company
Kees van der Sluijs	Flowserve Corporation
Jared Wageman	Sundyne LLC
Clint Zentic	SULZER

14.4 Manuals describing installation, operation, and maintenance

14.4.1 Introduction

ANSI/HI Standards for Rotodynamic Installation, Operation, and Maintenance (IOM) have historically been subdivided into ANSI/HI 1.4 *Rotodynamic Centrifugal Pumps for Manuals Describing Installation, Operation, and Maintenance* and ANSI/HI 2.4 for *Rotodynamic Vertical Pumps for Manuals Describing Installation, Operation, and Maintenance*. The demarcation between these two standards was determined by the arrangement of the hydraulic configuration (impeller, casing, bowl, or diffuser).

However, in each case they have shared a standard outline with similar content that is better addressed collectively rather than separately Every effort has been made to include and expand all the information contained in these previous standards into a single resource **This document establishes a single source for a standard outline for IOM manuals for the pump community**.

The normative portion of this standard is prescriptive in nature and thereby mandatory for compliance to this standard; it provides a standard outline for manufacturer's 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 manufacturer's IOM manuals for IOM information specific to their equipment.

14.4.1.1 Purpose

The purpose of this standard is provide a normative outline for pump manufacturer's IOM manuals and reference materials to serve as a manufacturer's guideline for the development of an IOM manual that complies with the requirements of the standard.

14.4.1.2 Scope

This standard applies to IOM manuals for all rotodynamic pumps For additional instructions on sealless rotodynamic pumps, see ANSI/HI 5.1-5.6 *Sealless Rotodynamic Pumps for Nomenclature, Definitions, Application, Operation, and Test* For additional information on rotodynamic pumps types, see ANSI/HI *14.1-14.2 Rotodynamic Pump for Nomenclature and Definitions*.

14.4.1.3 Units, Symbols, and Subscripts

The normative portion of this standard is related to to the outline of the IOM only; therefore, this section is left blank.

14.4.2 Standard outline for IOM manuals

The standard outline shall be used when writing IOM manuals. The subtopics 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 subtopics listed need to be included in the IOM manual for all products; the manufacturer will be given the latitude to decide if a particular subtopic is applicable. If the manufacturer has elected not to include a specific section they should include the section in their document and table of contents but identify it as not applicable. Additional content may be added after Section A.9.

For example, in Section A.1, the explanation of safety designations should precede specific safety warnings for a product.

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A.9 Other relevant, instruction, drawings, documentation, and certification

Appendix A

Installation, Operation, and Maintenance Manual Reference Information

This appendix is ***not*** a normative part of this standard, but it is presented as a manufacturer's guideline for the development of an IOM manual that complies with the requirements of the standard. The content is copyrighted and ***not*** intended to be copied verbatim, but should be thoroughly reviewed and properly tailored to the subject equipment.

A.1 Introduction and safety

When properly sized, installed, operated, and maintained, rotodynamic pumps will operate for a long time. While proper sizing of a rotodynamic pump is beyond the scope of this document, the following paragraphs outline general principles that should be considered during the installation, operation, and maintenance of rotodynamic pumps to ensure safe and trouble-free pump operation.

Rotodynamic 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.

A.1.1 Marking and approvals (UL, CSA, NSF, 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 standards and safety agencies. Some examples are: Underwriters Laboratories (UL), Canadian Standards Association (CSA), National Sanitation Foundation or NSF International (NSF), European Conformity (CE) marking directives, Electromagnetic Compatibility (EMC), and Pressure Equipment Directive.

Directives, agency listings, and approvals cover important safety aspects relating to machinery and equipment and the satisfactory provision of technical documents and safety instructions. Check product nameplates for applicable directives and approvals (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 codes and regulations should be consulted to ensure compliance. The following cannot be guaranteed as to its completeness or continuing accuracy.

A.1.2.1 Personal protective equipment

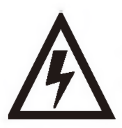
The user shall provide required training and personal protective equipment (PPE) to all personnel that provide IOM of pumping equipment to protect from hazards.

A.1.2.2 Manufacturer's responsibility

The manufacturers shall make all attempts to provide clear instruction and warnings for IOM to avoid risk to personal safety and damage to the equipment by the user.

A.1.2.3 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 onncompliance 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 indicate 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.

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

Note: The following are examples of other useful symbols for use in the IOM. Additional symbols may be found in ANSI Z535 and ISO/TC 94.

 Wear safety gloves

 Wear Hearing Protection

 Wear saftey glasses

 Wear Hard Hat

 Wear Safety shoes

A.1.2.4 Rigging and lifting

 DANGER

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

A.1.2.5 General guidelines

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

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 ensure reliability in service and avoid risks. The instructions may not reflect all current legal requirements and local codes and 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, applicable safety and health laws/regulations, and local codes and 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.1.2.5.1 Safety training

A.1.2.5.2 Safety data sheet (SDS)

Note: As a matter of general practice, SDSs are not supplied with the pumps.

A.1.2.5.3 Personnel qualification and training

It is the responsibility of the owner or operator to ensure that 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. **Proper documentation as to the qualifications of personnel should be maintained by the owner and/or operator of the equipment.**

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

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

It is the responsibility of the owner or operator to provide training for all personnel involved in the operation, installation, inspection, and maintenance of the equipment. The owner or operator shall identify and provide proper training for the use of any PPE as required by specific site.

A.1.2.5.4 Personnel safety actions

These are some typical examples of conditions and actions required to prevent injury to personnel and damage to the environment and equipment.

Warnings

DANGER

NEVER DO MAINTENANCE WORK THAT MAY EXPOSE PERSONNEL TO HAZARDOUS ENERGY.

ALWAYS FOLLOW LOCK OUT – TAG OUT PROCEDURES

GUARDS MUST NOT BE REMOVED WHILE THE PUMP IS OPERATIONAL. ALWAYS FOLLOW LOCK OUT – TAG OUT PROCEDURES

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 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 WITHOUT CONSULTING WITH AND GAINING APPROVAL FROM THE MANUFACTURER. Personal injury and damage to equipment could occur as a result of an explosion. A shaft wrench, release collar, or other special tools may be required to assist with impeller removal.

CAUTION 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, equipped with proper PPE, 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.

HAZARDOUS LIQUIDS

When the pump is handling hazardous liquids, care must be taken to avoid exposure to the liquid by following proper safety precautions, 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 wetted with 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. Refer to ANSI/HI 9.6.2 *Rotodynamic Pumps for Assessment of Applied Nozzle Loads* for additional cautionary actions.

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 PROPERLY ADJUSTED AS REQUIRED BY THE PUMP DESIGN

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 motor overloading 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.)

NEVER RUN THE PUMP DRY

INLET VALVES TO BE FULLY OPEN WHEN PUMP IS RUNNING

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

A.1.2.5.5 Products used in potentially explosive atmospheres

The following instructions for pumps and pump units, when installed in potentially explosive atmospheres, must be followed to help ensure explosion protection. A reference for the requirements of electrical and nonelectrical equipment is the European Union ATEX Directive 2014/34/EU.

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.

A.1.2.5.5.1 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 by third party agencies as required for the classification of the specific atmosphere in which they are to be installed.

Consult the manufacturer for considerations for markings, surface temperature, spark prevention, leakage prevention and maintenance.

The output from a variable frequency drive (VFD) can cause additional heating effects in the motor, and the motor manufacturer 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.1.2.5.5.2 ATEX marking example

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

Category 3 = Normal level of protection

Gas and/or dust

G = Gas

D = Dust

c = Constructional safety

(in accordance with EN 13463-5 / ISO 80079-37)

Gas Group (Equipment Category 2 only)

IIA – Propane (typical)

IIB – Ethylene (typical)

IIC – Hydrogen (typical)

A.1.2.5.5.3 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	Maximum temperature 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 plant operator is responsible for compliance with the specified maximum liquid temperature.

A.1.2.5.5.4 Preventing the buildup of explosive mixtures

If an explosive atmosphere exists during the installation, 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 resulting in elevated 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.

ENSURE THE PUMP IS PROPERLY FILLED AND VENTED AND DOES NOT RUN DRY

Ensure the pump and relevant inlet and outlet pipeline system are completely filled with liquid at all times during the pump operation so that an explosive atmosphere is prevented. In addition, it is essential to verify 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, it is recommended to fit an appropriate dry-run protection device (for example, a liquid detector 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.1.2.5.5.5 Preventing sparks

To prevent a potential hazard from mechanical contact, the coupling guard must be non-sparking and anti-static for Category 2 (see Section **A.1.1.2**).

To avoid the potential hazard of 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 European Union ATEX Directive 2014/34/EU and correct alignment must be maintained.

A.1.2.5.5.6 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 inlet and outlet 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 and leak containment apparatus is recommended.

A.1.2.5.5.7 Maintenance to avoid hazards with a potential of explosion

Ex

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.

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.

Note: As a matter of general practice, safety data sheets are not supplied with the pumps.

A.1.2.6 Noise level data

⚠ CAUTION

Whenever pump and/or driver noise level exceeds 85 dBA, attention must be given to the 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.

While a limiting noise level may have been specified when the equipment was ordered, 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 depends on a number of factors, including the type of driver fitted, the operating capacity, pipework design, and acoustics of the building.

A.1.2.7 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:

DANGER

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

Review Sections A.1.2.1 Personal protective equipment and A.1.2.5.3 Personnel qualification and training prior to any lifting or rigging of the equipment.

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 vibration and g-forces during the handling or transport. For equipment with large and heavy rotating parts, the motor and pump shaft may have been locked to casing or housing to prevent damage of bearing due to jarring motion during shipment. Remove factory-installed blocking only as required during installation to minimize potential damage.

A.2.2 Rigging and lifting

CAUTION The following instructions are for the safe handling of the pump. When shipment is received, extreme care should be exercised during unloading.

CAUTION **Any and all nylon slings, chains, wire rope, hooks and shackles used for lifting must be maintained and inspected to be in good condition and appropriate for the weight and marked accordingly.**

Heavy parts or large parts may shipped braced or palletized and may require lifting equipment to unload.

For example, with a relatively short vertical pump whose overall length is 12 m (40 ft.) or less, it may be convenient to have it shipped as an assembly, less driver braced directly to the transportation vehicle. For longer units over 12m (40 ft.) in length, pump sections may be shipped disconnected requiring the column and shaft sections to be assembled as they are removed from the transporting vehicle. 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.

CAUTION 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.

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.

The unit should be unloaded and handled by lifting equally. Size the lifting equipment for the load. Ensure that the lift angle of the slings, chains or wire rope will be less than 45° from the vertical.

Base plated units should be lifted at four or more points on the baseplate. Some bases are supplied with lifting holes or lugs; in that case, use approved hooks or clevises placed into the holes provided. Then attach nylon slings, chains, or wire rope to the hooks or clevises for lifting.

CAUTION Do not use lifting lugs on drivers or pumps to lift base plated units; these are only for the individual driver or pump.

For base plated units without driver, extra care must be taken when lifting because of the unbalanced load that may exist because the driver is not mounted on the base.

For unassembled vertical pumps that will be installed by assembling at site 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 adequate supports parallel on the ground in the cleared area allowing the pump column and shafts to be safely stored to prevent damage.

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, they should be unloaded from the vehicle in the crate and not be uncrated until ready for installation. For inspection and inventory, 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.

CAUTION 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 may occur. Shafts are especially sensitive to abuse and easily bent if mishandled. 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 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 inlet manifold to avoid damage to the strainer when lifting the pump.

A.2.3 Receipt, inspection, and damage reporting

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 shortages or damage to the transport company handling the shipment and to the equipment manufacturer at receipt of equipment. Note 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 Section A.2.5 Storage.)

Large vertically suspended pumps are normally shipped without the driver attached. The pump itself may be shipped assembled (typically 12 m [40 ft.] or less in length) or as a bowl assembly, column and shafting, outlet 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 line-shaft couplings) that are best left in their shipping container until installation.

A.2.4 Unpacking

Note: Review Sections A.1.2.1 Personal protective equipment and A.1.2.5.3 Personnel qualification and training prior to proceeding.

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 non-coated machined surfaces. If the pump is to be installed immediately, then clean all coated machined surfaces too. Follow the instructions from the Safety Data Sheet (SDS) for any products used to remove protective coatings. Refer to product SDS sheets for instructions on how to properly dispose of all solvents and storage materials. Remove any rust spots found on the machined surfaces with a fine emery cloth. Clean all threaded connections and any accessory equipment.

Note: Many packing materials can be recycled. Please dispose any materials in an environmentally sound way.

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 2 to 3 months from date of shipment, depending on the severity of the environment in which the equipment is stored as recommended by the manufacturer.

A.2.5.1 Recommended storage environment

- Equipment should be protected from flooding, properly supported, and protected from the elements 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 6 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, crusting grease, vapor phase inhibitor, or rust-preventative coating.

A.2.5.2 Uncontrolled storage moisture protection

- All pipe threads and flanged pipe covers are to be sealed. In addition, appropriate amounts of moisture-absorbing desiccant or vapor phase inhibitor crystals should be placed near the center of pump.
- If equipped, connect space heaters on equipment such as motors, engines, or controls.
- WARNING: All desiccants or vapor crystals shall be removed prior to installation.

- 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.

A.2.5.3 Precautions when stored in potential freezing temperatures

Avoid rotating the impeller/propeller by hand at temperatures below freezing

To avoid freeze damage:

- Pumps should be checked to ensure the pump is devoid of all pumped liquid.
- Pumps recently removed from liquid should not be stored at freezing temperature as impeller/propeller and shaft seal can be damaged.
- All liquids, such as lubrication or cooling fluids should be checked to ensure they do not contain unacceptable amounts of water and changed if necessary.
- Prior to storage, if a cooling jacket is present, it should be drained.

A.2.5.4 Short-term storage

The pump and equipment, as shipped, have adequate protection for short-term (up to 3 months) storage in a covered, dry, and ventilated location at the jobsite prior to installation.

- Dry pump internals and spray the liquid end with a water-displacement rust inhibitor.
- Enclose vapor inhibitor in pump internals.
- Apply a film of compatible lube oil over the water-displacement rust preventative.
- After the pump has been thoroughly drained, cover the pump inlet and outlet flanges with full gasket material and blank off these openings with metal blank flanges and a minimum of four bolts. Cover the pump stuffing-box opening with a non-hygroscopic 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 that is readily removable with a suitably environmentally safe 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 verify with the manufacture if the pump shaft should be rotated by hand at intervals of approximately 4 to 6 weeks.
- To place the pump in operation, all protective coverings, coatings, and desiccants 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. Refer to the SDS for instructions on handling and disposal of all products used for preservation in storage or their removal

- Carefully follow all manufacturer's storage and handling recommendations.
- Long-term storage procedures should be followed as detailed by the OEM when the start-up of equipment is made over 3 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 3 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 may be recommended during long-term storage (consult the equipment manufacturer), 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. Refer to the product SDS for instruction on handling and disposal of all 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.3 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.

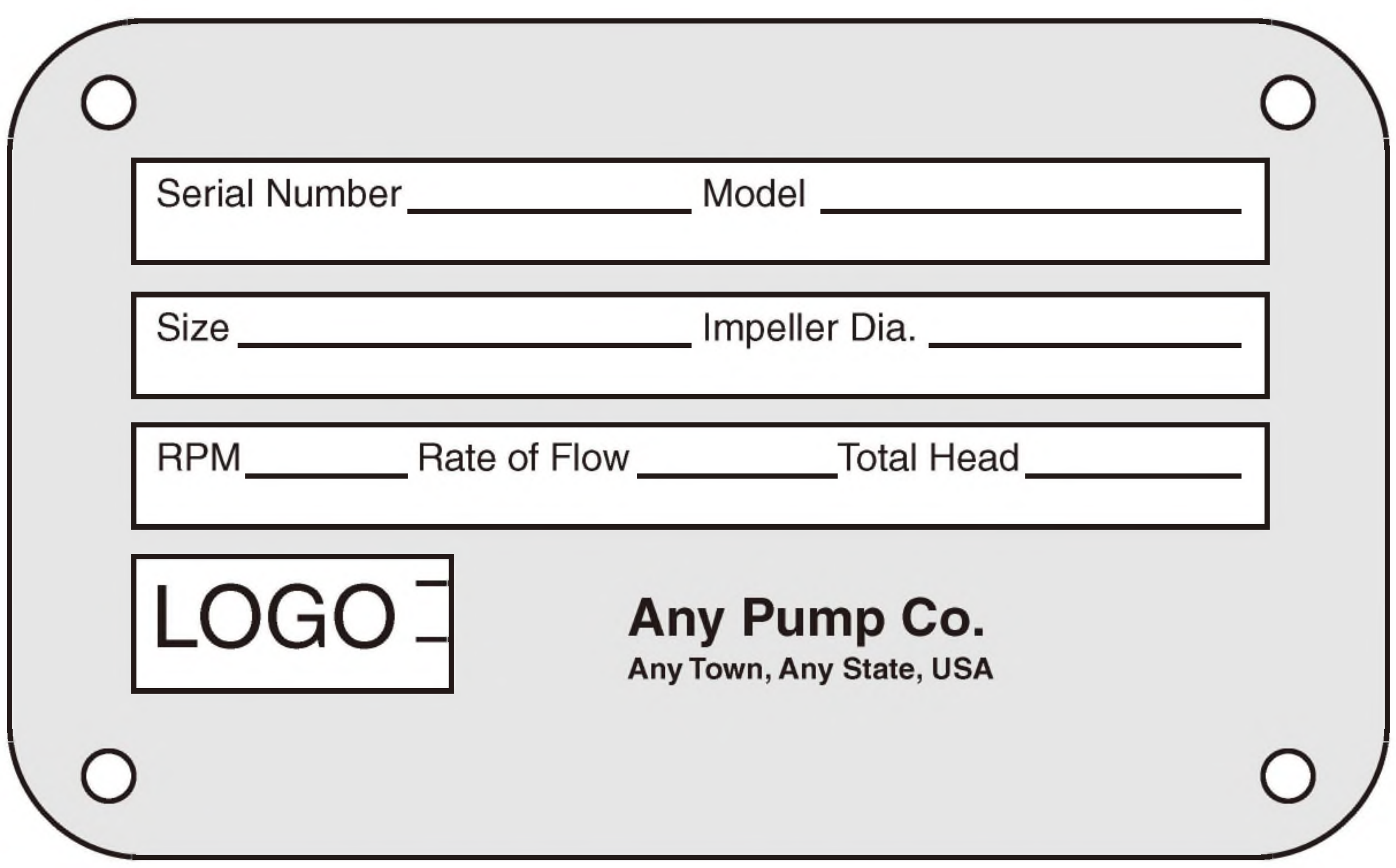


Figure A.3 — Identification plate

A.3.2 Nomenclature

The pump size/model can be given in many different formats by different manufacturers.

A.3.2.1 Nameplate information

- Manufacturer and location
- Size/model
- Serial number/part number/date code
- Rated flow
- Total head
- Rated rpm
- Impeller diameter.

A.3.2.2 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 service personnel 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 and to assist in training operators of the equipment.

A.4.2 Location

For pumps that require assembly on site, a clean, dry 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. Pump accessories such controls instrumentation or intermediate junction boxes must be protected from damage and moisture. 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 outlet piping (and inlet 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 inlet piping and with the least number of elbows and fittings. See ANSI / HI 9.6.6 *Rotodynamic Pumps for Pump Piping*. 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 line-shaft or submersible type, are to be installed in wells, consideration should be given to the well before application and installation (see Figure A.4 — Typical deep-well type installation).

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.

Any wells that have not been properly constructed or developed or produce sand can be detrimental to the reliability and safe operation of 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.

A.4.2.2 Checking wet pits

Guidance from ANSI/HI 9.8 *Rotodynamic Pumps for Pump Intake Design* and ANSI/HI 9.6.6 should be followed to insure proper intake configuration and pump piping. 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 outlet head to outlet piping.

d) Proper conduit location provided for driver.

e) Sufficient head room for handling.

A.4.3 Foundation

Refer to ANSI/HI 14.3 *Rotodynamic Pumps for Design and Application* for specific design considerations for the foundation and foundation bolts

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 and so they can provide proper tension to retain the equipment to the foundation. (See Figure A.4.5).

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. See ANSI HI 9.6.8 Rotodynamic Pumps – *Guideline for Dynamics of Pumping Machinery* for further considerations for structural design and analysis of pumping systems.

Vertical pumps (types VS1, VS2, VS3, VS4, VS5, VS6, VS7, and VS8) should be mounted to ensure they rest on a flat surface without distortion and to minimize any potential pipe strain. The proper design and execution of a sole plate is shown in the section A.4.5 Baseplate/Sole Plate.

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.

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

A.4.4 Rigging and lifting for installation

Refer to A.2.2 Rigging and lifting

⚠ CAUTION **Any and all nylon slings, chains, wire rope, hooks, and shackles used for lifting must be maintained and inspected to be in good condition and appropriate for the weight and marked accordingly.**

For typical installations, suitable overhead lifting equipment of adequate capacity and overhead clearance 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.

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

⚠ CAUTION **Properly sized slings, chains, and shackles should be available for attachment to the equipment lifting lugs. Eye-bolts 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 / Sole Plate

A.4.5.1 Leveling

Provisions to properly fill and vent the baseplate/soleplate must be made prior to installation.

As shown in Figure A.4.5 — Typical foundation bolt, leveling screw, and grout details, baseplates may be mounted on a soleplate or sub-base grouted to a concrete foundation. Shims and metal wedges are not recommended for leveling because they are difficult to remove after grouting

On large units, small leveling screws made of cap screws and nuts under the soleplate may be used. Leveling screws should bear on small stainless steel pads to prevent damage to the foundation.

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

Prior to installation check the baseplate for distortion. Machined bedplates or soleplates mounting pads should be flat and coplanar. Mounting pads for other equipment mounted on the baseplate should be parallel to pump mounting pads. Tolerances for baseplate flatness and leveling pumps sold to API must be to the applicable API standard.

Pumps using un-machined fabricated baseplates the flatness is limited by the mill standards used to manufacture. They may need to have the shims placed between the equipment and base to provide the necessary level and flatness for mounting the equipment. Consult manufacturer for specific tolerances.

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.

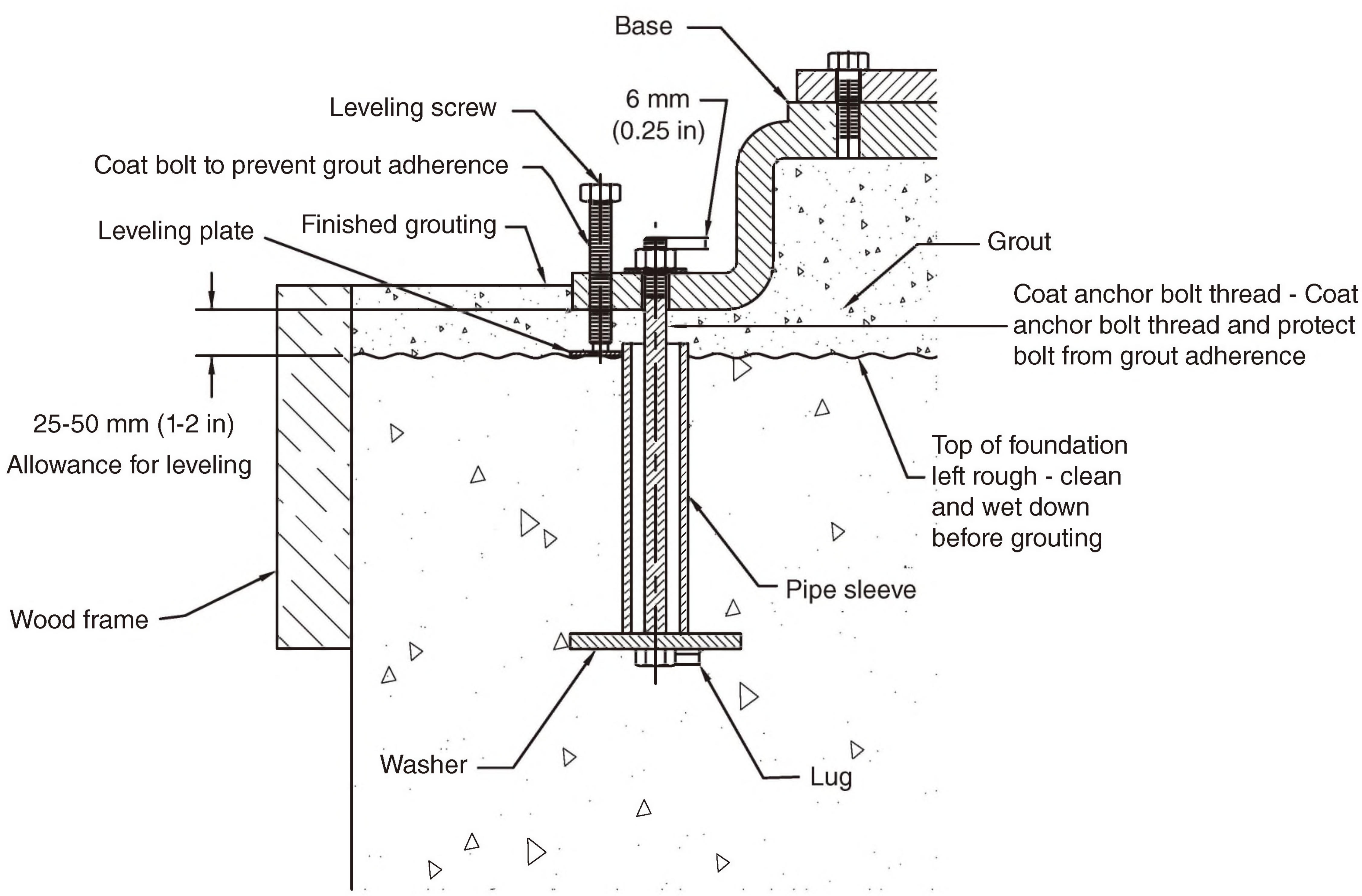
A.4.5.2 Grouting

Baseplates are designed not to capture air during grouting, so no additional venting should be required to prevent voids between the baseplate and the grout. Do not in any way modify the baseplates without consulting the manufacturer.

The addition of grout expansion joints may be required when there are multiple weight bearing foundations and/or a large foundation. Follow the manufactures recommendations.

After the initial grout has cured, the forms may be removed and remaining voids filled with a second application of grout.

CAUTION Properly torque the foundation bolts to the manufacturer's recommendations.



Note: After grout is set, remove leveling screws and torque anchor bolts.

Figure A.4.5 — Typical foundation bolt, leveling screw, and grout details

A.4.6 Pump systems

A.4.6.1 Piping, general guidelines

A.4.6.1.1 Pipe supports/anchors/joints

Inlet and outlet 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 and ANSI/HI 9.6.2.

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.

It's recommended that the first section of pipe be installed on the pump flange and then properly supported. The system piping should then be brought into alignment to the first section of pipe attached to the pump before completing the connections to the piping system.

To verify that no static piping loads are being transmitted to the pump the flange connections are loosened and the alignment of the piping inspected. The piping to the pump inlet and outlet should be aligned to the pump flanges. The bolts should freely pass through flange with no binding. The alignment of the axis of the flanges should be within a tolerance of ½ the radial bolt clearance. Faces of the flanges should be in alignment so that the dimensions between the faces indicate that they are parallel and allow for the insertion of the gasket.

Expansion joints or flexible connections (also referred to as *compensators*) provided at the pump inlet and outlet need to be restrained to prevent transmitting excessive internal thrust loads to the pump. Refer to Figure A.4.6.1—Typical expansion joint with tie rods. An anchor located between the pump and the expansion joint will 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 and setting of the restraint. The total axial elongation of the tie rod and pipe assembly should not exceed the pump manufacturer's recommendation.

Installation of the tie rod is critical. The nuts should be first installed finger tight and carefully tightened as to maintain the spacing between the supporting brackets or flanges of the expansion joint. Lock nut, jam nuts or equivalent methods must be used to prevent the loosening of the rod and movement of the joint in operation due to vibration.

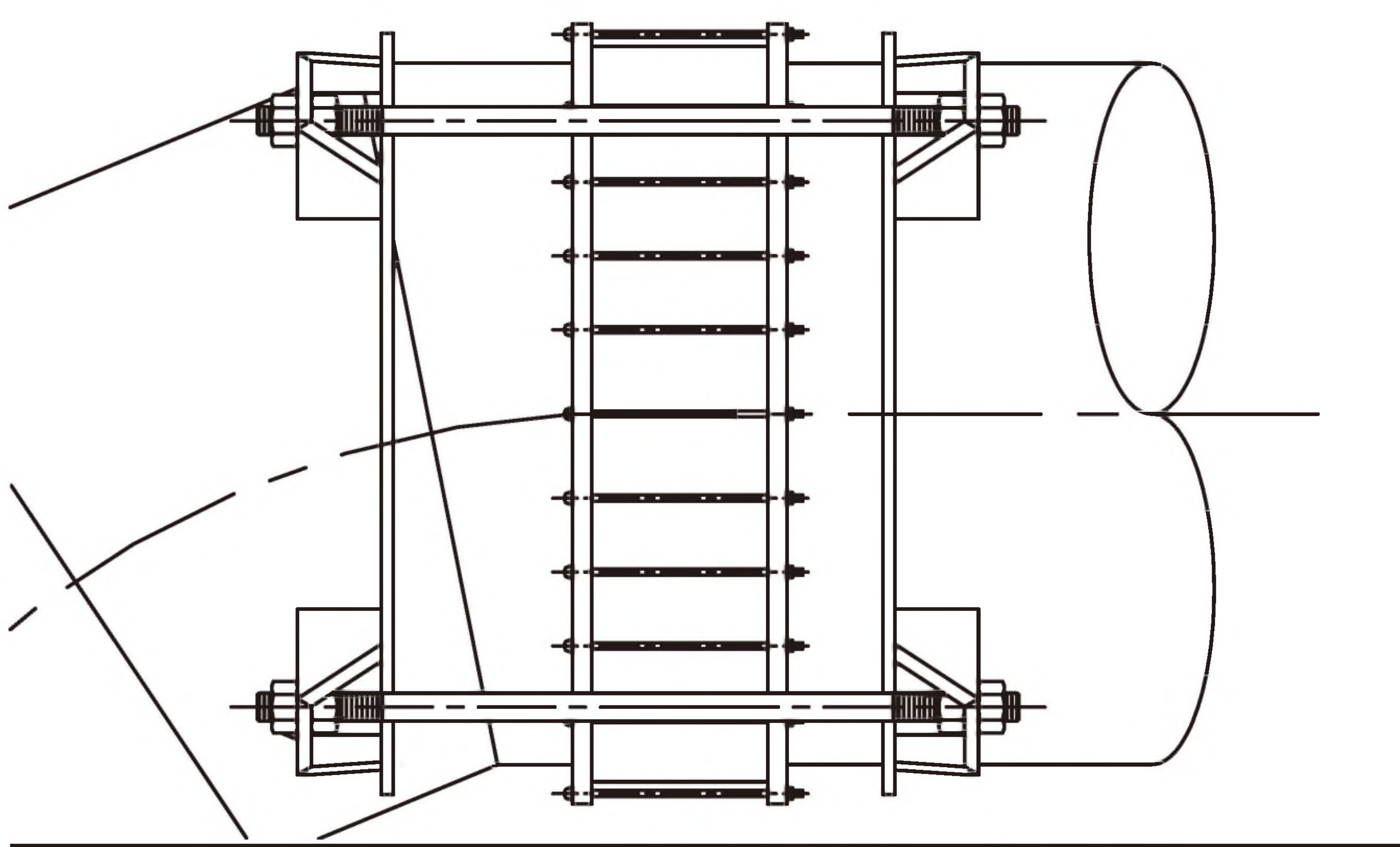


Figure A.4.6.1 — Typical expansion joint with tie rods

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. Because deflection is proportional to stress, these high allowable stresses result in high deflections. 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. If reducers or increasers are used, the flexible connection should be placed in the smaller diameter pipe. 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*, present information on the design of expansion joints and the calculation of thrust.

ANSI/HI 9.6.2 provides methods for evaluating forces and moments imposed on the pump by the piping and determining if they are allowable or not.

A.4.6.1.2 Inlet piping requirements

A pump 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 inlet head available (NPSHA).

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

For pumps operating with inlet pressure below atmospheric pressure, or handling fluids near their vapor pressure, the inlet line should slope constantly upwards toward the pump to avoid trapping vapor using eccentric reducers where necessary. Vertical pumps should have a vent line installed to release trapped air (see Figure A.4.6.1.2 — Typical deep-well type installation).

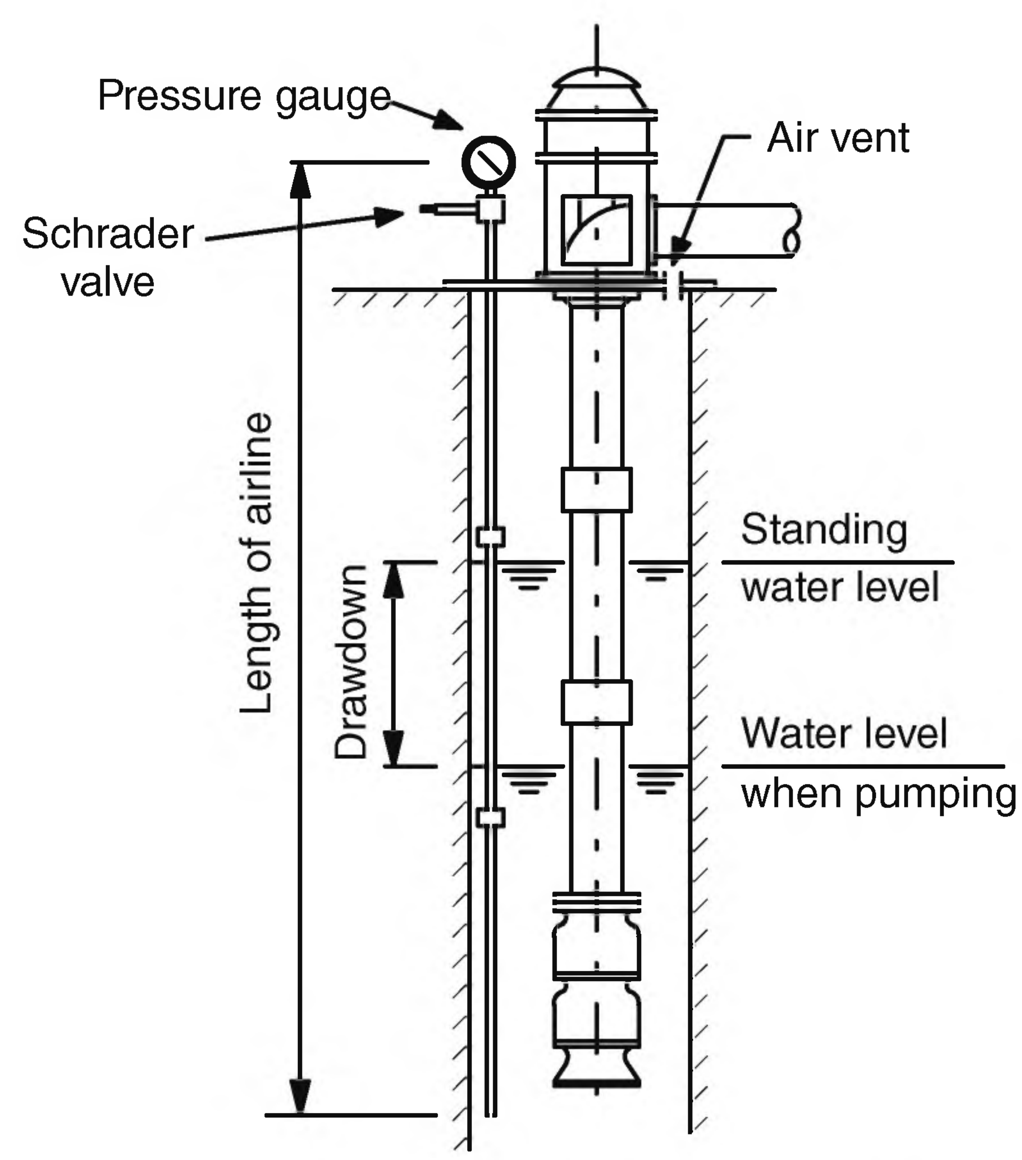


Figure A.4.6.1.2 — Typical deep-well type installation

In systems where the inlet 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 an inlet line will accumulate gas with similar results.

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 inlet. 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.

See ANSI/HI 9.6.6 and ANSI/HI 9.8, for more information.

A.4.6.1.3 Pipe reducers

Reducers may be installed just ahead of the pump inlet when the pipe is larger than the pump nozzle. Reducers used at the pump inlet should be sufficiently long to prevent liquid turbulence. Refer to ANSI/HI 9.6.6 for proper installation of pump piping.

With the liquid source below the pump, the reducer should be eccentric and installed with the level side up (see Figure A.4.6.2).

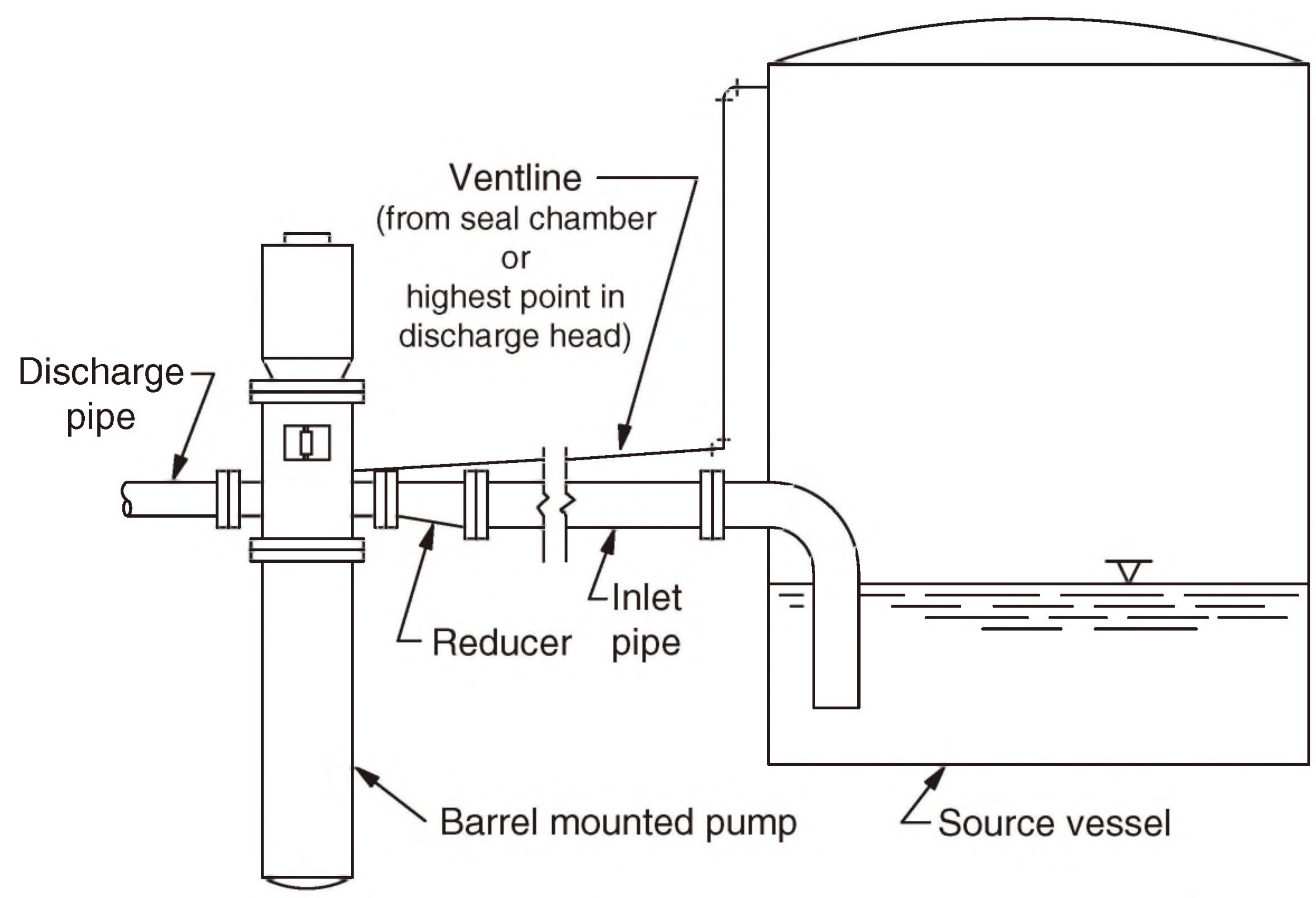


Figure A.4.6.2 — Pump system with eccentric reducer in inlet pipe

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

A.4.6.1.4 Inlet 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 end of inlet piping to keep the pump and inlet pipe water filled and to prevent reverse rotation and loss of prime.

A.4.6.1.5 Elbow at pump inlet

When a straight run of pipe at the pump inlet cannot be provided, certain arrangements of fittings should be avoided. When fittings such as tees and elbows (especially two elbows at right angles) are located too close to the pump inlet, the velocity will be strongly non-uniform, and a spinning action or *swirl* is induced. This swirl may adversely affect pump performance by reducing efficiency, head, and net positive inlet head (NPSH) available, and potentially cause noise, vibration, and damage. Therefore, it is recommended that a straight uninterrupted section of pipe be installed between the pump and the nearest fitting. If the minimum recommended pipe lengths cannot be provided, flow-straightening devices should be considered. Refer to ANSI/HI 9.6.6.

For a double inlet between-bearing pumps, when liquid flows through an elbow or makes a turn through a tee, the exit velocity will be strongly non-uniform. Elbows with a plane parallel to the pump shaft should not be used due to an unbalanced flow to the impeller eyes. This could lead to reduced bearing life and cavitation damage in the starved eye. Elbows should be installed in the plane perpendicular to the pump shaft.

For vertical pumps installed in inlet barrels and for vertical multistage pumps (VS8) when a straight run of pipe at the pump inlet cannot be provided, certain arrangements of fittings should be avoided. For example, elbows positioned with their plane of curvature perpendicular to the pump shaft should not be used, because 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. Refer to ANSI/HI 9.6.6.

A.4.6.1.6 Inlet supply tanks

In many process applications, an inlet 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 tank outlet to the inlet pipe is adequate to prevent vortices. ANSI/HI 9.8 indicates recommended minimum values of submergence over the tank outlet 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.4.6.1.7 Submersible motor cooling

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. 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 motor cooling shroud 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 shroud and the motor. This device also prevents accumulations around the motor.

A.4.6.1.8 Outlet valves

A check valve and an isolation valve can be installed in the outlet 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 outlet 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 ANSI/HI 14.3.

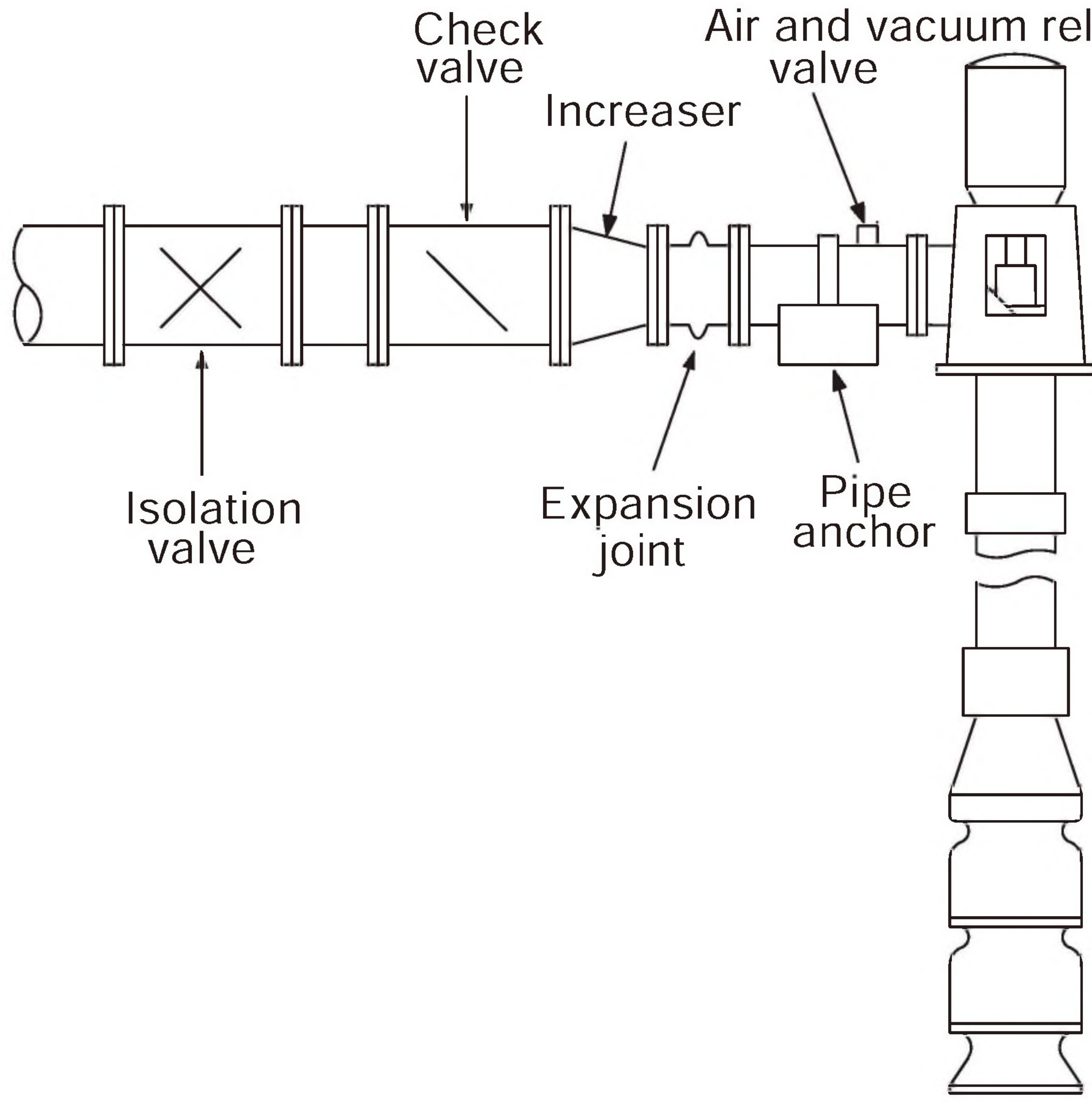


Figure A.4.6.1.8 — Outlet valves

A.4.6.1.9 Air release for self-priming pumps

During the priming cycle, air from the inlet piping is evacuated into the outlet piping. There must be a way for this air to vent. If air is not able to freely vent out the outlet pipe, then it is usually recommended to install an air bleed line. The air bleed line is typically connected from the outlet pipe to the sump. Care must be taken to prevent air from reentering inlet pipe. See ANSI/HI 14.3.

A.4.6.1.10 Siphons

When a siphon is used in the pump outlet 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 to clear the siphon piping of air. For high specific-speed pumps (greater than n_s = 85, N_s = 4400), this may result in a significant increase in required input power. Additionally, if the height of the siphon above the outlet 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.4.6.1.11 Check valves

Check valves may be located in the outlet piping to prevent backflow, but are typically not used in the inlet 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 dash-pots to mitigate the slamming effect of the valve during closing. Pump reverse rotation and hydraulic shock can cause severe damage to pump and motor. Install at least one check valve to help prevent this. In addition, a check valve maintains pressure in the process system after the pump has been turned off.

A common use of a check valve is to prevent loss of prime in applications where the liquid source is below the centerline of the pump. A foot valve is a specialized version installed on the end of a submerged inlet line and is designed to retain liquid in the inlet piping.

A check valve installed in an outlet pipe for a vertical pump should be no more than 8 m (26.2 ft.) above the pump or a previous check valve. For submersible pumps installed more than 183 m (600 ft.) deep, install a second check valve at the next pipe joint nearest to the pump no more than 8 m (26.2 ft.)

⚠ CAUTION To avoid water hammer and pipe breakage in a system with a vertically suspended submersible pump, the distance from first check valve to second check valve should not equal the 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 outlet adapter. Alternately, a line check valve may be threaded directly into the outlet 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. An additional check valve shall be installed every 60 m (200 ft.) of installed depth as required.

⚠ CAUTION No check valve, or an improperly placed check valve, can result in severe damage to the rotating elements of the pump, the supporting motor thrust bearing, surface piping, and other pump system components.

Note: The system head 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.

Note: For vertical pumps starting with an empty outlet 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 up thrust at each start could cause excessive wear in the motor up thrust bearings.

Note: 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.4.6.2 Strainers

To keep unwanted solids out of the pump, strainers may be installed in the pump inlet piping or at the inlet of a vertical pump. Installation of a strainer may be temporary during start up or permanent. 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 down-stream pressure taps and that the pressure drop is monitored.

Vertical pump intake strainers typically clear themselves, if a check valve is not installed, 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.

⚠ CAUTION Inlet strainers require monitoring and periodic cleaning to avoid damaging the pump.

A.4.7 Vertical pump, lift (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 a calculation 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 inline multistage pumps (VS8) require rotor running height alignments to ensure proper operation.

⚠ CAUTION Improper or failure to set clearance will result in damage to pump or driver.

A.4.8 Alignment

A.4.8.1 Alignment general, horizontal pumps

The following discussion of alignment applies primarily to horizontal, rotodynamic pumps driven by an independent driver through a flexible coupling and with pump and driver mounted on a common baseplate.

Pumps and drivers received from the factory with both machines mounted on a common baseplate are aligned or checked for alignment before shipment. All baseplates are flexible to some extent and, therefore, must not be relied on to maintain the factory alignment. Realignment is necessary after the complete unit has been leveled, the grout has set, and foundation bolts have been tightened. The alignment must be rechecked after the unit is piped and rechecked periodically as outlined in the following paragraphs. To facilitate field alignment, most manufacturers do not dowel the pump or drivers on the baseplates before shipment, or at most, dowel the pump only.

When the driver is to be mounted at the place of installation, the pump is positioned and bolted to the base at the factory, but the holes for fastening the driver may not be provided.

A.4.8.1.1 Shaft/coupling alignment

A flexible coupling is used to compensate for minor misalignment of the pump and driver shafts (refer to pump manufacturer's recommendations).

The main purpose of the flexible coupling is to compensate for minor temperature changes and to permit end movement of the shaft without interference with each other while transmitting power from the driver to the pump. A "hot" alignment may be required for equipment pumping hot liquid, steam turbines, etc.

There are two forms of misalignment between the pump shaft and the driver shaft: angular misalignment - shafts with axes concentric but not parallel; and parallel misalignment - shafts with axes parallel but not concentric.

Each motor and pump foot should be checked for soft foot. Soft foot is a condition that occurs when 3 feet of a 4-(or more) footed piece of equipment contact the mounting surface and the 4th (or other) foot is not contacting the mounting surface, or when an equipment foot is contacting a mounting surface at an angle (part of the foot is elevated while part is in contact). Soft foot can be caused by an un-level surface, bent foot, or improper shims. Unless this condition is corrected, the joint under the soft foot acts like a spring rather than a rigid connection when the bolts are tightened.

A.4.8.1.2 Straightedge method of alignment

The necessary tools for checking the alignment of a flexible coupling are a straightedge and a taper gauge or a set of feeler gauges.

The faces of the coupling halves should be spaced far enough apart so that they cannot strike each other when the driver rotor is moved axially toward the pump as far as it will go. A minimum dimension for the separation of the coupling halves and the misalignment limits are specified by the manufacturer.

Proceed with checks for angular and parallel alignment by the following method only if satisfied that face and outside diameters of the coupling halves are square and concentric with the coupling bores. If this condition does not exist, the alternate method of alignment described below is recommended. A check for angular alignment is made by inserting the taper gauge or feelers between the coupling faces at 90° intervals (see Figures A.4.8.1.2a and b).

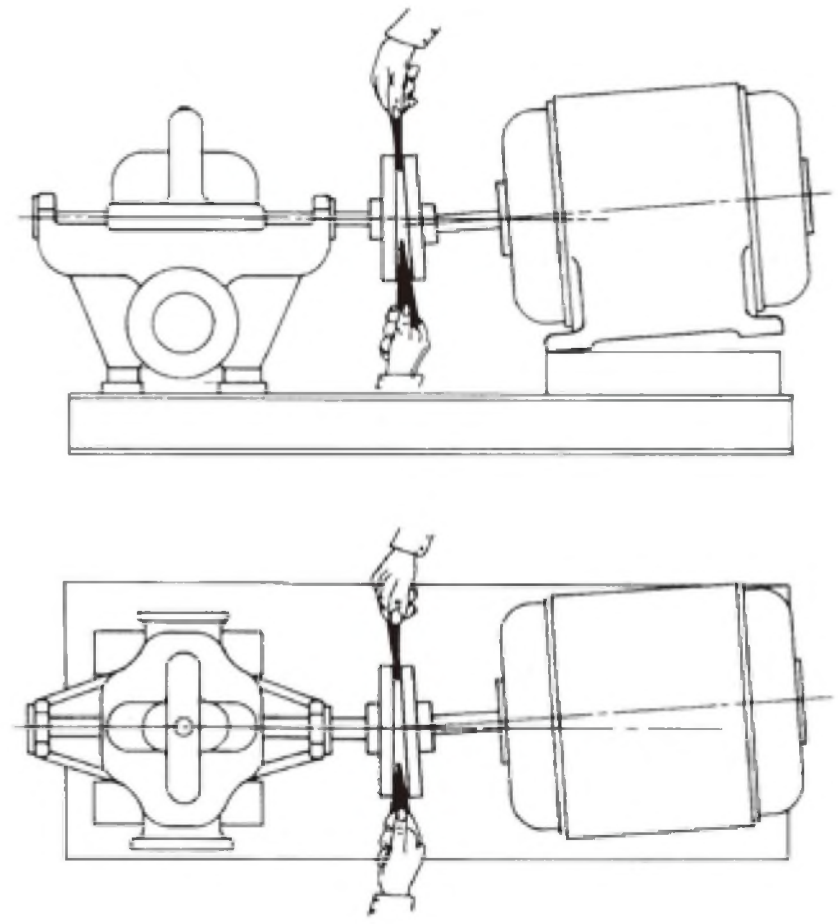


Figure A.4.8.1.2a — Checking angular alignment

The unit will be in angular alignment when the measurements show that the coupling faces are the same distance apart at all points.

A check for parallel alignment is made by placing a straight-edge across both coupling rims at the top, bottom, and at both sides. The unit will be in parallel alignment when the straightedge rests evenly across both coupling rims at all positions (see Figure A.4 .8.1.2b).

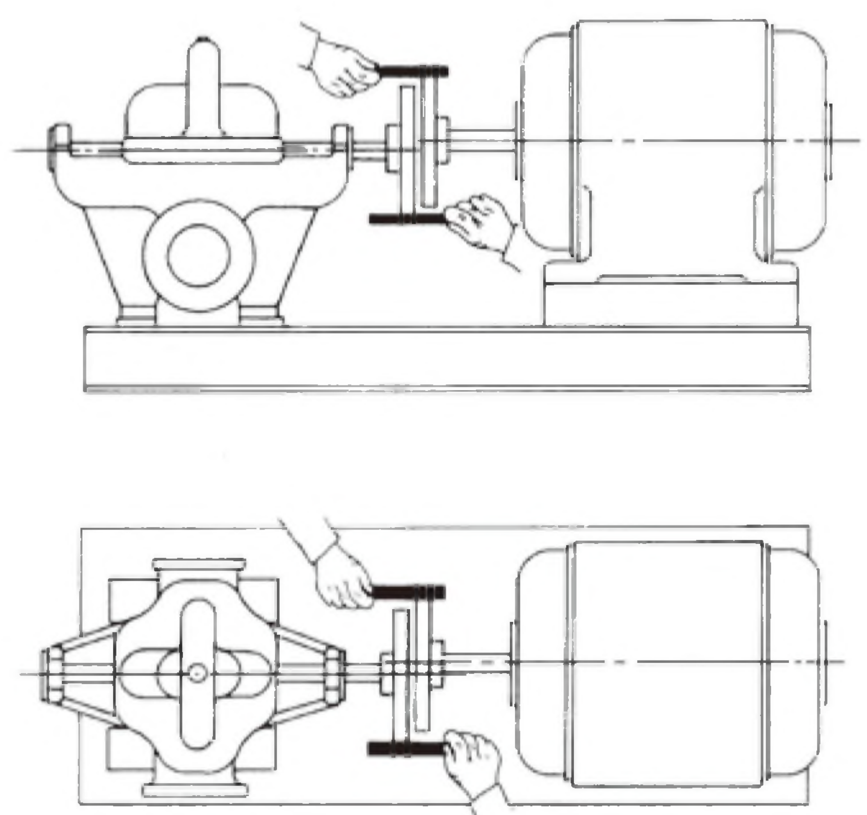


Figure A.4.8.1.2b — Checking parallel alignment

Allowance may be necessary for coupling halves that do not have the same outside diameter. Angular and parallel misalignment in the vertical direction is corrected with shims under the motor mounting feet. After each change, it is necessary to recheck the alignment.

Adjustment in one direction may disturb adjustments already made in another direction. It is wise to start with shims under all motor feet so it can be raised or lowered during initial or subsequent aligning procedures.

When the driver is to be mounted on the baseplate in the field, it is necessary to place the baseplate with pump on the foundation; to level the pump shaft; to check the coupling faces, inlet, and outlet flanges for horizontal or vertical position; and to make any necessary corrective adjustments. If not predrilled by the manufacturer, pads, if provided on the baseplate for the driver, should be coated with chalk to facilitate marking the location of the bolt holes. Place the driver on the baseplate so that the distance between the coupling halves is correct. The alignment of pump and driver coupling halves should then be checked and corrected. Then, scribe the circumference of the bolt holes in the driver feet on the baseplate pads. Remove the driver and drill and tap as required for bolts, allowing clearance for subsequent alignments. Replace driver on the baseplate, check motor rotation, insert the bolts, and align the driver before tightening. The subsequent procedures are the same as for factory-mounted drivers or predrilled baseplate.

When units are aligned cold, it may be necessary to make allowance for the vertical rise of the driver and/or pump caused by heating. Finally, adjust at operating temperature. Refer to instructions supplied by manufacturer for specific couplings.

A.4.8.1.3 Dial Indicator method of alignment

A dial indicator can be used to attain more accurate coupling alignment. First, rough align by using a straightedge, tapered gauge, or feelers using the procedure indicated previously.

Fasten the indicator to the pump half of the coupling, with the indicator button resting on the other half coupling periphery (see Figure A.4.8.1.3 — Dial indicator method of alignment). Set the dial to zero, and mark the coupling half beside where the button rests. Rotate both shafts by the same amount, i.e., all readings on the dial must be made with button beside the mark.

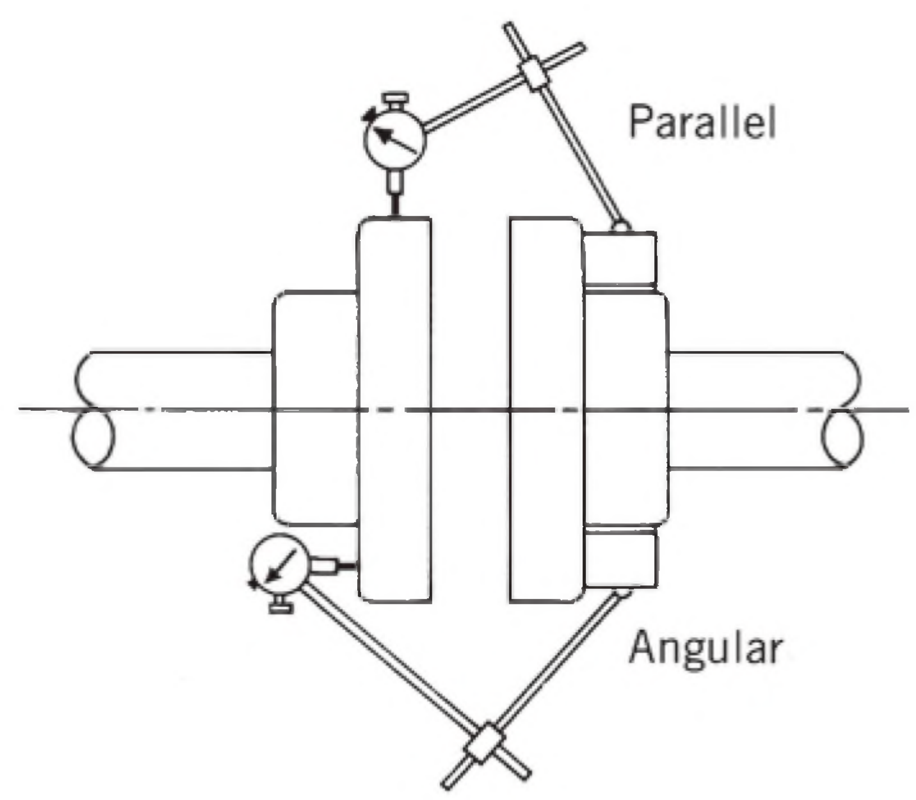


Figure A.4.8.1.3 — Dial indicator method of alignment

The dial readings will indicate whether the driver has to be raised, lowered, or moved to either side. After each adjustment, recheck both parallel and angular alignments. Accurate alignment of shaft centers can be obtained with this method, even where faces or outside diameters of the coupling halves are not square or concentric with the bores, provided all measurements for angular alignment are made between the same two points on the outside diameters. For angular alignment, change the indicator so it bears against the face of the same coupling half and proceed as described for parallel alignment. However, gross deviations in squareness or concentricity may cause problems due to coupling unbalance or abnormal coupling wear and may need to be corrected for reasons other than accomplishment of shaft alignment.

Indicator sag is the difference in the indicator readings due to gravitational forces on the indicator and setup deflection from the top position (12:00 o'clock) and the bottom position (6:00 o'clock). The best way to determine this value is to clamp the brackets on a piece of pipe the same distance they will be when placed on the equipment. Zero both indicators on top, and then rotate to the bottom. The difference between the top and bottom reading is the sag. Readings taken during the alignment process must be corrected by this amount. Refer to instructions for supplied by manufacturer for specific couplings.

Example: If the dial reading at the starting point (either top or one side) is set to zero and the diametrically opposite reading at the bottom or other side shows a plus or minus reading of 0.5 mm (0.020 in), then the driver must be raised or lowered by the use of suitable shims, or moved to one side or the other by half of this reading.

Note: Keep both shafts pressed radially to one side when taking concentricity readings and push both shaft ends as far apart as possible when checking for angular alignment.

A.4.8.1.4 Alignment of shafts with spacer couplings

To align units with spacer coupling, remove the spacer between the pump and driver. Make a bracket, as shown in Figure A.8 which can be fastened to one of the coupling halves and is long enough to reach the other coupling half. Fasten this bracket to one coupling half and a dial indicator to the bracket arm so that the indicator button is in contact with the other coupling half as shown at A, Figure A.4.8.1.4 — Alignment of spacer-type couplings. Make a mark on the coupling half beside where the button rests and set the dial to zero. To check for parallel alignment, rotate both shafts by the same amount, i.e., all readings are made with the button beside the chalk mark.

Indicator sag will be worse with the longer reach needed for spacer couplings.

After parallel alignment has been obtained, change the indicator so it bears against the face of the same coupling half and follow the same procedure to check for angular alignment that was used for parallel alignment.

If the shafts have end play, then it is preferable to make this check of angular alignment by using inside micrometers as shown at B, Figure A.4.8.1.4.

After final alignment is obtained, replace the spacer.

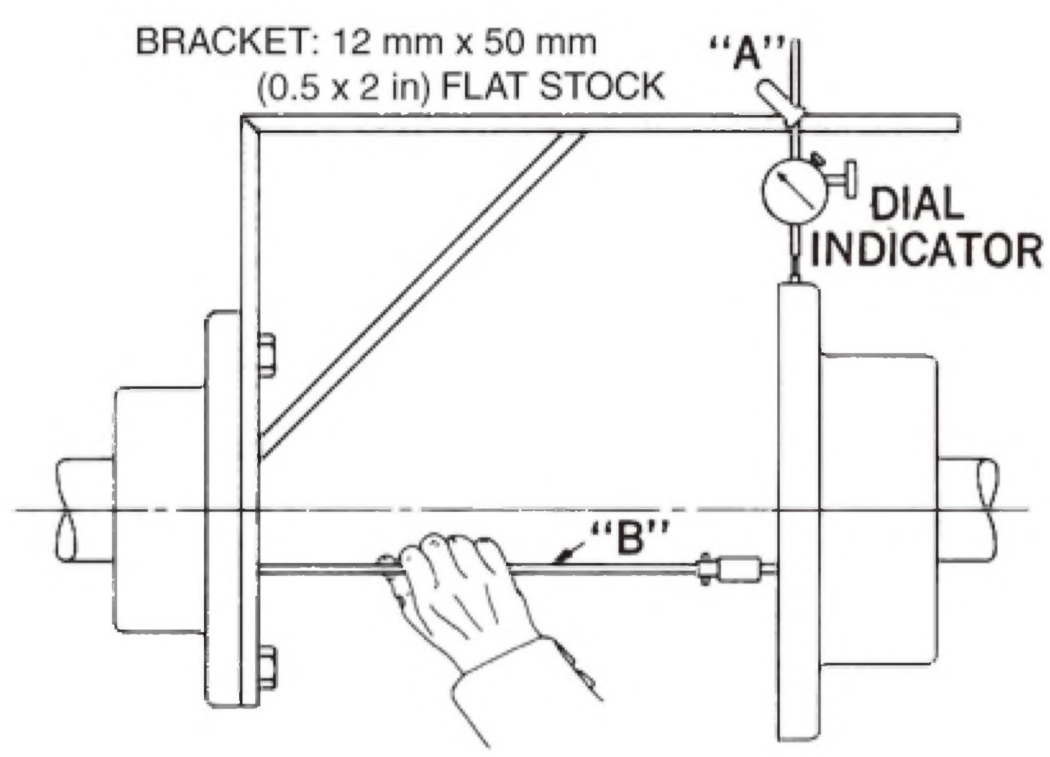


Figure A.4.8.1.4 — Alignment of spacer-type couplings

A.4.8.1.5 Laser method of alignment

Laser detector systems are used to determine the extent of shaft misalignment by measuring the movement of a laser beam across the surface of a detector plate as the shafts are rotated. Several different systems of lasers and detectors are used, and the procedure for alignment is provided by the laser system's producer. They are capable of aligning couplings both with and without spacers. A typical laser method alignment is shown in Figure A.4.8.1.5

Figure A.4.8.1.5 — Laser method of alignment (Figure courtesy John Crane Inc.)

A.4.8.1.6 Special couplings

Note: Limited end-float couplings are used on certain large units, and the instruction book furnished with such units should be consulted for the special alignment instructions that apply.

A.4.8.1.7 V-belt drive

Good alignment must be maintained for full power transmission, minimum vibration, and long life. Parallel and angular alignment are verified by placing a straightedge or a string across the faces of the sheaves.

Regardless of belt section used, the belt should never be allowed to bottom in the groove. This will cause the belts to lose the wedging action, and slippage can occur. Maintain proper belt tension. Excess tension can cause belt fatigue and hot bearings. Keep the belts clean. Belt dressing is not recommended because it has only a temporary effect. Maintained section belts should be periodically inspected for wear and condition.

A.4.8.1.8 Protective guarding

Before proceeding, after alignment is complete, make sure that the coupling guard provided by the manufacturer is properly reinstalled.

A.4.8.1.9 Hot alignment considerations

The manufacturer will include information in this section regarding hot alignment considerations.

A.4.8.2 Alignment, vertically suspended pumps

Vertical line-shaft, submersible turbine pumps and vertically suspended inline pumps are typically aligned through registered fits between mating parts. However, on line-shaft 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 inlet and outlet 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) Settling, curing, seasoning, or springing of the foundation

b) Excessive pipe strain distorting or shifting the machine.

A.4.8.2.1 Vertical solid shaft drivers

Before mounting the driver on the outlet 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, which is mounted on the shaft with a proper locational clearance fit and seated against a split ring, using a dial indicator on a firm base.

With the driver bolted to the outlet 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 for P base motors, some adjustment may be made at the motor mounting flange. If motor mounting features do not allow adjustment, parts may need to be inspected and corrected. 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 mounted to a convenient stationary surface on the outlet head/driver stand and slowly rotate the pump's shaft. 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 re-doweling is required after disassembly/reassembly, because tolerance buildup in the multiple vertical joints results in alignment variation.

A.4.8.2.2 Vertical hollow shaft drivers

Remove the clutch or coupling from the top of the hollow shaft motor, and mount the driver on top of the outlet 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 outlet head to driver, or out-of-plumb of the suspended pump. Shims can be placed under the outlet head to center the head shaft, but shims should not be placed between the motor and the outlet head unless recommended by the manufacturer.

The head shaft may 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. A steady bushing can be requested on all hollow shaft motors, but is most common on motors operating above 1800 RPM, because the bushing provides addition support to the line shaft to prevent extraneous vibration, and premature seal failure. A steady bushing should be supplied by the motor manufacturer.

Steady bushings of smaller motors often are installed on site. They slip it over the line shaft before installing the motor.

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, therefore, is normally not required, nor are dowels recommended.

A.4.9 Special driver (motor) considerations for submersible vertical turbine units

While it is important to comply with the manufacturer's installation instructions for all equipment, this is imperative for submersible pumps to avoid start-up failure, because 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.

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.

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 outlet pipe should not have sharp edges and should be properly spaced to keep the cable closely attached to the outlet pipe. Small VS0 pumps suspended from plastic pipe should have slight slack in the cable between clamps to prevent stressing of the cable and any spliced connections as the pipe elongates under pressure. Additionally, smaller VS0 pumps suspended from plastic pipe require a torque arrestor just above the pump on the outlet pipe and, for installations greater than 61 m (200 ft.), additional torque arrestors may be required to prevent abrasive damage to the cable.

The couplings for the outlet 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.

The necessary electrical controls should be provided in the starting panel. A time-delay relay is to provide a sufficient time delay between stops and starts to the motor manufactures recommendations

A.4.9.1 Submersible bore hole pump 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 300 mm (6 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 14.3.

A.4.9.2 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. It is recommended that motors operating with VFD use twisted conductors to minimize the potential negative electrical effects of long parallel cables.

A.4.9.3 Lightning and surge protection for submersible motors

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.4.10 IOM installation check list

A check list may be useful in insuring all tasks are completed as to the manufactures recommendations. This check list does not include all possible check offs for various installations and is shown as an example of what may be included to insure the proper and complete installation prior to start-up.

CUSTOMER ________________ ORDER NO. ________________ PRODUCT ________________

TEMP (°F) ___________ SPECIFIC GRAVITY ___________ ROTATION CW ☐ CCW ☐ RPM ___________

RATED HEAD (FT) ___________ FLOW (USGPM) ___________ INLET PRESSURE (PSIG) ___________

DRIVER ___________ COUPLING ___________ MECH. SEAL

EVENT

☐ Foundation Construction (All)

☐ Prepare Foundation (All)

☐ Place Spacer Blocks (All)

☐ Set Baseplate/Soleplate over Foundation Bolts (All)

☐ Level Baseplate/Soleplate using Jack Screws and Shim Pack (All)

☐ Snug-Up Foundation Bolt Nut (All)

☐ Check Leveling of Baseplate/Soleplate (All)

☐ Mount Driver - If field mounted (Horizontal pump)

- ☐ Check for Soft Feet, Pump and Driver (Horizontal pump)
- ☐ Align Driver to Pump (Horizontal pump)
- ☐ Grout Baseplate/Soleplate (All)
- ☐ Non-Grout Baseplate
- ☐ Final Torque Foundation Bolts after Grout Cures (All)
- ☐ Check and re-align Driver to Pump (Horizontal pump)
- ☐ Set Pump on Soleplate (Vertical pump)
- ☐ Install Main Piping (All)
- ☐ Check Pipe Strain (All)
- ☐ Mount Driver (Vertical)
- ☐ Align Driver to Pump (Vertical pump)
- ☐ Final Alignment (Horizontal pump)

Note: ☐ Check off when satisfactorily completed

A.4.11 Lubrication, priming, and cooling systems

Refer to Section A.5 Commissioning, start-up, operation, and shut-down, for guidance. (Manufacturer will include information in this section regarding lubrication, priming, and cooling systems.)

A.4.12 Electrical

Electrical conduit and boxes should be located to avoid obstruction of the windows of the outlet head on vertically suspended pumps. Electrical conduit and boxes should be sized to manufacturer' recommendations along with all appropriate standards and local statutes. Large and heavy conduit boxes may require additional support. Consult the manufacturer for guidance.

To achieve a smooth start for the pumping equipment, reduced voltage starters, autotransformers, variable speed driver (VSD), or soft starters 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.4.13 Control, monitoring, and alarm equipment

The following protection systems are recommended, particularly if the pump is installed in a potentially explosive area or is handling a hazardous liquid.

If there is any possibility of the system allowing the pump to run against a closed valve or below minimum continuous safe flow, then a protection device should be installed to ensure the temperature of the liquid does not rise to an unsafe level.

If there are any circumstances in which the system can allow the pump to run dry, or start up empty, then a power monitor should be fitted to stop the pump or prevent it from being started. This is particularly relevant if the pump is handling a flammable liquid.

If leakage of product from the pump or its associated sealing system can cause a hazard, then it is recommended that an appropriate leakage detection system be installed.

To prevent excessive surface temperatures or damaging vibrations at bearings, it is recommended that temperature or vibration monitoring be carried out.

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.

When a vertically suspended pump starts pumping, the liquid level in the well will draw down. However, excessive drawdown may cause the unit, either line shaft or submersible, to entrain air, 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 inlet and outlet to monitor pump operation.

A.4.14 Stopping unit/reverse runaway speed

A sudden power and check valve failure during pump operation against a static head will result in reverse pump rotation.

If the pump is driven by a prime mover offering little resistance while running backwards, then the reverse speed may approach its maximum consistent with zero torque. This speed is called *reverse runaway speed*. If the static head, under which such operation may occur, is equal to or greater than that developed by the pump at its best efficiency point during normal operation, then the runaway speed may exceed the normal operating speed of the pump. This excess speed may impose high mechanical stresses on the rotating parts both of the pump and the prime mover and, therefore, knowledge of this speed is essential to safeguard the equipment from possible damage. Note that transient conditions, during which runaway speed may take place, often result in considerable head variations due to surging in the pressure line. Because most pumping units have relatively little inertia, surging can cause rapid speed fluctuations. In such a case, the runaway speed may 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.

Refer to ANSI/HI 14.3 for additional information on reverse runaway speed.

A.4.14.1 Stopping unit/reverse runaway speed for vertical pumps

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.

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

A.5.1 Lubrication

⚠ **CAUTION: Proper lubrication is critical for trouble-free, long-term operation of the equipment. Lubrication methods and frequency vary with bearing type, application, environment, and the unique operating characteristics of the individual piece of equipment. Ensure lubrication is present and lubrication systems are connected and operational per manufacturer's instructions.**

⚠ **CAUTION: Do not mix greases, Polyurea grease, frequently used in electric motors and many other types of grease are not compatible.**

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

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

- Verify that all automatic lubricators are functioning properly.
- Verify that all lubrication systems, pumps, filters and other auxiliaries are functioning properly.
- Verify lubrication cooling systems are functioning where applicable.
- Check driver coolant where applicable.

A.5.1.1 Vertically suspended pumps, line shaft

Vertically suspended pumps with line shafts are either furnished with product-lubricated, clean compatible fluid flush, 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), pre-lubrication with a compatible fluid should be provided for all pump bearings above static fluid 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 pre-lubrication for bearings made of self-lubricating materials.

b) For pumps with oil-lubricated bearings, it is recommended to pour the manufacture's recommended volume 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.5.1.2 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 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.5.2 Rotation

Before starting, check the direction of rotation. The proper direction is usually indicated by a direction arrow on the pump casing or bearing housing. The proper rotation is also easily determined by observing the direction of the casing scroll and the position of the outlet nozzle. When electric motors are used as drivers, the rotation should be checked with the coupling disconnected from the driven equipment.

It is absolutely essential that the rotation of the motor be checked before connecting the shaft coupling. Incorrect rotation of the pump, for even a short time, can dislodge and damage the impeller, casing, shaft, and shaft seal.

A.5.2.1 Rotation, considerations for vertical pumps

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 drive train should also be checked at this time.

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 Start-up considerations

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 manufacture shall be consulted as to the suitability of any chemical flush additives added to the system. 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 (can pump) vertical 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 line-shaft pumps and submersible pumps, and the barrel and inlet line should be filled with liquid for barrel-mounted pumps. Minimum required submergence to prevent vortices is specified by the manufacturer. See also ANSI/HI 9.8 and ANSI/HI 14.3.

The vertical 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 vertical pumps mounted in a 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 inlet supply 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 non-submerged part of the pump. However, for vertical line-shaft pumps, this depends on the column length and bearing construction, such as metallic and nonmetallic material.

A.5.4.2 Priming and filling

Unless the pump is a self-primer or an prime-assist pump, it should not be run unless it is completely filled with liquid, or an initial charge with liquid if a self-primer or prime-assist pump, as there is danger of damaging some of the pump components.

A pump is considered to be primed when the casing and the inlet piping are completely filled with liquid. Open outlet valves a slight amount. This allows any entrapped air to escape and will normally allow the pump to prime, if the inlet source is above the pump. When a condition exists where the inlet pressure may drop below the pump's capability, it is advisable to add a low-pressure control device to shut the pump down when the pressure drops below a predetermined minimum. Submersible pumps such as OH8A and OH8B, as well as some VS4 and VS5 pumps, are equipped with air bleed holes designed to vent the pumps during installation. All air should be allowed to vent from the casing prior to starting.

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 applications with a positive inlet pressure. 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.5.4.2.1 Priming by ejector or exhauster

When steam, high-pressure water, or compressed air is available, the pump may be primed by attaching an ejector to the highest point on the outlet nozzle or outlet pipe, close to the outlet valve. This will remove the air from the pump, inlet piping, and can for barrel-mounted vertical pumps, provided the outlet valve forms a tight seal. Prime is obtained when a fluid flows from the ejector or outlet 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 outlet nozzle is located above the level of the supply source, and a foot valve is not used, the outlet valve should not be opened until the driver has been started because this may result in loss of prime.

A.5.4.2.2 Priming by vacuum pumps

When neither of the above methods is practical, the pump may be primed by the use of a vacuum pump to exhaust the air from the pump, inlet can, and piping, 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.5.4.3 Shaft sealing settings and adjustments (mechanical seals, packing, etc.)

A.5.4.3.1 Packed stuffing box

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 or the shaft sleeve. Where compatible, lightly lubricate the packing ID and outside diameter (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. 5.4.4.1 — Packed-type stuffing box). 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 pumped fluid. 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.

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.

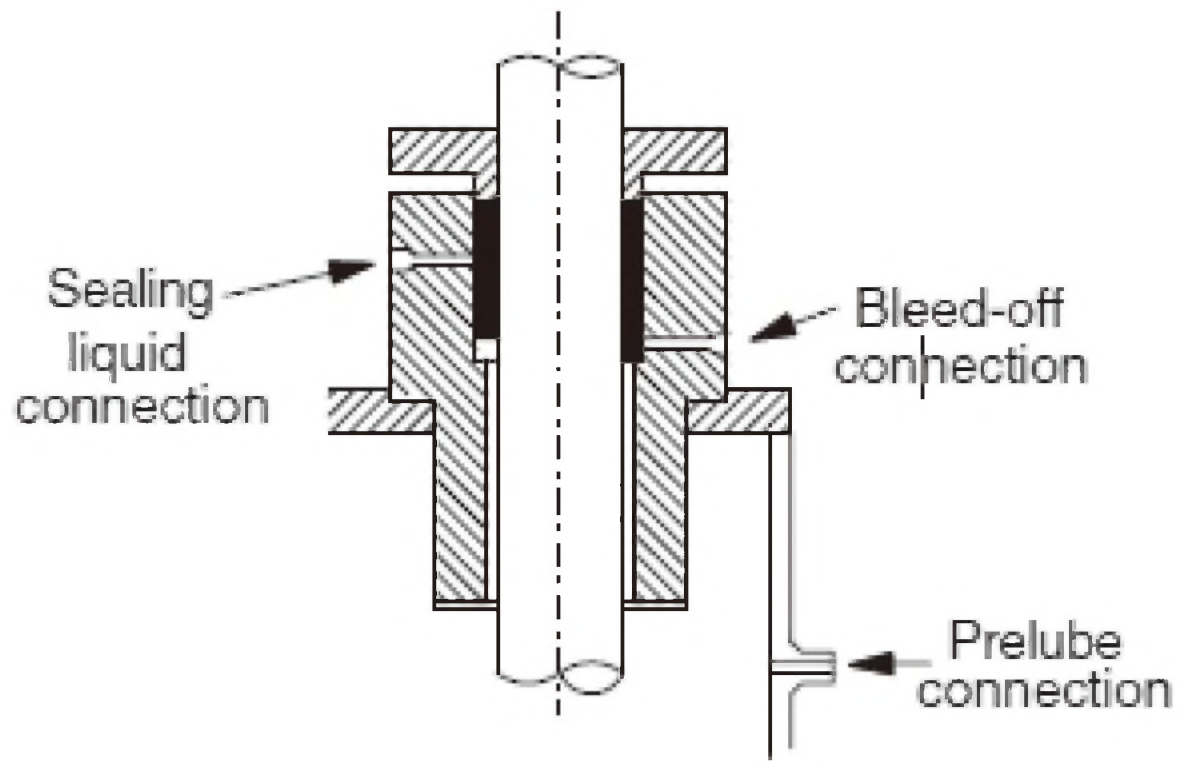


Figure A.5.4.4.1 — Packed-type stuffing box

A.5.4.3.2 Mechanical seals

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

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 are made in a wide variety of designs; therefore, 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 slight initial leakage, the seal should operate with negligible leakage.

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.

⚠ **CAUTION: Mechanical seals should not be run dry unless allowed by the manufacturer. Seals require a continuous supply of flush and/or cooling fluid.**

If 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 pumped fluid is different from the final process pumped fluid, and they are replaced prior to commissioning into the process.

All VS8-style pumps are equipped with mechanical seals. Mechanical seals on vertically suspended in-line diffuser double casing pump (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 *Rotodynamic Pumps — Guideline for Operating Regions*.

A.5.5.2 Minimum thermal flow

See ANSI/HI 14.3.

A.5.5.3 Drive system settings

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

A.5.5.4 Valve settings and operation

A.5.5.4.1 Valve setting at start-up

A.5.5.4.1.1 Position of outlet 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 outlet valve closed, require less power input than when operated at the rated flow rate and head with the outlet valve open. For this reason, it is advantageous to have the outlet valve closed or partially open when starting the pump. Refer to Section A.5.5.4.4 Reduced flow/minimum flow outlet bypass.

A.5.5.4.1.2 Position of outlet valve on starting, mixed or axial flow pumps

Mixed and axial flow pumps of 100 (5000) specific speed and higher usually require greater input power with the outlet 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 outlet 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.5.5.4.2 Valve settings and operation (timing)

A.5.5.4.2.1 Across-the-line or reduced voltage start

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

A.5.5.4.3 Warning against closed valve operation

⚠ WARNING

The pump should not be operated with the inlet or outlet valves closed. The operation of a pump with the inlet valve closed may cause serious damage and should not be attempted. Operation with both inlet and outlet valves closed for even brief periods of time is an unacceptable and dangerous practice. It can rapidly lead to a violent pump failure. If the outlet valve is closed and no by-pass is present, 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 outlet valve, install a pressure relief or bypass valve in the outlet 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 outlet 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 outlet 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 outlet 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 outlet valve closed can result in serious mechanical overloads as well as motor overload.

A.5.5.4.4 Reduced flow/minimum flow outlet bypass

When operating at rates of flow less than best efficiency point (BEP), 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 Minimum Continuous Stable Flow (MCSF), then a bypass line should be installed from the pump outlet to the supply source. See ANSI/HI 9.6.3. 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.5.5.4.5 Water (hydraulic) hammer

Water hammer is a sudden change 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 14.3. It is recommended that specialized engineering services be engaged for water hammer analysis.

A.5.5.5 Parallel and series operation

Pumps should not be operated in series or in parallel unless specifically designed for this purpose, because serious equipment damage may occur. Inlet piping shall be sufficient to adequately supply all pumps without causing NPSH-related issues. Refer to ANSI/HI 9.6.6.

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 outlet 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 supply 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 outlet pressure of the first pump must be sufficient to provide adequate net positive inlet head available (NPSHA) to the inlet of the second pump.

A.5.5.6 Shut-down

In general, the shut-down procedure is a reverse of the start-up procedure. Restore valve positions to the start-up positions prior to de-energizing the pump. Shut auxiliaries and cooling water, etc. as required. The manufacture provides specific instructions a required.

A.5.5.7 Condition monitoring

See ANSI/HI 9.6.5 *Rotodynamic Pumps for Condition Monitoring.*

A.5.5.8 Vibration (alarms and trip points)

See ANSI/HI 9.6.4 *Rotodynamic Pumps for Vibration Measurement and Allowable Values* for acceptance levels for new equipment and refer to ANSI/HI 9.6.5.

Rotodynamic Pumps — Guideline for Condition Monitoring for initial alarm and trip settings.

A.5.5.8.1 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. Additionally, if reflective surfaces are close by the pump, sound levels will increase. Sound may be transmitted in three ways:

a) Airborne within the machinery room

b) Liquid borne by the liquid being pumped

c) Structure borne 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 inlet conditions should be provided.

The prevention of excessive noise greatly depends on the pump installation. Proper alignment of the pump and the driver is essential, as well as the support of the inlet and outlet 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 the measurement of airborne sound is contained in ANSI/HI 9.1-9.5 *Pumps – General Guidelines*.

A.5.5.8.2 Hydraulic resonance in piping

Severe vibration problems often are 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.

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

d) Change the internal design characteristics of the pump.

Any modifications applied to the pump or piping, including the supporting structures that do not change the pulsation response of the pump/piping system, will not affect the resonant condition and therefore will not be an effective solution.

A.5.5.9 Performance testing/verification

Once the unit is energized, check operating speed, rate of flow, inlet and outlet 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.5.5.9.1 Bearing temperature

See Section A.7.2.2 Bearing operating temperature.

A.6 Maintenance

Review Sections A.1.2.1 Personal protective equipment and A.1.2.5.3 Personnel qualification and training prior to proceeding.

Pumps with specific certifications or approvals may have certain requirements or limitations regarding maintenance and repair activities, and should be followed as not to jeopardize the certification or approval.

A.6.1 Schedule

Frequent inspection and periodic maintenance are required to ensure satisfactory operation of the pumping equipment. 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. This table is an example and the manufacturer shall provide his recommended frequency of maintenance and inspection. Unusual applications with abnormal heat, moisture, dust, etc., may require more frequent inspection and service.

Table A.6 Guide for Preventive maintenance

Item	Action required	Frequency
Packing, Packing box, seals	Inspect for excessive leakage. Adjust gland, replace packing, repair or replace seal.	150 hours of operation, as necessary
Pump/Motor alignment	Check for change in alignment.	Annually
Changes in noise during operation	Unusual or changes in sounds during operation.	Daily observation
Vibration	Check for change in vibration levels.	Refer to ANSI/HI 9.6.5.
Bearings	Lubricate (refer to manufacturer). Check vibration, noise level.	Refer to manufacturer for proper interval.
Bolting	Check for proper bolt torque.	Annually (Refer to A.6.5)
Mechanical seals	Monitor seal leakage.	Refer to ANSI/HI 9.6.5.
Surface Inspection	Check for coating integrity or signs of corrosion.	Exterior components: Quarterly Interior components: Annually
Submersible motor, pump types OH8 and VS0	Inspect motor oil, propylene glycol - water fill, dual seal chambers and coolant for contamination and change as applicable and required.	Annually
Wear and running clearance	Inspect and measure.	Annually or as determined by service condition when performance decreases are noted or as recommended

Table A6 Guide for Preventive maintenance *(Continued)*

Item	Action required	Frequency
Submersible power and accessory cables pump types OH8 and VS0	Inspection for damage / megger unit.	Annually
Motor and cable insulation resistance, pump types VS0, OH8A, and OH8B	Megger test for resistance, label phases to insure proper rotation.	Annually
Controls and accessories	Inspect for damage, proper function and condition.	Annually
General site conditions	Check that dirt and dust are removed from areas around close clearances, bearing housings, and motors.	150 hours of operation as necessary
Drive belts	Inspect for damage, proper function and condition.	2000 hours of operation as necessary

A.6.1.1 Cold weather maintenance

When handling water or other liquids that may freeze at low temperatures, care should be taken to prevent the pump from freezing in cold environments when the pump is not in operation or when operation cycles are spread out over extended periods of time. Consult the manufacturer's instructions on properly draining and preparing the pump for freezing temperatures. It may be necessary to drain the pump casing on dry pit applications during extended non-operational periods by removing the bottom drain plug. In some pumps, draining the inlet line is sufficient. For vertical wet pit pumps, removal of the unit is required.

A.6.2 Wear/parts replacements

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.

A.6.2.1 Wear/parts replacements for rotodynamic pumps

Wear rings are commonly fitted in the casing or 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 inlet 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 inlet. 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. The following is only a guide.

Below is a suggested list of spare parts for pumping units. Domestic service handling clean, noncorrosive liquids where interrupted service is not important:

- Coupling connectors (if applicable)

Domestic service handling abrasive or corrosive liquids or where some interruption in continuity of service is possible:

- Shaft sleeves
- Bearings

- Wearing rings
- Packing or mechanical seal
- Gaskets/O-rings
- Coupling connectors (if applicable)
- Impeller.

Export, marine, or domestic service where minimum loss of service is essential, components in addition to those listed above include:

- Complete pump rotating assembly or bowl assembly

A.6.2.2 Wear/parts replacements for vertically suspended pumps

Wear/parts replacements for vertically suspended pumps in addition to those listed above:

- Packing gland and studs or gland bolts b) for continuous service (in addition to above):
- Stuffing-box sleeve bearing
- Head shaft (if used)
- Line shaft (one set)
- Line-shaft coupling (one set)
- Sleeve bearings, both line shaft and bowl shaft
- Pump shaft
- Impeller lock collets (one set).

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

Wear replacement parts for submersible pumps OH8B in addition to those listed above:

- Thread locking compound
- Cable seals / packing.

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. This list is not all inclusive.

- Replacement packing, if used
- Lubricant (grease or oil)
- Cleaning materials
- Touch-up coating

- Anodic protection
- Coolant (if applicable)
- Mechanical seal barrier fluid (if applicable).

A.6.4 Tools and fixtures

Many preventive maintenance tasks may require only the use of standard hand tools, but may also require specialty tools such as:

- Lifting devices (crane, hoist, lifting chains or straps)
- Impeller puller (to remove pressed-on 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)
- Packing removal tool
- 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)
- Lock collet hammer (to remove colleted impeller from shaft, vertical pumps).

Any special tools or fixtures required by the manufacturer must be specified in the instructions and made available to the purchaser along with full instruction on the proper safe use and warnings for all foreseeable misuse of these items.

A.6.5 Fastener torques, rotation direction, and sequence

Proper tightening of bolting is very important. Torque values will vary depending on the size and grade of bolting used. Refer to the IOM manual provided by the pump manufacturer 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 by the pump manufacturer 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 in a center out or star pattern) may result in misalignment, binding, and leakage.

A.6.6 Pump decontamination

Note:	**Review Section A.1.2.5.3 Personnel qualification and training prior to proceeding. It is the responsibility of the owner or operator to ensure all proper personal protective equipment is provided.**

Refer to ANSI/HI 9.1-9.5 for specific procedures on 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 pumped liquids, such as potable water pumps. 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.

Note: Contact the manufacturer if there is a question about potential damage caused by decontamination cleansers.

CAUTION **Any decontamination of pumps handling hazardous or toxic liquids must comply with any and all applicable OSHA requirements and all local codes and ordinances. All product removed and cleaners used to decontaminate the pump must be properly disposed of.**

A.6.7 Disassembly

Note: **Review Section A.1.2.5.3 Personnel qualification and training prior to proceeding. It is the responsibility of the owner or operator to ensure all proper personal protective equipment is provided.**

Pump disassembly should be performed as outlined in the IOM manuals provided by the pump manufacturer. In most cases, the pumps are removed from their installed locations and disassembly is performed in a well-equipped authorized 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. Consult the pump manufacturer for the proper inspection and straightening process, especially when the pump is within its warranty period.

A.6.9 Assembly

The pump may be reassembled following disassembly, cleaning, inspection, and replacement or repair of the component parts. 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 Adjustments, clearance and final settings

Proper adjustments, clearances, and final settings are shown in the installation operation and maintenance manual for the pump in question.

⚠ CAUTION If allowed, following assembly of the pump, rotate it carefully it to be sure it turns freely without binding or rubbing as a final inspection of the assembly.

A.6.10 Auxiliary equipment

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, then first check the correct use and accuracy of instruments. In addition, note that pump performance is substantially affected by such liquid characteristics as temperature, specific gravity, and viscosity. The following table is an example for typical symptoms and possible causes.

Table A.7 Troubleshooting Guide

			Event Time Frame	
Symptoms		**Possible Causes of faults**	**Start-up, Rebuild, Recommission**	**Long-term Operation**
1	**Insufficient Pressure**	Speed too low	X	X
		Improper impeller adjustment	X	
		Loose impeller (rarely occurs)	X	X
		Plugged impeller	X	X
		Worn or damaged running clearances	X	X
		Entrained air in pump	X	X
		Air Leak in inlet line	X	X
		Internal or external leakage	X	X
		Wrong direction of rotation	X	
		Inlet valve/line blocked, incl strainer clogged	X	X
		Outlet valve/line blocked or damaged	X	X
		System head not as anticipated	X	X
		Wear rings missing	X	
		Incorrect pump selection	X	

		Missing splitters (multi-stage pumps)	X	
		Impeller damaged	X	X
		Impeller diameter too small	X	
		Insufficient margin between NPSHA vs. NPSHR (Cavitation)	X	X
		Insufficient submergence (vertical)	X	X
		Broken shaft or coupling	X	X
		Poor intake conditions (Ref. ANSI/HI 9.8)	X	
		Viscosity of liquid too high	X	X
2	**No/Insufficient Capacity**	Speed too slow	X	X
		Improper impeller adjustment	X	
		Loose Impeller	X	X
		Impeller, bowl or volute partially plugged	X	X
		Balance drum worn/damaged	X	X
		Entrained air in pump	X	X
		Internal or external leakage	X	X
		Wrong direction of rotation	X	
		Wrong impeller and/or volute/bowl hydraulics	X	
		Inlet valve/line blocked, incl strainer clogged	X	X
		Outlet valve/line blocked or damaged	X	X
		System head not as anticipated	X	X
		Impeller damaged	X	X
		Impeller diameter too small	X	
		Insufficient margin between NPSHA vs. NPSHR (Cavitation)	X	X
		Insufficient submergence (vertical)	X	X
		Broken shaft or coupling	X	X
		Leaking joints	X	X
		Minimum flow line open, minimum flow valve damaged or bypass orifice worn	X	X
		Pump not primed	X	
		Air leak in inlet line	X	X
		Pump hunting in parallel operation (incompatible pump curves) - one pump unable to open the check valve / dead headed	X	
		Poor intake conditions (Ref. ANSI/HI 9.8)	X	X

3	**Using too Much Power**	Speed too high	X	
		Improper impeller adjustment	X	
		Improper impeller trim	X	
		Pump out of alignment or shaft bent	X	X
		Lubricating oil too heavy	X	X
		Pumping sand, silt, or foreign material	X	X
		System head not as anticipated	X	X
		S.G. or viscosity of liquid too high	X	X
		Rotating element rubbing	X	
		Gland packing too tight	X	X
		Worn or damaged running clearances	X	X
		Electrical mechanical defect in driver	X	X
		Undersized motor cable or poor motor Connection	X	X
		Poor lubrication in shaft enclosing tube (vertical)	X	X
		Improper flow reading - operating at an higher flow	X	X
4	**Vibration / Resonance**	Motor imbalance (electrical)	X	X
		Shaft alignment faults	X	X
		Worn/damaged shaft coupling	X	X
		VFD frequency too low, coupling unstable	X	X
		Misalignment of pump castings, outlet head, column or bowls	X	
		Bent shaft	X	
		Worn/damaged bearings	X	X
		Clogged impeller of foreign material in pump.	X	X
		Improper impeller adjustment	X	
		Insufficient submergence (vertical)	X	X
		Piping strain, excessive high nozzle forces and moments	X	
		Foundation too weak, base not correctly grouted. Voids under skid / deck.	X	
		Pump rotor imbalance	X	
		Operating near natural frequency	X	X
		Loose component(s)		X
		Pump and/or motor soft foot	X	
		Vane pass	X	
		Rubbing or binding of rotating element	X	X

5	**Abnormal Noise**	Motor noise	X	X
		Damaged shaft or shaft enclosing tube	X	X
		Cavitation	X	X
		Foreign material in pump	X	X
		Broken / loose wear ring	X	X
		Recirculation - inlet or outlet	X	X
		VFD carrier frequency	X	
		Loose or broken pump components	X	X
		Rubbing or binding of rotating element	X	
		Operation outside the Allowable Operation Region (AOR)	X	X
		Vane Pass	X	
6	**High shaft seal temperature. High leakage of mechanical seal. Short shaft seal life.**	Seal flush insufficient (flow rate) or missing	X	X
		Wrong orifice size or worn orifice	X	X
		Solids block seal rings/springs		X
		Vaporization in the seal ring area	X	
		Seal fluid not suitable (abrasive)	X	X
		Seal rings, auxiliary gaskets (O-rings) or springs damaged		X
		Dry operation of seal. Seal system not correctly filled or vented.	X	X
		Seal face material inadequate	X	
		Excessive shaft runout	X	
		Faces not flat	X	
		Insufficient pressure of flushing product over vapor pressure	X	X
		Improper seal setting	X	
		Contamination of seal faces	X	X
		Excessive pressure in seal housing	X	X
		Incompatible Seal materials	X	
		Thermal transients, excessive product temperature	X	X
		Mechanical seal selection	X	
		Out-of-specification seal mounting dimensions and tolerances	X	

7	**High Bearing Temperature. Short Bearing Life.**	Pump not running at operating point	X	X
		Coupling alignment faults	X	
		Too much grease or oil in the bearing	X	X
		Wrong lube oil quality/viscosity	X	X
		Improper bearing mounting	X	
		Insufficient bearing cooling (air / water)	X	X
		Bearings damaged	X	X
		Excessive bearing loads	X	X
		Shaft bent	X	
		Bearings insufficiently loaded	X	
		Contamination of the lubrication	X	X
		Loss or lack of lubrication	X	X
		Wrong bearing installed	X	
8	**Lube Oil Leakage**	Oil level too high	X	X
		Labyrinth seal or shaft seal improperly installed	X	
		Bearing cover gasket or seal damaged	X	X
		Vent blocked	X	X
		Loose fittings, plugs and components	X	X
		Excessive speed	X	X
		Blocked internal return passages	X	X
9	**Premature Wear of Pump Internals** - **Corrosion** - **Erosion** - **Loss of Material**	Operation outside the Allowable Operation Region (AOR)	X	X
		Cavitation	X	X
		Operating fluid differs from specified value (temperature, specific gravity)	X	
		Materials of construction not compatible with product delivered	X	
		Lack of submergence at intake	X	X
		Solids contamination in product	X	X
		Dry running, loss of flow	X	X
		Runout or misalignment	X	
		Unbalance	X	
10	**Pump Overheating/ Seizure**	Operating below minimum flow, pump running dry	X	X

A.7.1 Mechanical verification

A.7.1.1 Allowable vibration

Refer to ANSI/HI 9.6.4.

A.7.1.2 Bearing operating temperature

One of the following types of instruments — pyrometer, thermometer, or thermocouple — should be placed on the outer surface perpendicular to the shaft centerline, over the center of the bearing(s) being recorded (see Figure A.7.1.2 — Locations for the measurement of bearing temperature). On pumps with horizontal shafts, the instrument should be placed as close as possible to a vertical position. The instrument should be placed between any structural ribbing when ribbing is part of the design.

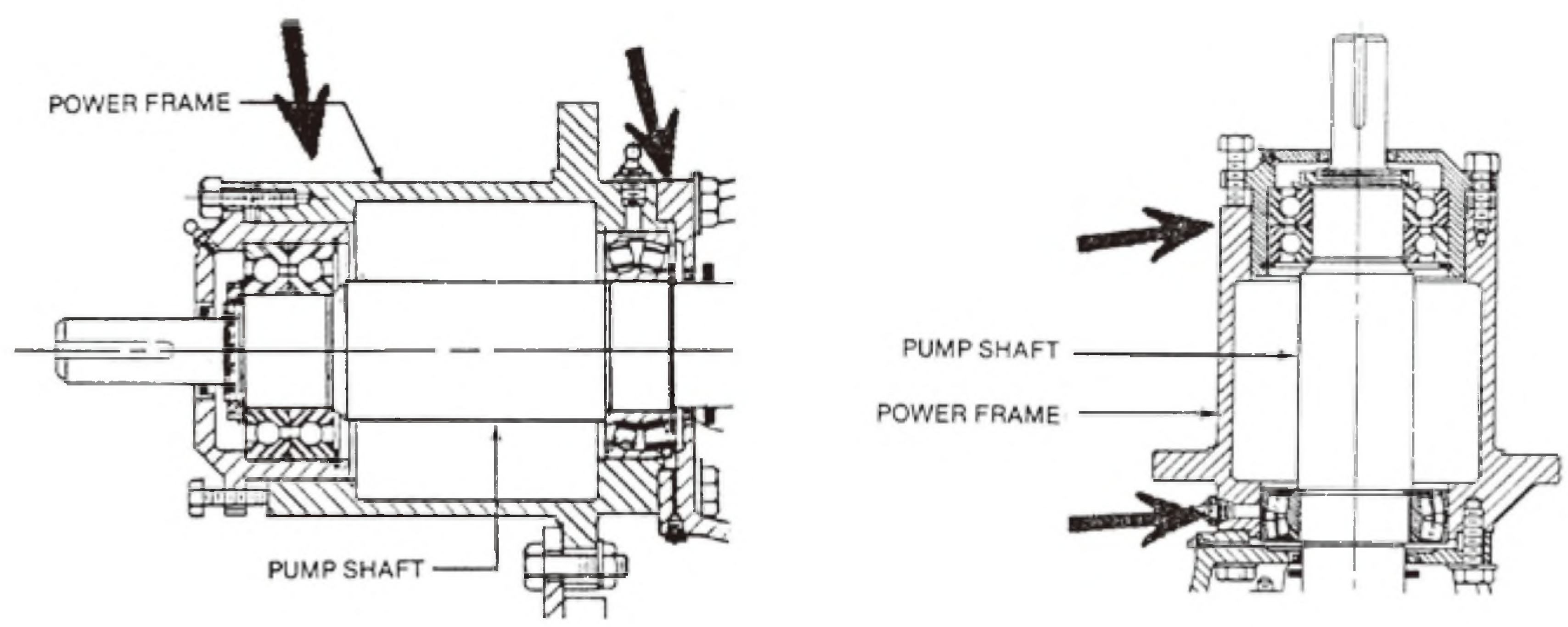


Figure A.7.1.2 — Locations for the measurement of bearing temperature

The pump should be operated at rated conditions. When there are differences between test and jobsite liquid, testing protocols must be agreed on by all parties prior to testing. Cooling plans should be installed and be operational if necessary to duplicate field conditions. This should be agreed to by all parties.

Temperature readings shall be taken every 10 minutes for the first hour and every 15 minutes until stabilization. Some bearings take up to 24 hours to stabilize and should be noted by all parties before the start of the test.) Stabilization is defined as three consecutively recorded readings taken over intervals of at least 15 minutes that fall within a 2 °C (3.6 °F) band when adjusted for a change in ambient temperature, if it occurs.

When testing with a totally enclosed, fan-cooled (TEFC) motor, a barrier should be introduced between the pump and the motor to prevent the air flow from altering the temperature of bearing housing where testing is being conducted. Tests have shown that the motor air flow can cause as much as an 11 °C (20 °F) false temperature reading.

Similarly, the ambient air must be still. Circulating fans and opened windows can cause false readings.

The temperature of the sleeve bearing (bushings) 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. The manufacturer will include information in this section regarding values for allowable bearing temperatures.

A.7.1.3 Noise or sound in rotodynamic pumps

The sound generated within a rotodynamic pump is discussed in ANSI/HI 14.3. The sound pressure level for rotodynamic (centrifugal) pumps is usually less than the sound generated by the driver. Refer to ANSI/HI 9.1-9.5 for the procedure to measure airborne sound of pumping equipment.

A.7.2. Electrical

The manufacturer shall include information in this section regarding electrical troubleshooting.

A.8 Parts Listing and Cross-Sectional Drawings

See ANSI/HI 14.1-14.2 for example cross-sectional drawings and parts lists of overhung, between bearings and vertically suspended rotodynamic pumps.

The manufacturer IOM must provide drawings and parts listing specific to the product(s) included in the IOM.

A.9 Other relevant documentation and 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.

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 provides credible evidence that a product has been independently tested and certified to meet recognized standards for safety or performance.

It makes good sense to look for a reputable certification mark on products 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.

The manufacturer's IOM should include reference and/or description of the various certifications or listings and their corresponding symbols and markings on the product that is included in the IOM.

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Note**:** Bold numbers indicate the standard number, non-bold numbers indicate the page number; an f. indicates a figure, a t. indicates a table.