ANSI/HI 1.4-2010

Approved American National Standard

ANSI

American National Standard for

Rotodynamic (Centrifugal) Pumps

for Manuals Describing Installation, Operation, and Maintenance

ANSI/HI 1.4-2010

Hydraulic Institute

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

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Sponsor

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Approved June 25, 2010

American National Standards Institute, Inc.

American National Standard

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Foreword (Not part of Standard)

Scope

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

a) To develop and publish standards for pumps;

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

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

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

e) To support educational and research activities;

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

Purpose of Standards

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

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

Definition of a Standard of the Hydraulic Institute

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

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

Comments from users

Comments from users of this standard will be appreciated, to help the Hydraulic Institute prepare even more useful future editions. Questions arising from the content of this standard may be directed to the Hydraulic Institute. It will direct all such questions to the appropriate technical committee for provision of a suitable answer.

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

Revisions

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

Units of measurement

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

Consensus for this standard was achieved by use of the Canvass Method

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

Baldor Electric Company
ekwestrel corp
Flow Solutions Group
Fluid Sealing Association
GIW Industries, Inc.
Healy Engineering, Inc.
J.A.S. Solutions Ltd.
John Anspach Consulting
KBR, Inc.
Kemet Inc.
Las Vegas Valley Water District
Lovejoy, Inc.
Malcolm Pirnie, Inc.
Mechanical Solutions, Inc.
Patterson Pump Company
Pentair Water - Engineered Flow GBU
Southern Company
Sulzer Pumps (US) Inc.
The Conservation Fund
Weir Floway, Inc.
Weir Minerals North America
Whitley Burchett & Associates

Committee List

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

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

Committee Members	Company
Edward Allis	Peerless Pump Company
James Bonifas	Emerson Motors / US Motors
Charles Cappellino	ITT - Industrial Process
Michael Cropper	Sulzer Pumps (US) Inc.
Michael Derr	Afton Pumps
Ralph Gabriel	John Crane Inc.
Allen Hobratschk	National Pump Company, LLC
Al Iseppon	Pentair Water
William Livoti	Baldor Electric Company
Brett Zerba	TACO, Inc.

Alternates	Company
Michael Coussens	Peerless Pump Company
William Ellis	Weir Floway, Inc.
Randal Ferman	Flowserve Pump Division
Peter Noll	Peerless Pump Company
Kees van der Sluijs	Flowserve Pump Division

1.4 Manuals describing installation, operation, and maintenance

1.4.1 Introduction

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

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

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

1.4.2 Scope

This standard applies to IOM manuals for rotodynamic (centrifugal) pumps, including the following:

a) Overhung impeller, rigidly-coupled pumps (OH4, OH5, OH5A, OH6, OH7, OH8A, and OH8B).

b) Horizontal, flexibly coupled, axial flow, single stage, overhung design (OH00).

c) Overhung impeller, separately coupled pumps (OH0, OH1, OH1A, OH2, OH3, and OH3A).

d) Sealless centrifugal pumps (OH9, OH10, OH11, and OH12).

e) Between-bearing, separately coupled, single-stage pumps (BB1 and BB2).

f) Between-bearing, separately coupled, multistage pumps (BB3, BB4, and BB5).

g) Vertically suspended, separate discharge (sump), volute style (VS4 and VS5).

h) Regenerative turbine pumps (RT1, RT2, RT3, and RT4).

i) Special-effects pumps (Pitot tube, etc.)

For instructions on sealless rotodynamic pumps, see ANSI/HI 5.1-5.6 *Sealless Rotodynamic Pumps for Nomenclature, Definitions, Application, Operation and Test.*

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

Installation, operation, and maintenance manuals shall be comprised of 10 sections. Each section must appear in the IOM manual in the sequence shown. The topics that appear under each section may be combined and/or arranged to meet the specific needs of the product being addressed, although every effort shall be made to remain logical and consistent. For example, in Section A.1, the explanation of safety designations should precede specific safety warnings for a product. Not all of the topics listed need to be included in the IOM manual for all products; the manufacturer will be given the latitude to decide if a particular topic is applicable.

1.4.3 Standard outline for IOM manuals

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A.1.2.2 General guidelines
A.1.2.3 Safety labels
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A.3.4 Support systems

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A.4.9 Lubrication, priming, and cooling systems
A.4.10 Electrical
A.4.11 Control, monitoring, and alarm equipment (hardware)
A.4.11.1 Stopping unit/reverse runaway speed

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

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Appendix A

Installation, Operation, and Maintenance Manual Reference Information

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

A.1 Introduction and safety

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

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

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

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

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

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

A.1.2 Safety

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

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

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

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

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

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

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

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

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

A.1.2.2 General guidelines

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

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

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

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

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

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

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

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

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

A.1.2.3 Safety labels

A.1.2.3.1 Personnel qualification and training

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

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

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

A.1.2.3.2 Safety action

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

DANGER NEVER DO MAINTENANCE WORK WHEN THE UNIT IS CONNECTED TO POWER. ALWAYS FOLLOW LOCK OUT – TAG OUT PROCEDURES WHEN WORKING ON EQUIPMENT THAT MAY TURN ON.

GUARDS MUST NOT BE REMOVED WHILE THE PUMP IS OPERATIONAL. ALWAYS FOLLOW LOCK OUT – TAG OUT PROCEDURES WHEN WORKING ON EQUIPMENT THAT MAY TURN ON.

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

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

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

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

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

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

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

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

HOT (and COLD) PARTS

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

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

HAZARDOUS LIQUIDS

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

Gland packing must not be used when pumping hazardous liquids.

CAUTION PREVENT EXCESSIVE EXTERNAL PIPE LOAD

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

CAUTION ENSURE CORRECT LUBRICATION

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

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

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

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

CAUTION NEVER RUN THE PUMP DRY

CAUTION INLET VALVES TO BE FULLY OPEN WHEN PUMP IS RUNNING

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

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

A.1.2.3.2.1 Products used in potentially explosive atmospheres

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

Ex 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.1.2.3.2.2 Scope of compliance

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

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

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

A.1.2.3.2.3 Marking

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

Ex **II 2 GD c IIC 135°T (T4)**

Equipment Group
I = Mining
II = Nonmining

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

Gas and/or Dust
G = Gas
D = Dust

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

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

A.1.2.3.2.4 Avoiding excessive surface temperatures

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

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

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

Temperature class (reference NEC[a], CEC[b], IEC[c], CENELEC[d])	Maximum surface temperature permitted	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 responsibility for compliance with the specified maximum liquid temperature is with the plant operator.

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

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

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

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

A.1.2.3.2.5 Preventing the buildup of explosive mixtures

ENSURE THE PUMP IS PROPERLY FILLED AND VENTED AND DOES NOT RUN DRY
Ensure the pump and relevant suction and discharge pipeline system 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 make sure that seal chambers, auxiliary shaft seal systems, and any heating and cooling systems are properly filled.

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

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

A.1.2.3.2.6 Preventing sparks

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

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

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

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

A.1.2.3.2.7 Preventing leakage

The pump must only be used to handle liquids for which it has been approved.

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

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

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

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

A.1.2.3.2.8 Maintenance to avoid the hazard

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

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

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

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

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

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

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

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

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

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

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

h) Check coupling alignment and realign if necessary.

A.1.2.4 Material safety data sheet (MSDS)

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

A.1.2.5 Noise level data

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

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

A.1.2.6 Rigging and lifting

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

A.2 Transport and storage

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

A.2.1 Transport and handling requirements

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

A.2.2 Rigging and lifting

The following instructions are for the safe handling of the pump. When shipment is received extreme care should be exercised during unloading. Heavy parts should be skidded to the ground if lifting equipment is not available. It is recommended a forklift or crane be used to unload equipment. Do not drop the unit, or any parts, as damage may cause trouble in assembly and operation of the units. Improper placements of slings or chains can result in deformation or other serious damage.

Bare pump: Using a nylon sling, chain, or wire rope, hitch around both the inboard and outboard bearing housings. Size the equipment for the load, and so the lift angle will be less than 45° from the vertical.

Pump, base, and driver: The unit should be unloaded and handled by lifting equally at four or more points on the baseplate. Some bases are supplied with lifting holes; in that case, use approved “S” hooks placed into the holes provided. Then attach nylon slings, chains, or wire rope to the “S” hooks for lifting. Size the equipment for the load, and so the lift angle will be less than 45° from the vertical.

Pump and base without driver: The unit should be unloaded and handled by lifting equally at four or more points on the baseplate. Extra care must be taken when lifting because of the unbalanced load that may exist because the driver is not mounted on the base. Size the equipment for the load, and so the lift angle will be less than 45° from the vertical.

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

A.2.4 Unpacking

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

A.2.5 Storage

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

A.2.5.1 Recommended storage environment

- Equipment should be protected from flooding and harmful chemical vapors.
- Whether indoors or out, the area of storage should be free from ambient vibration. Excessive vibration can cause bearing damage.
- Precautions should be taken to prevent rodents, snakes, birds, or other small animals from nesting inside the equipment. In areas where they are prevalent, precautions should also be taken to prevent insects, such as mud dauber and wasps, from gaining access to the interior of the equipment.
- Controlled storage facilities should be maintained with the ambient temperature 5.5 °C (10 °F) above the dew point temperature, relative humidity less than 50%, and little or no dust. If these requirements cannot be met, the pump is to be considered in uncontrolled storage.
- For uncontrolled storage periods of six months or less, the equipment is to be inspected weekly to ensure that all preservatives are intact and internals are protected.
- Periodically inspect and recoat the equipment with water-displacement rust inhibitors, 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 with tape. In addition, 4.5 kg (10 lb) of moisture-absorbing desiccant or 2.3 kg (5 lb) of vapor phase inhibitor crystals should be placed near the center of pump.
- If the pump is assembled, then place an additional 0.5 kg (1 lb) (securely fastened) in the discharge of the pump.
- Also install a moisture indicator near the perimeter of the pump.
- Cover the equipment with 0.15-mm (0.006-in) minimum thickness black polyethylene or equal and seal it with tape. Provide a small ventilation hole approximately 12.7 mm (0.5 in) in diameter.
- Provide a roof or shed shelter for protection from direct exposure to the elements.
- If equipped, connect space heaters on equipment such as motors, engines, or controls.

A.2.5.3 Short-term storage

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

- Remove and discard stuffing-box packing, if pump is packed type. Fill the stuffing box with a crusting grease, then pack the end of the stuffing box with rolled vapor phase inhibitor paper and seal with weatherproof tape.
- Dry pump internals and spray the liquid end with a water-displacement rust inhibitor.
- 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 suction and discharge flanges with full gasket material and blank off these openings with metal blank flanges and a minimum of four full-sized bolts. Cover the pump stuffing-box opening with a nonhygroscopic tape. If packed-type pump, the packing gland may be left on the pump shaft, but should be wired or otherwise securely fastened in position. If mechanical seals have been used, then the annular opening between gland plate and shaft should be closed by a removable sealing ring supplied by the pump original equipment manufacturer (OEM) to exclude airborne dust. Additionally, all connections in the seal cartridge must be plugged or sealed.
- All exposed machined surfaces should be thoroughly coated with a firm film rust-preventative material (Rust-Ban 373, CRC-SP-350, Enis fluid 264, Protec 612801, or equal) that is readily removable with a petroleum distillate product.
- All exposed painted surfaces should be dry, clean, and free of grease and other contaminates.
- The pump should be covered with a weather-resistant cover of waterproof paper or plastic to prohibit the buildup of dirt and dust accumulations.
- The pump should be inspected at regular periods during storage, and the pump shaft should be rotated by hand at intervals of approximately four to six weeks to coat the bearing with lubricant and to retard oxidation and corrosion, flat spots, and staining, and to prevent galling.
- To place the pump in operation, all protective coverings and coatings should be properly removed. Removal shall be sufficient to minimize any adverse effect on the intended pumpage.
- 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.

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

A.2.5.4 Long-term storage

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

A.2.6 Disposal of packaging materials

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

A.3 Product description

A.3.1 Configuration

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

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

A.3.2 Nomenclature

A.3.2.1 Nameplate information

Information on the nameplate may include the following:

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

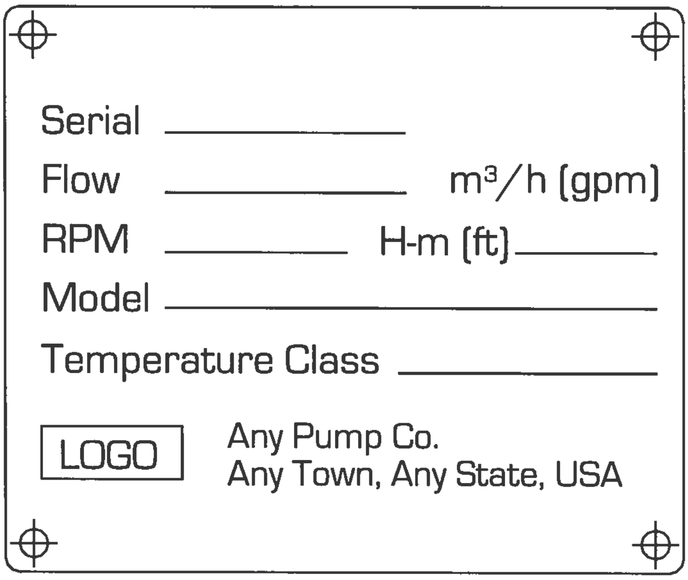


Figure A.1 — Identification plate

A.3.2.2 Pump

The pump size can be given in different formats by different manufacturers. For example, one format is to identify the size with three numbers, such as 8 × 6 × 17. These would represent the suction flange size, the discharge flange size, and the nominal maximum impeller diameter. Note that some manufacturers would identify this same pump as 6 × 8 × 17, where the discharge flange size instead of the suction flange is stated first. When there is a difference in the suction and discharge flange size, it is almost always true that the suction flange is the larger flange. Another style is to put the size and model together, such as 6XX17. This would be a 6-in discharge flange with a nominal maximum impeller diameter of 17 in on a model XX pump.

A.3.2.3 Parts

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

A.3.3 Auxiliaries

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

A.3.4 Support systems

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

A.4 Installation

A.4.1 Factory support requirements

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

A.4.2 Location

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

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

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

A.4.3 Foundation

The foundation should be sufficiently substantial to absorb vibration (e.g., at least five times the weight of the pump unit) and to form a permanent, rigid support for the baseplate. This is important in maintaining the alignment for a flexibly coupled unit. A concrete foundation on a solid base should be satisfactory. Foundation bolts of the proper size should be embedded in the concrete, located by a drawing or template. A pipe sleeve larger in diameter than the bolt should be used to allow movement for final positioning of the bolts (see Figure A.2).

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:

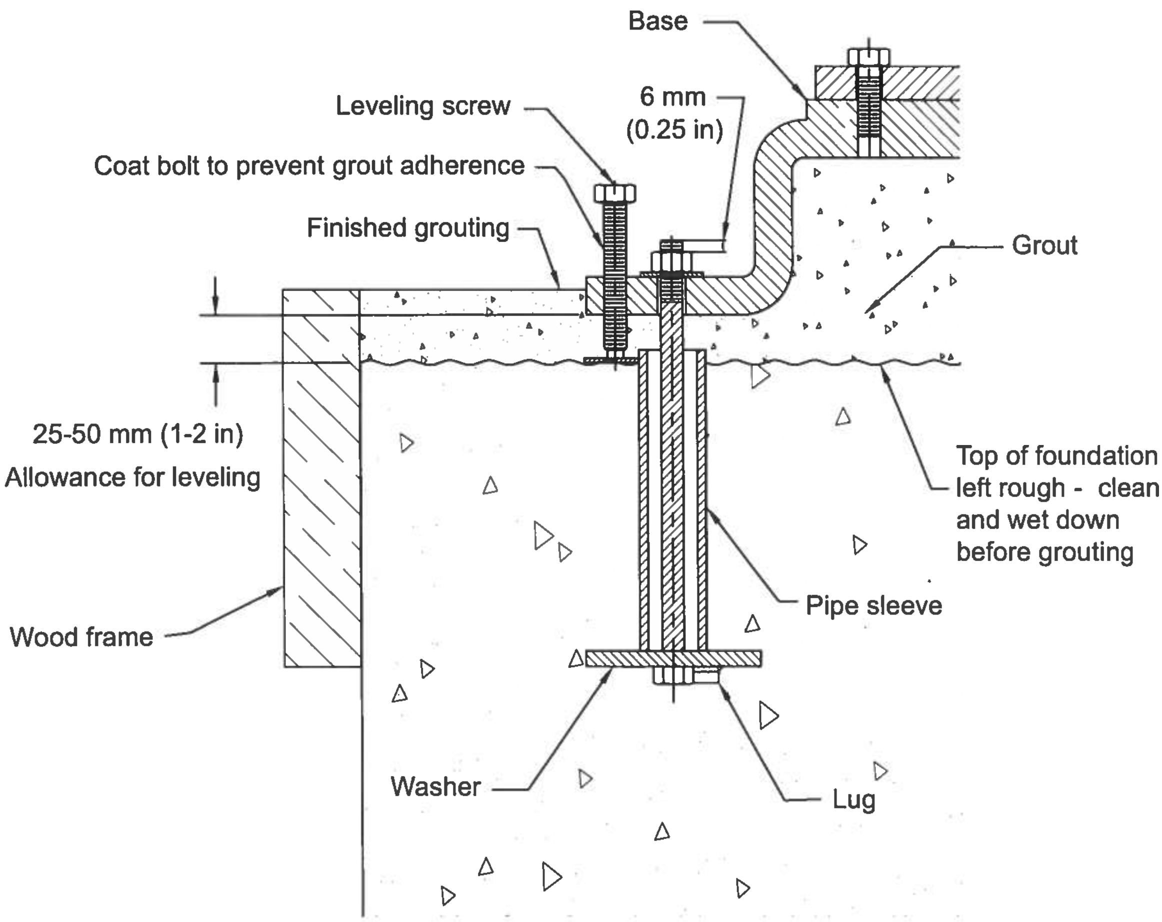
- The seismic criteria, such as acceleration, magnitudes, frequency spectrum, location, and direction relative to pump
- The qualification procedure required, i.e., analysis, testing, or a combination of these and requirements for operability during and/or after test

A.4.4 Rigging and lifting

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

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

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



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

Figure A.2 — Typical foundation bolt design

A.4.5 Baseplate

A.4.5.1 Leveling

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

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

When the baseplate has been correctly leveled using the leveling screws, it will be supported on the rectangular metal blocks and the leveling screws. The leveling screw threads should be covered with a nonbinding material, such as grease, putty, or tape, before grouting, to facilitate their removal. After the grout has cured, the forms and leveling bolts should be removed and the anchor bolts properly torqued.

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

Shims and metal wedges are not recommended for leveling because they are difficult to remove before or after grouting. If shims are used, forms should be placed to isolate them from the initial application of grout. After the initial grout has cured, the forms and shims shall be removed and the void filled with a second application of grout.

A.4.5.2 Grouting

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

A.4.6 Piping and connections

A.4.6.1 Piping, general guidelines

A.4.6.1.1 Pipe supports/anchors/joints

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

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

Expansion joints or flexible connections provided at the pump suction and discharge may need to be restrained to prevent transmitting excessive loads to the pump. The allowable thrust values that various compliant pump types can withstand are found in ANSI/HI 9.6.2 *Rotodynamic Pumps for Assessment of Applied Nozzle Loads.*

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

A.4.6.1.2 Suction piping requirements

A.4.6.1.2.1 Expansion joints and couplings

If an expansion joint is installed in the piping between the pump and the nearest anchor in the piping, then a force equal to the area of the maximum ID of the expansion joint, times the pressure in the pipe, will be transmitted to the pump. Pipe couplings that are not axially rigid have the same effect. This force may be larger than can be safely absorbed by the pump or its support system.

If a pipe anchor between an expansion joint or nonrigid coupling and a pump cannot be used, then acceptable installations can also be obtained using tie rods across the expansion joint or flexible pipe coupling, provided careful attention is given to the design of the tie rods. The total axial rigidity of the tie rods, including their supporting brackets, shall equal that of the pipe, or as an alternate, limit axial deflection to 0.125 mm (0.005 in) when subjected to the maximum working pressure and thermal loads of the system. Many standard tie rod designs are inadequate for use near pumps because they are based on maximum allowable stress only, and deflection is not considered. 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 that allow high stress values. Because deflection is proportional to stress, these high allowable stresses result in high deflections.

The Fluid Sealing Association's *Technical Handbook, Non-Metallic Expansion Joints and Flexible Pipe Connectors* presents information on the design of expansion joints and the calculation of thrust. The allowable forces and moments values that various pump types can withstand are found in ANSI/HI 9.6.2 *Rotodynamic Pumps for Assessment of Applied Nozzle Loads.*

A.4.6.1.3 Pipe reducers

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

With the liquid source below the pump, the reducer should be eccentric and installed with the level side up.

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

A.4.6.1.4 Suction valves and manifolds

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

Foot valves are specially designed check valves sometimes used at the inlet end of suction piping to keep the pump and suction pipe water filled and to prevent backspin and loss of prime.

A.4.6.1.5 Elbow at pump suction

When a straight run of pipe at the pump suction 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 (suction), a spinning action, or swirl, is induced. This swirl may adversely affect pump performance by reducing efficiency, head, and net positive suction 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, per the minimum lengths specified in ANSI/HI 9.6.6 *Rotodynamic Pumps for Pump Piping*, Table 9.6.6.3.2. If the minimum recommended pipe lengths cannot be provided, flow straightening devices should be considered (see ANSI/HI 9.6.6, Appendix E.2). For double suction, between-bearing pumps, when liquid flows through an elbow or makes a turn through a tee, the exit velocity will be strongly nonuniform. Elbows with a plane parallel to the pump shaft should therefore 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.

A.4.6.1.6 Suction tanks

In many process applications, a suction line may be taken off the side or bottom of a process or storage vessel. When this is done, it is necessary to ensure that the submergence level over the inlet to the suction pipe is adequate to prevent vortices. ANSI/HI 9.8 *Pump Intake Design* indicates recommended minimum values of submergence over the inlet as a function of pipe diameter and velocity at the suction inlet. 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 Discharge valves

A check valve and an isolation valve should be installed in the discharge line. The check valve serves to protect the pump from reverse flow and excessive backpressure. The isolation valve is used in priming, starting, and when shutting down the pump. Except on axial flow and mixed flow pumps, it is advisable to close the isolation valve before stopping or starting the pump. Operating pumps of specific speed over 100 (5000) at shut-off may cause a dangerous increase in pressure or power. If increasers are used on the discharge side of the pump to increase the size of piping, they should be placed between the check valve and the pump. If expansion joints are used, they should be placed between the pipe anchor and the check valve. (See Figure A.3.)

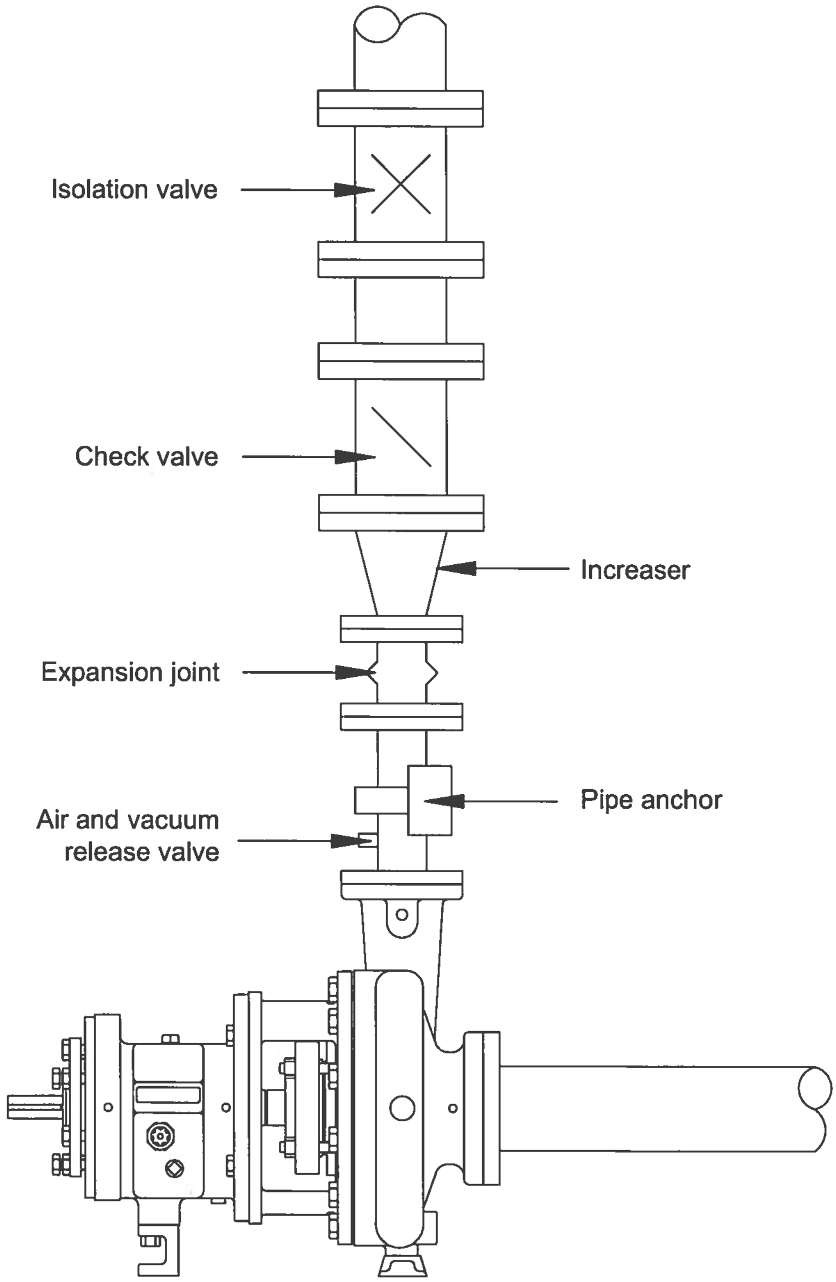


Figure A.3 — Discharge valve expansion joint

A.4.6.1.8 Air release valves for self-priming pumps

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

A.4.6.1.9 Siphons

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

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

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

A.4.6.2 Nozzle loads

The piping should be aligned with the pump nozzles to minimize pump nozzle loads. See ANSI/HI 9.6.2 *Rotodynamic Pumps for Assessment of Applied Nozzle Loads.*

A.4.6.3 Check valves

Check valves may be located in the discharge to prevent backflow, but are typically not used in the suction line. Pump backspin 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 will maintain 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 and is designed to retain liquid in the inlet piping.

Check valves 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 another. In some applications, check valves may be provided with dashpots to mitigate the slamming effect of the valve during closing. A check valve installed in a vertical section of discharge pipe should be no more than 8 m (26.2 ft) above the pump or a previous check valve.

A.4.6.4 Strainers

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

NOTE: Self-cleaning strainers are commercially available.

A.4.7 Clearance setting

The impeller clearance was set at the factory based on the application temperature at the time the pump was purchased. If the process temperature changes, then the impeller clearance must be reset. See Section A.6.9.

A.4.8 Alignment

A.4.8.1 Installation – horizontal pumps

A.4.8.1.1 Alignment steps

A.4.8.1.1.1 Alignment general

The following discussion of alignment applies primarily to horizontal, general service, centrifugal 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 were aligned or checked for alignability 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 drive 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.4.8.1.1.2 Shaft/coupling alignment

A flexible coupling is used to compensate for minor misalignment of the pump and driver shafts (refer to pump manufacturers' 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 hot pumpage, steam turbines, etc.

There are two forms of misalignment between the pump shaft and the driver shaft, as follows: 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 three feet of a four- (or more) footed piece of equipment are contacting the mounting surface and the fourth (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 unlevel surface, bent foot, or improper shims. Unless this condition is corrected, when the bolts are tightened, the joint under the soft foot acts like a spring rather than a rigid connection.

A.4.8.1.1.3 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 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 Figure A.4).

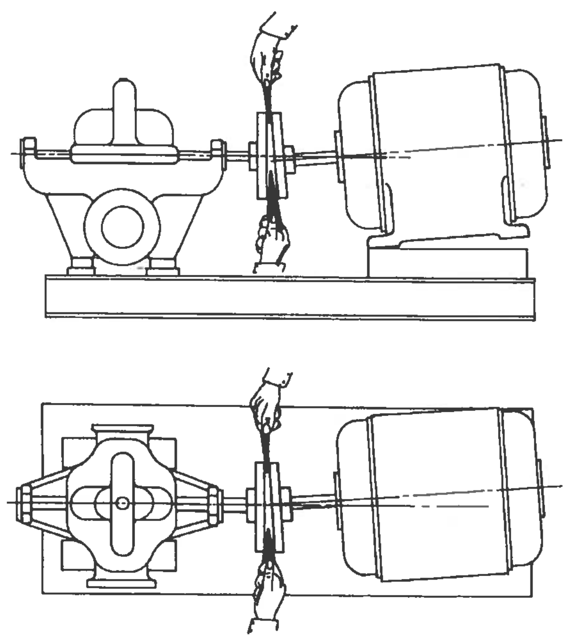


Figure A.4 — Checking angular alignment

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 straightedge 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.5).

Allowance may be necessary for coupling halves that are not of the same outside diameter. Angular and parallel misalignment are corrected by means of 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.

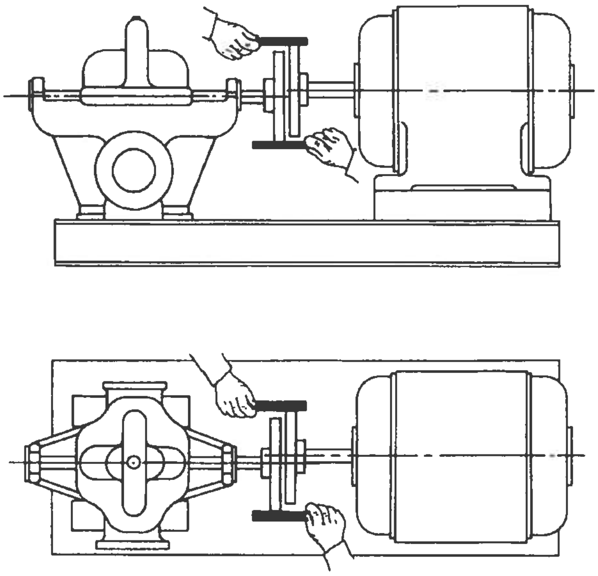


Figure A.5 — Checking parallel alignment

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, suction, and discharge flanges for horizontal or vertical position; and to make any necessary corrective adjustments. 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. If the base is not predrilled, then scribe on the baseplate pads the circumference of the bolt holes in the driver feet. 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 units.

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, i.e., rubber shear types for which the above instructions do not apply.

A.4.8.1.1.4 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.6). Set the dial to zero, and chalk 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 chalk mark.

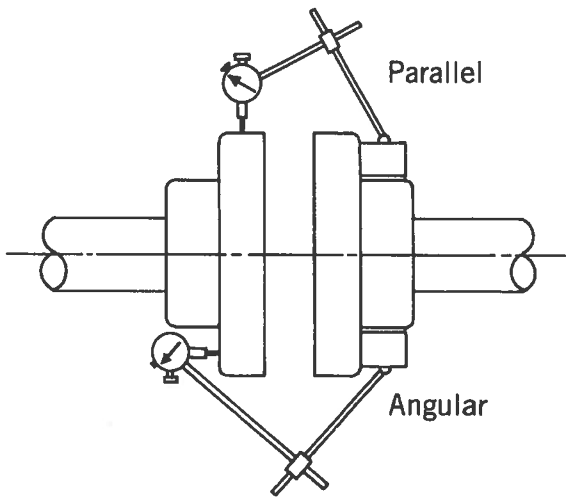


Figure A.6 — Dial indicator method of alignment

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. Gross deviations in squareness or concentricity, however, 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 set up 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, then rotate to the bottom. The difference between the top and bottom reading is the sag. Readings taken during the alignment process will have to be corrected by this amount.

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), 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.4.8.1.1.5 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.

A.4.8.1.1.6 Alignment of gear type couplings

Gear type couplings are aligned in the same manner as outlined above. However, the coupling covers must be moved back out of the way and measurements made on the coupling hubs as shown on Figure A.7.

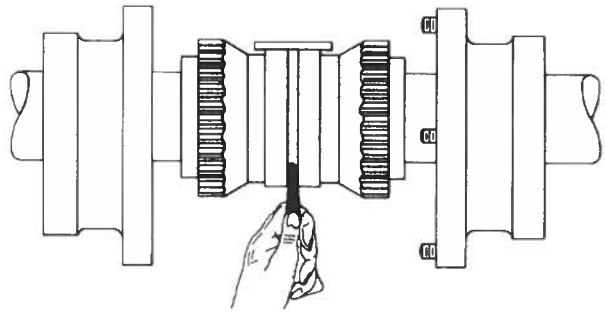


Figure A.7 — Alignment of gear type coupling

A.4.8.1.1.7 Alignment of spacer type couplings

To align units with spacer coupling, remove the spacer between the pump and driver. Make a bracket, as shown in Figure A.8, that 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.8. Make a chalk 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.8.

After final alignment is obtained, replace the spacer.

A.4.8.1.1.8 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.

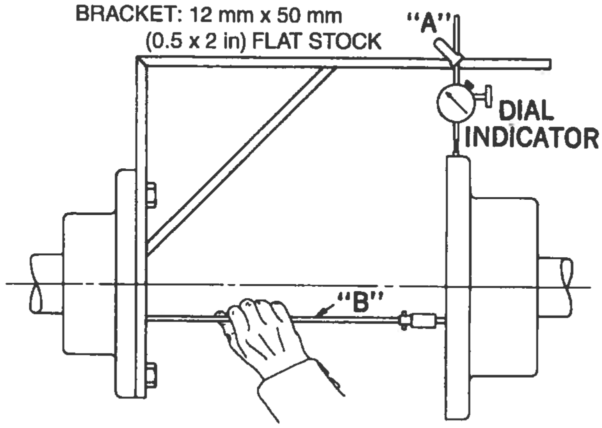


Figure A.8 — Alignment of spacer type couplings

A.4.8.1.1.9 V-belt drive

Good alignment must be maintained for full power transmission, minimum vibration, and long life. Parallel and angular alignment is 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.

A.4.8.1.1.10 Coupling guard

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

A.4.8.2 Motor selection

Selecting the best 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 are built to National Electrical Manufacturers Association (NEMA) or International Electrotechnical Commission (IEC) standards, which define their physical dimensions and electrical ratings. The motor should be capable of operation under all conditions anticipated at the installation site (e.g., dust, moisture, temperature, rodent protection, etc.).

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 1.3 *Rotodynamic (Centrifugal) Pumps for Design and Application.*

A.4.8.3 Hot alignment considerations

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

A.4.9 Lubrication, priming, and cooling systems

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

A.4.10 Electrical

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

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

A.4.11 Control, monitoring, and alarm equipment

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 at bearings, it is recommended that temperature or vibration monitoring be carried out.

A.4.11.1 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, the reverse speed may approach its maximum consistent with zero torque. This speed is called *reverse runaway speed*. If the 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 that corresponding to normal pump operation. 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.

It has been found practical to express the runaway speed as a percentage of that during normal operation. The head consistent with the runaway speed in this case is assumed to be equal to that developed by the pump at the best efficiency point.

The ratio of runaway speed (n_{ro}) to normal speed (n_{no}) for single and double suction pumps varies with specific speed. This relationship is shown by Figures A.9 and A.10. The data shown should be used as a guide, because it is recognized that variations can exist with individual designs.

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. The runaway speed may, in such a case, be consistent with the highest head resulting from surging. Therefore, knowledge of the surging characteristic of the pipeline is essential for determining the runaway speed, and this is particularly important in case of long lines.

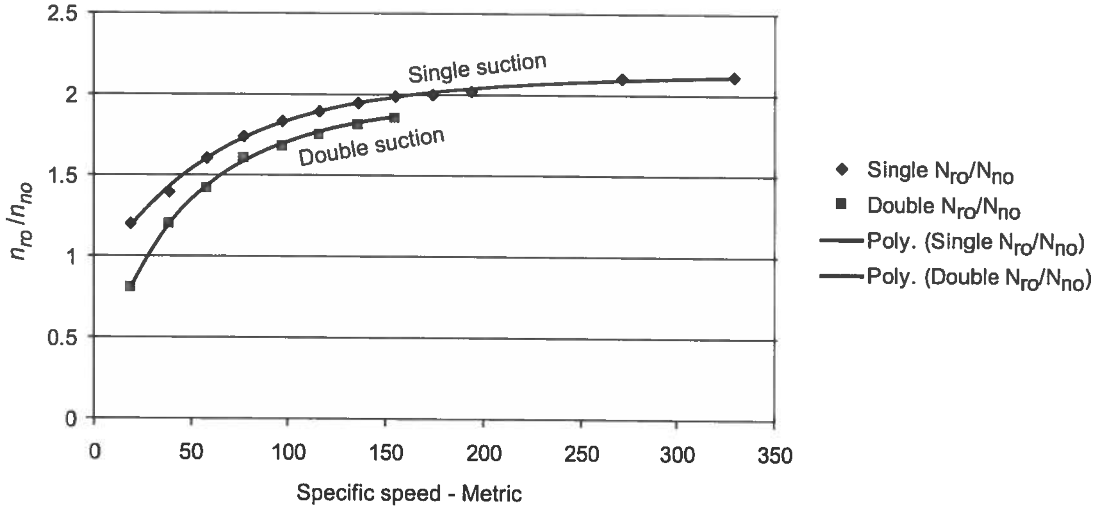


Figure A.9 — Reverse runaway speed ratio versus specific speed when head equals pump head at BEP (metric)

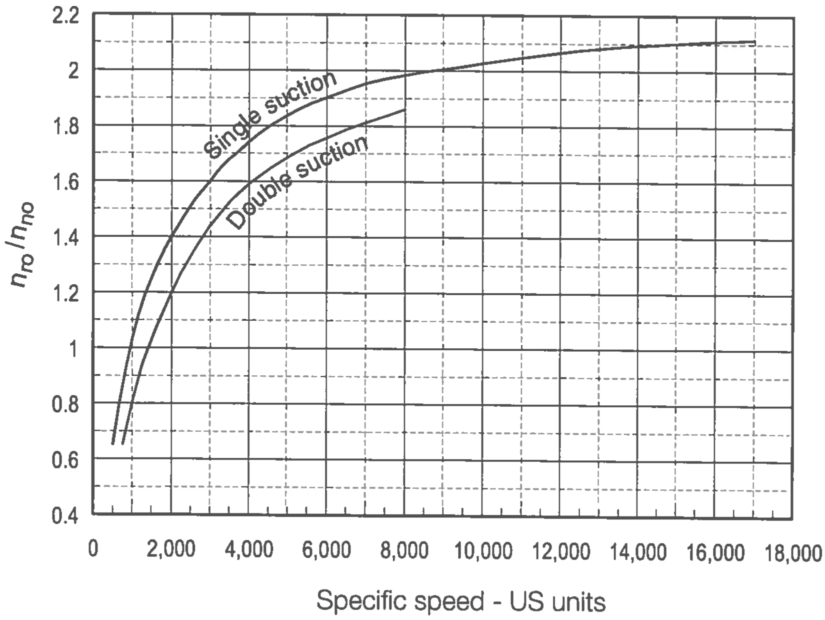


Figure A.10 — Reverse runaway speed ratio versus specific speed when head equals pump head at BEP (US customary units)

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

A.5.1 Lubrication

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

A.5.2 Rotation

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 discharge nozzle. When electric motors are used as drivers, the rotation should be checked with the coupling disconnected.

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 direction arrow is cast on the front of the casing. Make sure the motor rotates in the same direction.

A.5.3 Guarding

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

A.5.4 Checklist – start-up

A.5.4.1 System flushing

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

A.5.4.2 Priming and filling

The pump should not be run unless it is completely filled with liquid, as there is danger of damaging some of the pump components.

A pump is considered to be primed when the casing and the suction piping are completely filled with liquid. Open discharge valves a slight amount. This will allow any entrapped air to escape and will normally allow the pump to prime, if the suction source is above the pump. When a condition exists where the suction 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.

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

A.5.4.2.2 Priming by vacuum pumps

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

A.5.4.3 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. After the pump has been found to operate properly, the stuffing-box gland may be tightened very slowly and evenly, if the leakage is excessive. Instructions may be found with the box of packing. If not, the following may be used as a guide.

Carefully clean the stuffing box. 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 shaft sleeve. Where compatible, lightly lubricate the packing ID and OD with a suitable lubricant. When a lantern ring is required, be sure that sufficient packing is placed in back of the lantern ring so that the liquid for sealing is brought in at the lantern ring and not at the packing. Packing must be installed in the proper order to correctly align the lantern ring with the lubrication line.

The pipe supplying the sealing liquid should be fitted tightly so that no air enters. On suction lifts, a small quantity of air entering the pump at this point may result in loss of prime. If the liquid to be pumped is dirty or gritty, clean sealing liquid should be piped to the stuffing box to prevent damage to the packing and shaft sleeves. Clear sealing liquid is also required if the stuffing-box materials are not completely compatible with the pumpage. Sealing liquid should be at a pressure sufficient to ensure flow of clean liquid into the pump, but not so high as to require excessive tightening of the packing.

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 inch 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 of time, then it is recommended that the packing be replaced prior to starting up the pump.

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.

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

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

A.5.5.1 Minimum continuous flow

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

A.5.5.2 Minimum thermal flow

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

A.5.5.3 Lubrication system settings

A.5.5.3.1 Primary and secondary drivers

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

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

A.5.5.4 Drive system settings

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

A.5.5.5 Valve settings and operation

A.5.5.5.1 Valve setting at start-up

A.5.5.5.1.1 Position of discharge valve on starting, high or medium head pumps

Normally, pumps with specific speed below 100 (5000), when primed and operated at full speed with the discharge valve closed, require less power input than when operated at the rated flow rate and head with the discharge valve open. For this reason, it is advantageous to have the discharge valve closed when starting the pump.

A.5.5.5.1.2 Position of discharge 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 discharge valve closed than open. Axial flow type pumps nearly always require substantially more power and produce more pressure at shut-off than at rating and should be started with the discharge valve open or with the opening of the valve sequenced with starting of the pump. Flap valves are commonly used for these purposes. The manufacturer's instructions should be consulted for the characteristics of such pumps.

A.5.5.5.2 Reduced flow/minimum flow discharge bypass

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

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

A.5.5.5.3 Water (hydraulic) hammer

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

Water hammer may be controlled by regulating valve closure time, using relief valves or surge chambers, and certain other means. See ANSI/HI 1.3 *Rotodynamic (Centrifugal) Pumps for Design and Application*.

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

A.5.5.5.4 Parallel and series operation

Pumps should not be operated in series or in parallel unless specifically designed for this purpose, since serious equipment damage may occur. 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 discharge valve. Mismatched shut-off heads could also cause one pump to operate below the allowable operating region.

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

A.5.5.6 Condition monitoring

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

A.5.5.7 Vibration (alarms and trip points)

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

A.5.5.7.1 Noise in pumping machinery

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

a) Airborne within the machinery room.

b) Liquidborne by the liquid being pumped.

c) Structureborne through the attached piping and support system.

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

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

A.5.5.7.2 Hydraulic resonance in piping

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

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

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

a) Alter the resonant piping.

b) Change the pump speed.

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

d) Change the internal design characteristics of the pump.

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

A.5.5.8 Performance testing/verification

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

A.5.5.9 Bearing temperature

See Section A.7.2.2.

A.6 Maintenance

A.6.1 Schedule

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

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

A.6.1.1 Cold weather maintenance

When handling water, care should be taken to prevent the pump from freezing during cold weather when the pump is not in operation. It may be necessary to drain the pump casing during shut-down periods by removing the bottom drain plug.

A.6.1.2 Wear/parts replacements

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

Domestic service handling clean, noncorrosive liquids where interrupted service is not important:

- Shaft sleeves
- Stuffing-box packing or mechanical seal
- Gaskets
- Coupling connectors (if any)

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

- Shaft sleeves
- Bearings
- Wearing rings or parts
- Stuffing-box packing or mechanical seal
- Gaskets
- Coupling connectors (if any)

Export, marine, or domestic service where minimum loss of service is essential:

- Complete rotating assembly
- Gaskets
- Coupling connectors (if any)

A.6.2 Recommended spare parts for pumping units

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

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

A.6.3 Consumables

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

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

A.6.4 Required tools and fixtures

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

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

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

A.6.5 Fastener torques, rotation direction, and sequence

Proper tightening of bolting is very important. Torque values will vary depending on the size and grade of bolting used. Refer to the installation, operation, and maintenance (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 from one side to the other, then back) may result in misalignment, binding, and leakage.

A.6.6 Pump decontamination

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

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

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

Any decontamination of pumps handling hazardous or toxic liquids must comply with any and all applicable OSHA requirements and all local codes and ordinances.

A.6.7 Disassembly

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 repair facility.

A.6.8 Inspection

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

A.6.8.1 Acceptance criteria and dimensions

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

A.6.8.2 Shaft straightening

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

A.6.9 Assembly

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

A.6.9.1 Clearances

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

A.6.10 Auxiliary equipment – see separate documentation

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

A.7 Troubleshooting guide

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

A.7.1 Hydraulic performance

A.7.1.1 Pressure

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

a) Speed too low.

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

b) System head less than anticipated.

c) Air or gas in liquid.

d) Impeller rings worn.

e) Impeller damaged.

f) Impeller diameter too small.

g) Impeller for wrong direction of rotation.

h) Wrong direction of rotation.

i) Excessive clearance adjustment on semi-open impellers.

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

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

a) Suction line drawing air.

b) Suction lift too high or insufficient NPSHA.

c) Air or gas in liquid.

d) Clogging of strainer.

e) Excessive suction vessel drawdown.

f) High liquid temperature.

g) Possible closed valve.

A.7.1.2 Flow

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

a) Pump not primed.

b) Speed too low.

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

c) System head exceeds shut-off head.

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

e) Wrong direction of rotation.

f) Air leak in the suction line.

g) Pump damaged during installation.

h) Broken shaft or coupling.

i) Impeller(s) loose on shaft.

j) Closed suction valve.

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

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

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

a) Air leaks in suction line.

b) Speed too low.

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

c) System head higher than anticipated.

d) Insufficient NPSHA.

e) Clogged suction line or screen.

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

g) Impeller partially plugged.

h) Rings worn.

i) Impeller damaged.

j) Impeller(s) loose on shaft.

k) Excessive clearance adjustment on semi-open impeller.

l) Suction valve partially closed.

m) Impeller installed backwards.

n) Wrong direction of rotation.

A.7.1.3 Power

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

a) Speed too high.

b) System head lower than rating, pumps too much liquid.

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

d) Rotating element binds.

e) Stuffing boxes too tight.

f) Impeller rings worn.

g) Electrical or mechanical defect in motor.

h) Incorrect lubrication of driver.

A.7.2 Mechanical

A.7.2.1 Vibration

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

A.7.2.2 Measurement of operating temperature of ball bearings

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.11). On pumps with horizontal shafts, the instrument should be placed as close as possible to a vertical position. The instrument should be placed between structural ribbing when ribbing is part of the design.

The pump should be operated at rated conditions. When there are differences in specific gravity or viscosity between test and jobsite liquid, adjustment to test bearing temperatures must be agreed to by all parties prior to

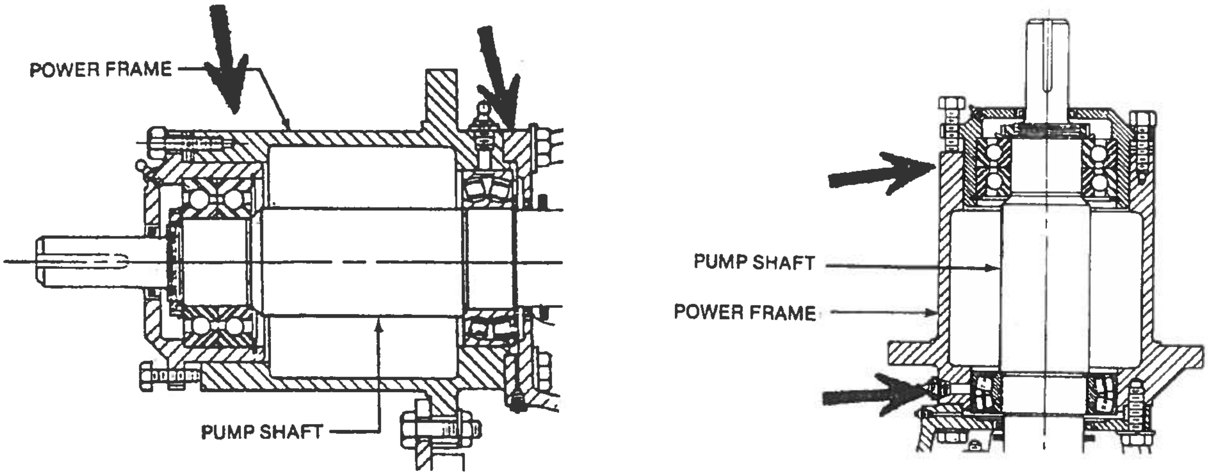


Figure A.11 — Instrument locations

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. (Basic temperature stabilization usually occurs after the first 45 minutes. However, 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 TEFC motor, the air flow from the motor should be blocked from the 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.

A.7.2.3 Noise

The sound generated within a rotodynamic (centrifugal) pump is discussed in ANSI/HI 1.3 *Rotodynamic (Centrifugal) Pumps for Design and Application.* The sound pressure level for rotodynamic (centrifugal) pumps is usually less than the sound generated by the driver.

A.7.3 Electrical

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

A.8 Cross-sectional drawings

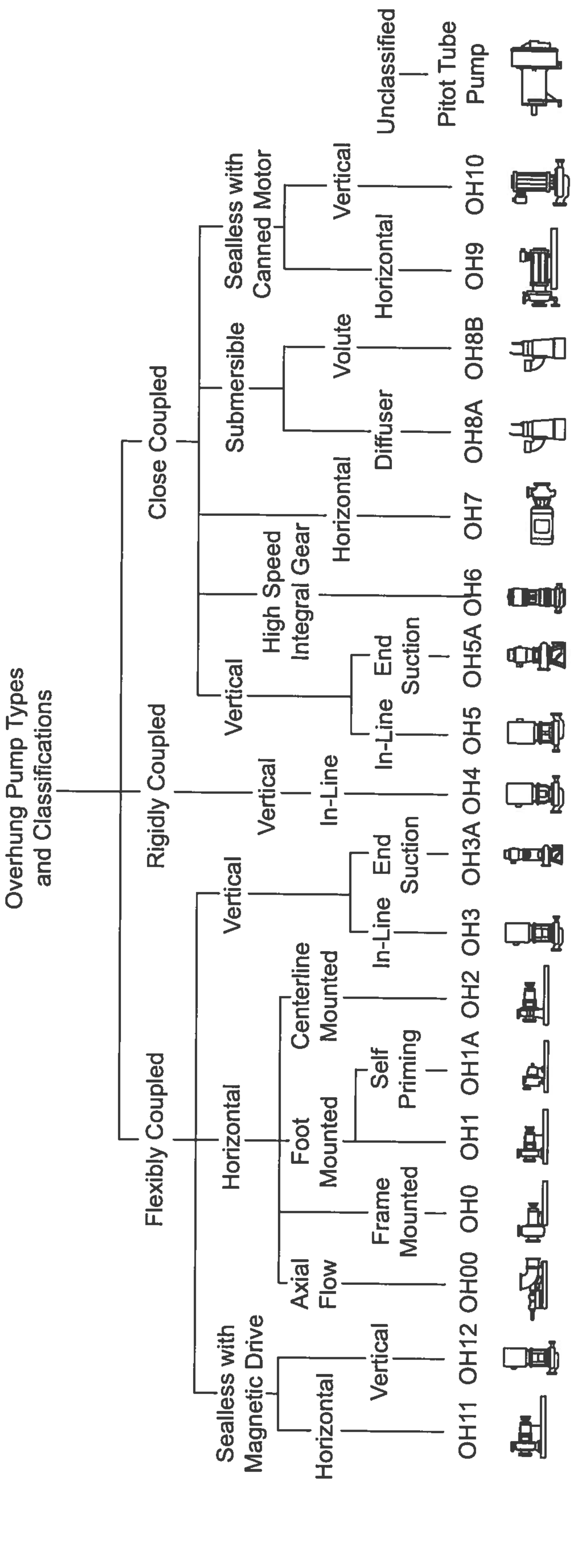


Figure A.12 — Rotodynamic pump types - overhung

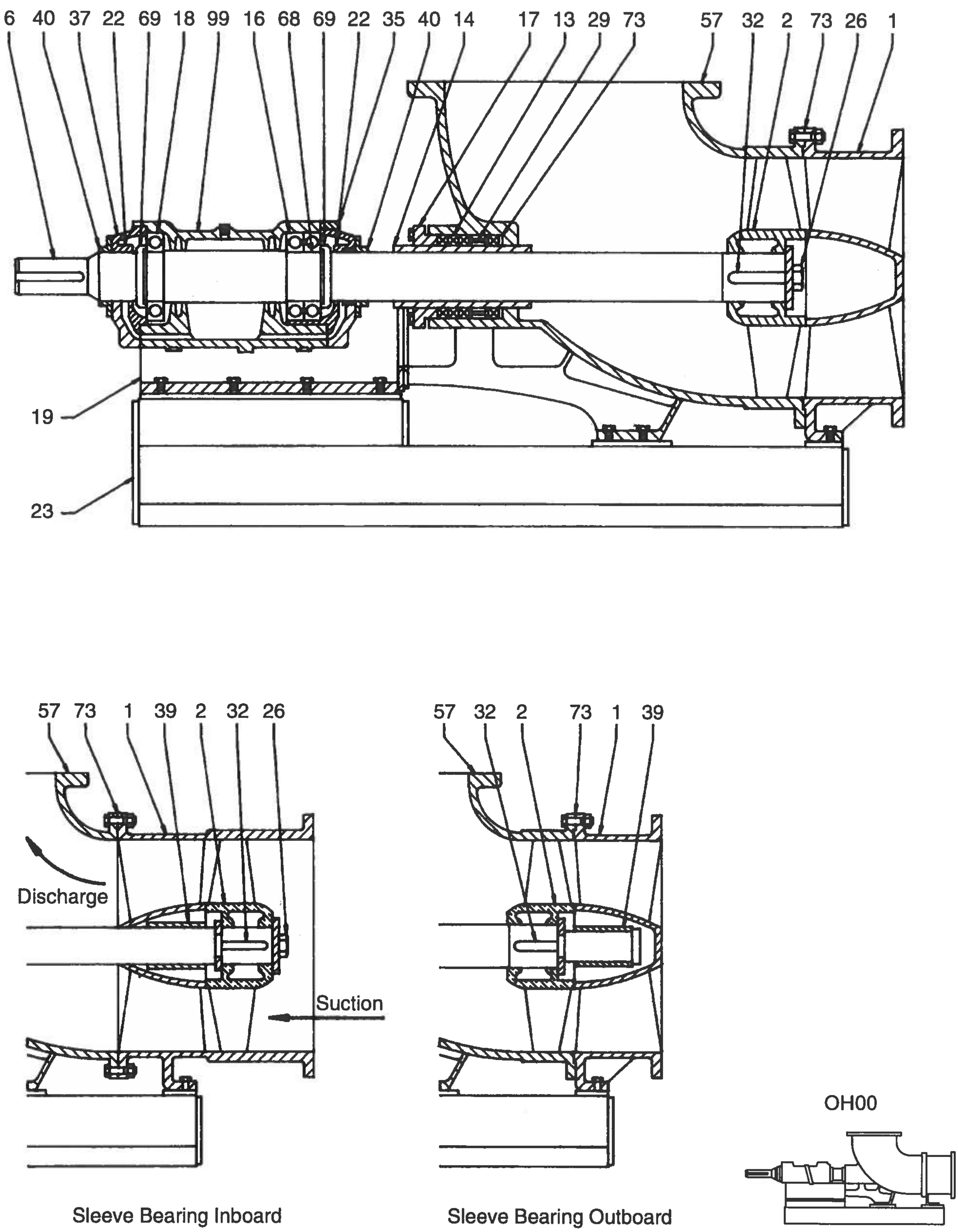


Figure A.13 — Overhung impeller – flexibly coupled – single stage – axial flow – horizontal

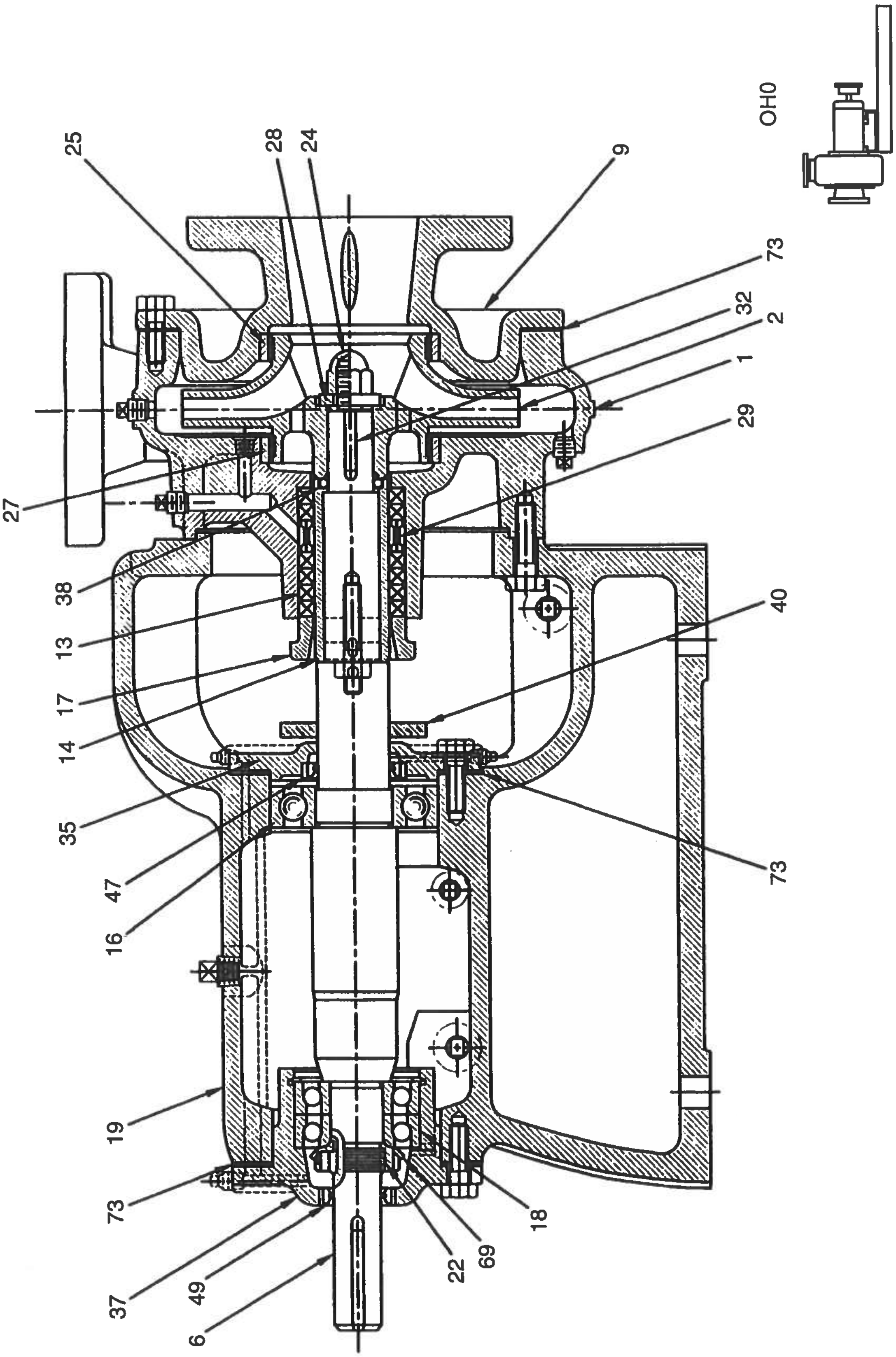


Figure A.14 — Overhung impeller – flexibly coupled – single stage – frame mounted

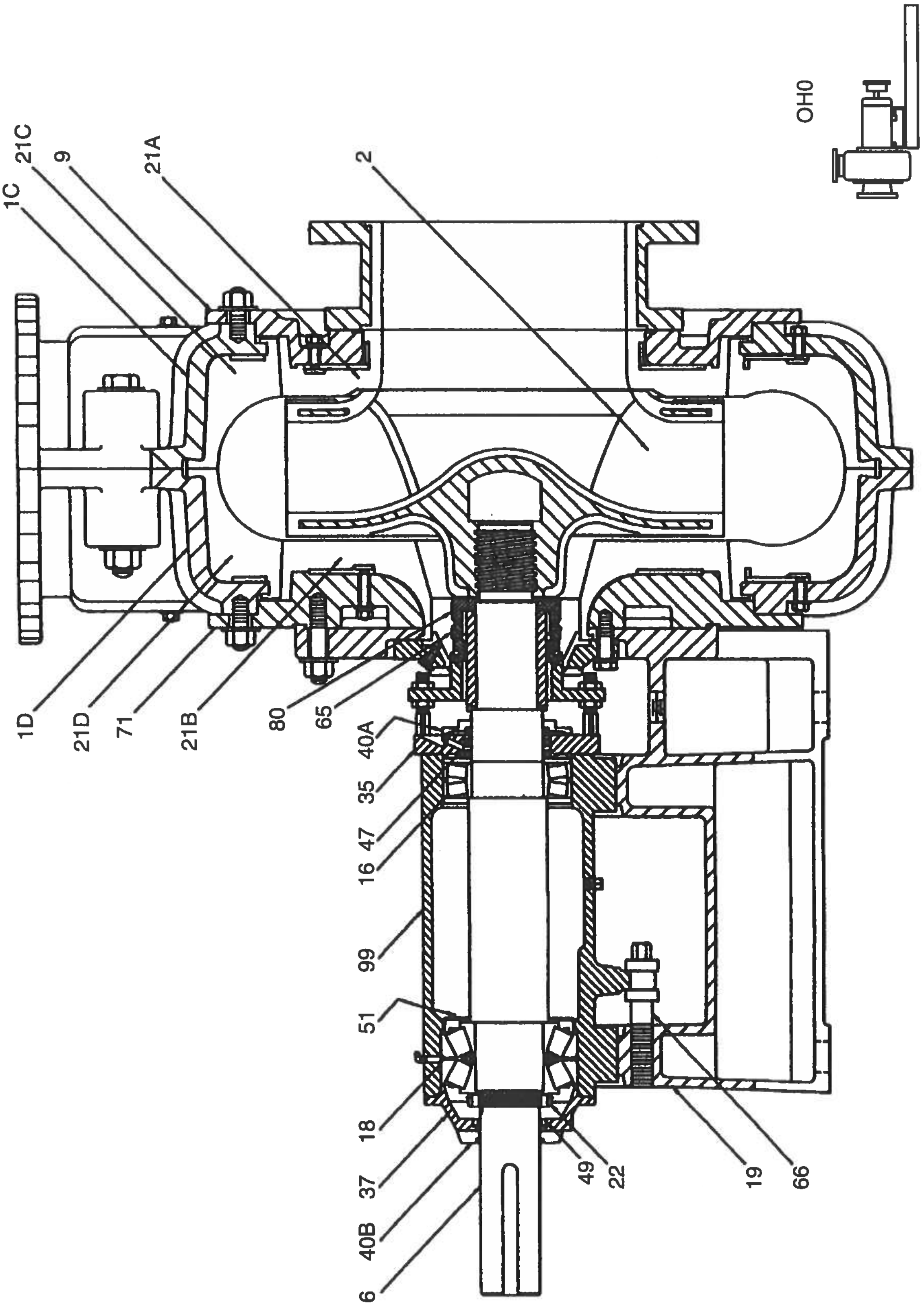


Figure A.15 — Overhung impeller – flexibly coupled – single stage – frame mounted – lined pump

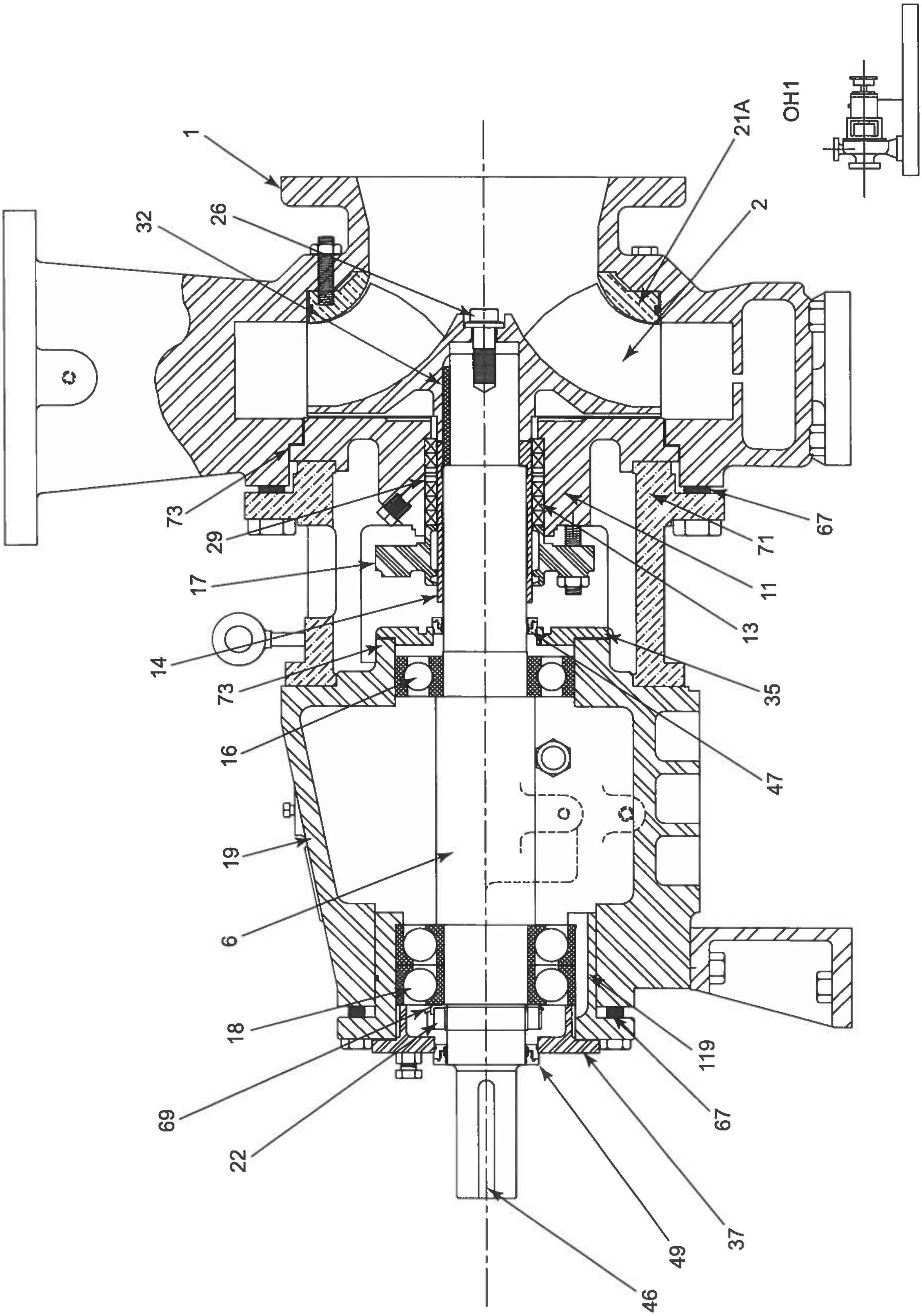


Figure A.16 — Stock pump – flexibly coupled – single stage – foot mounted

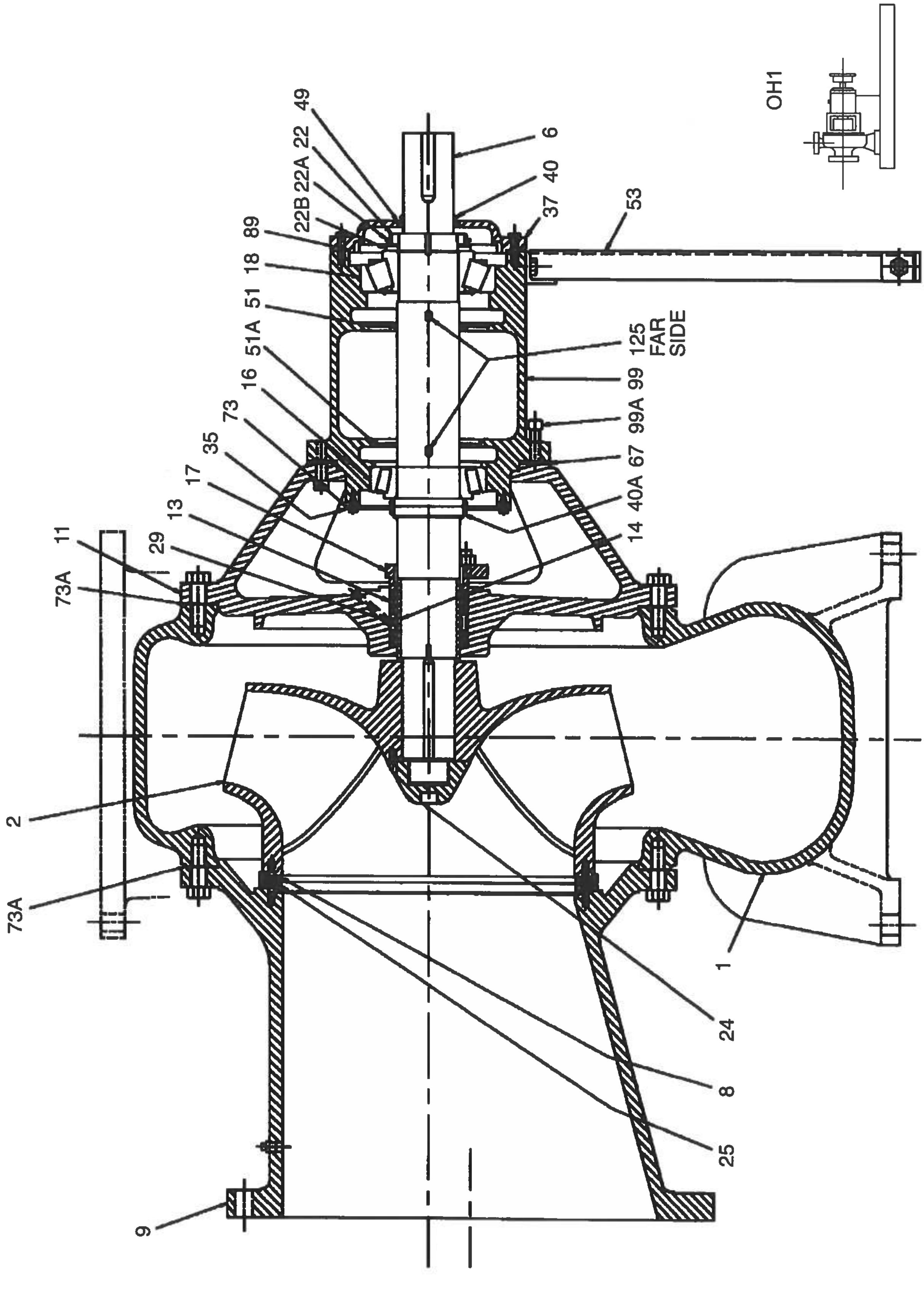


Figure A.17 — Overhung impeller – flexibly coupled – single stage – foot mounted – mixed flow

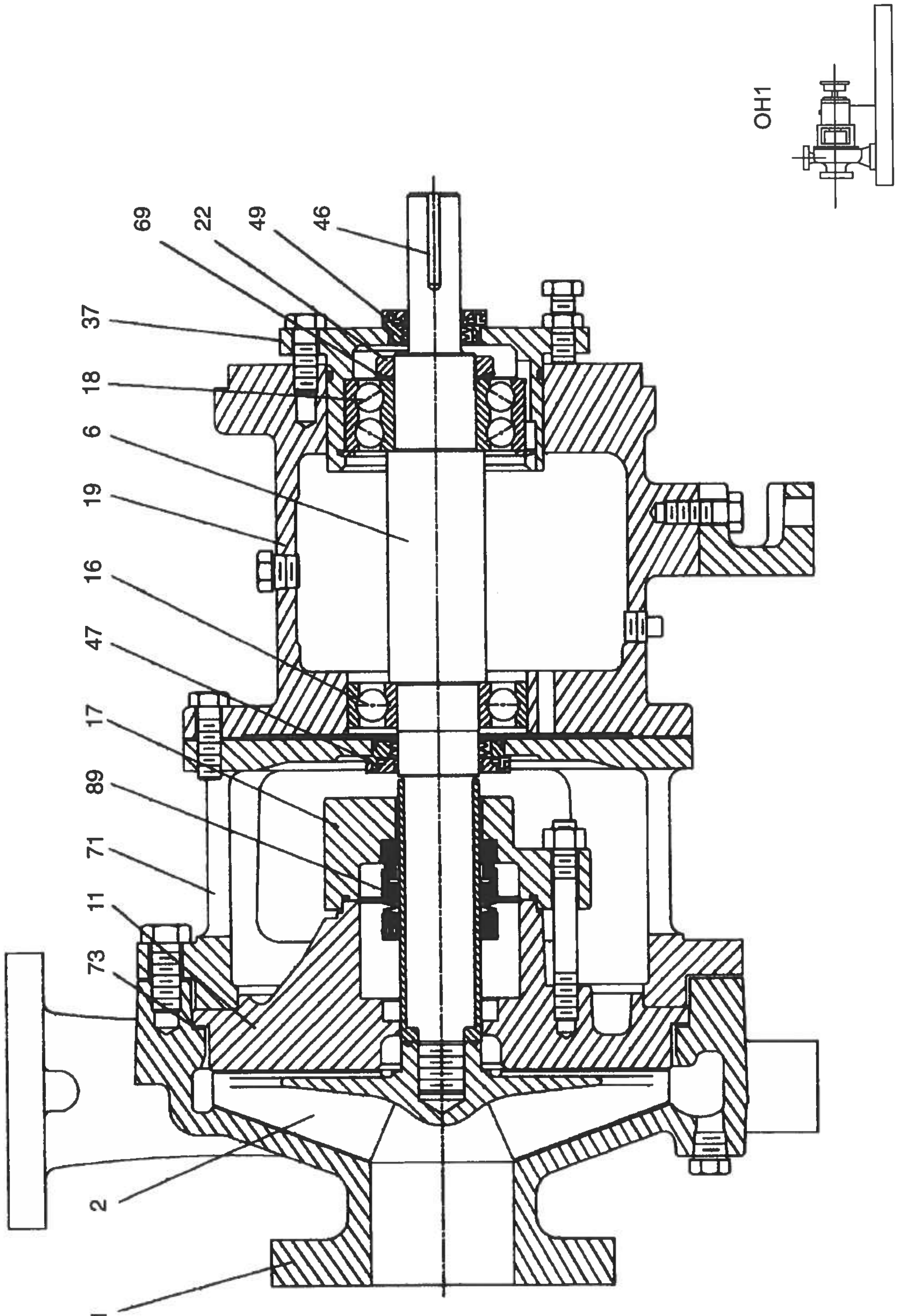


Figure A.18 — Overhung impeller – flexibly coupled – single stage – foot mounted – ASME B73.1

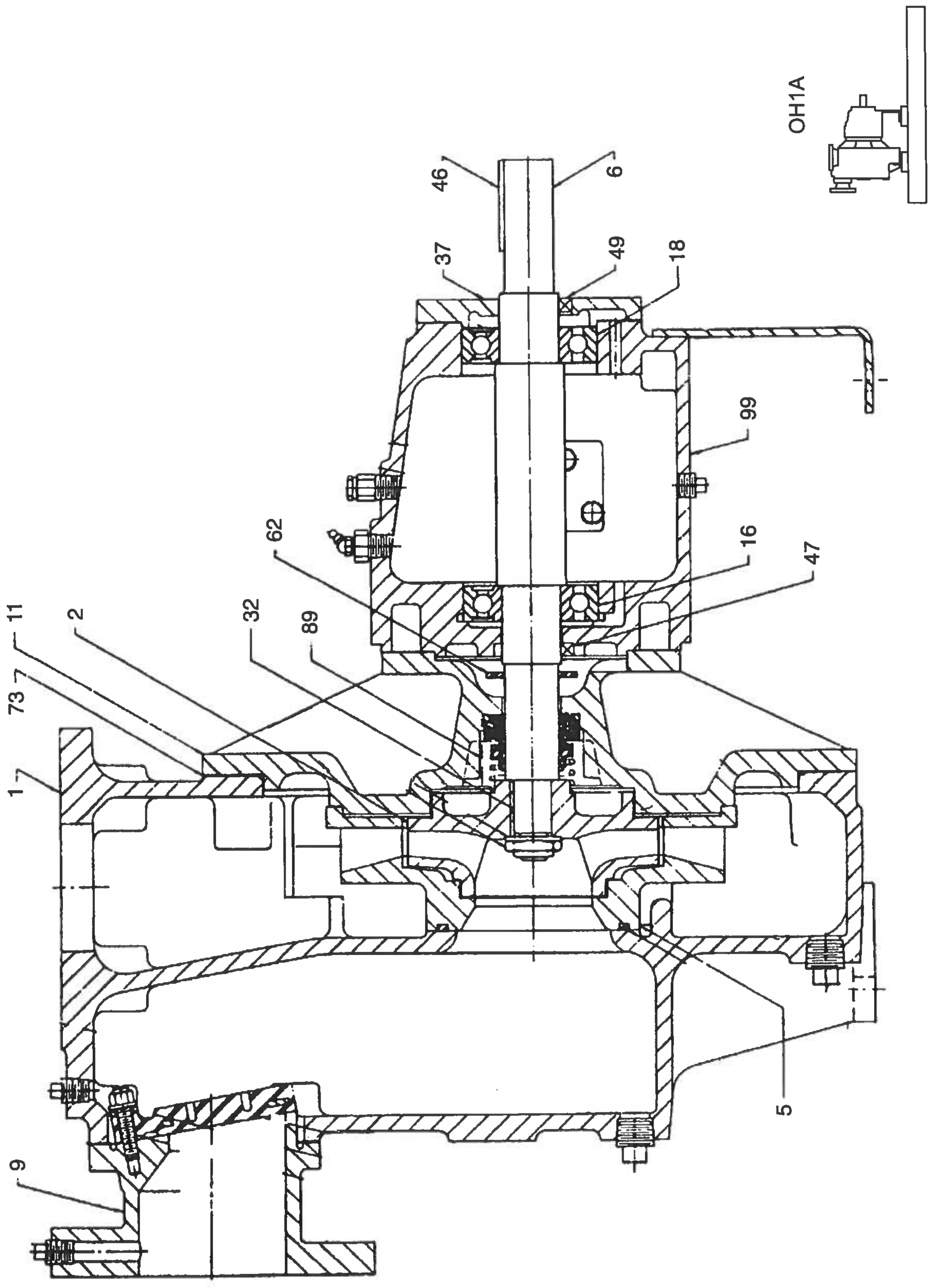


Figure A.19 — Overhung impeller – flexibly coupled – single stage – foot mounted – self-priming

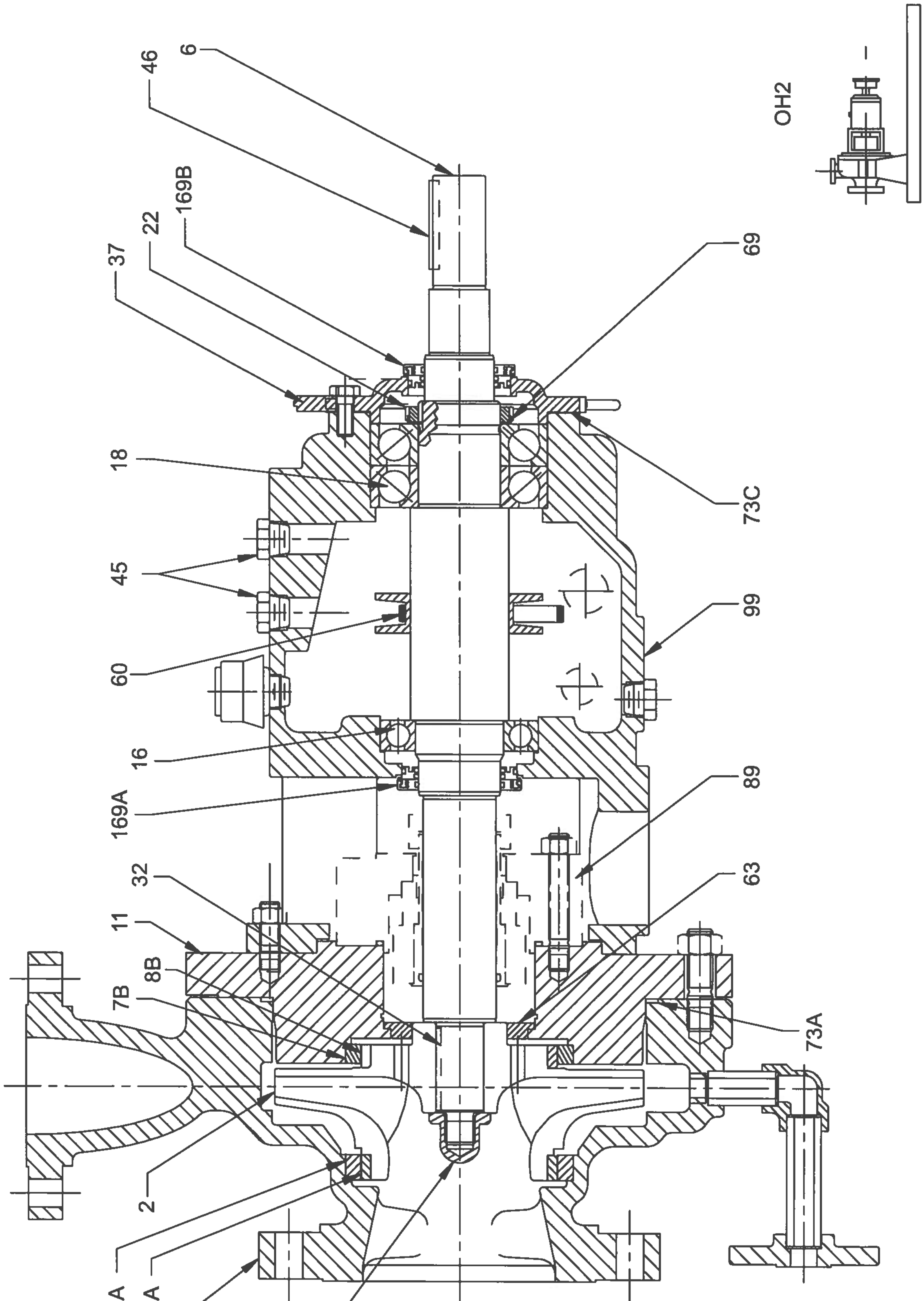


Figure A.20 — Overhung impeller – flexibly coupled – single stage – centerline mounted – API 610

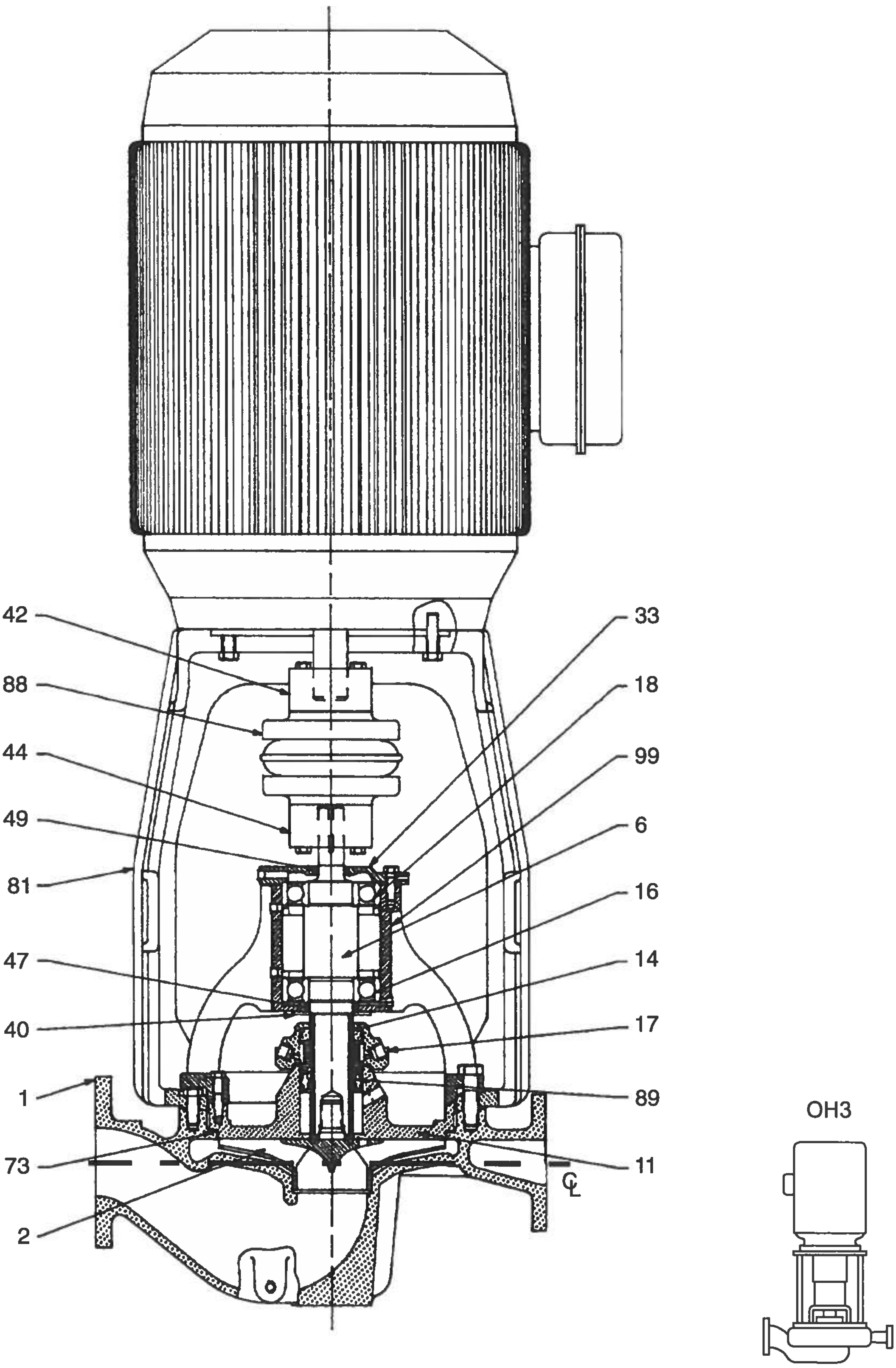
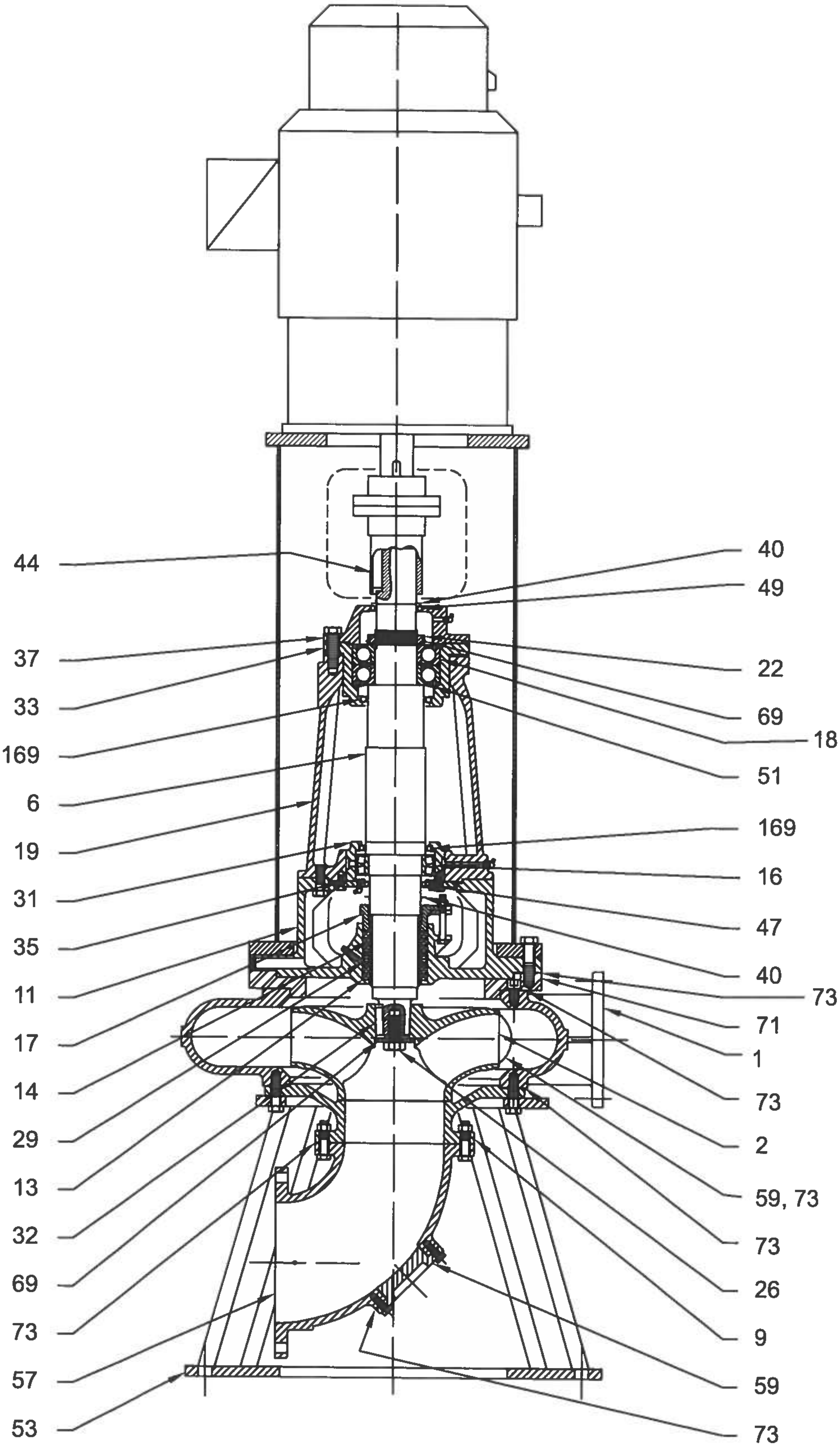


Figure A.21 — Overhung impeller – integral bearing frame – single stage – in-line – flexible coupling



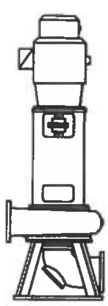
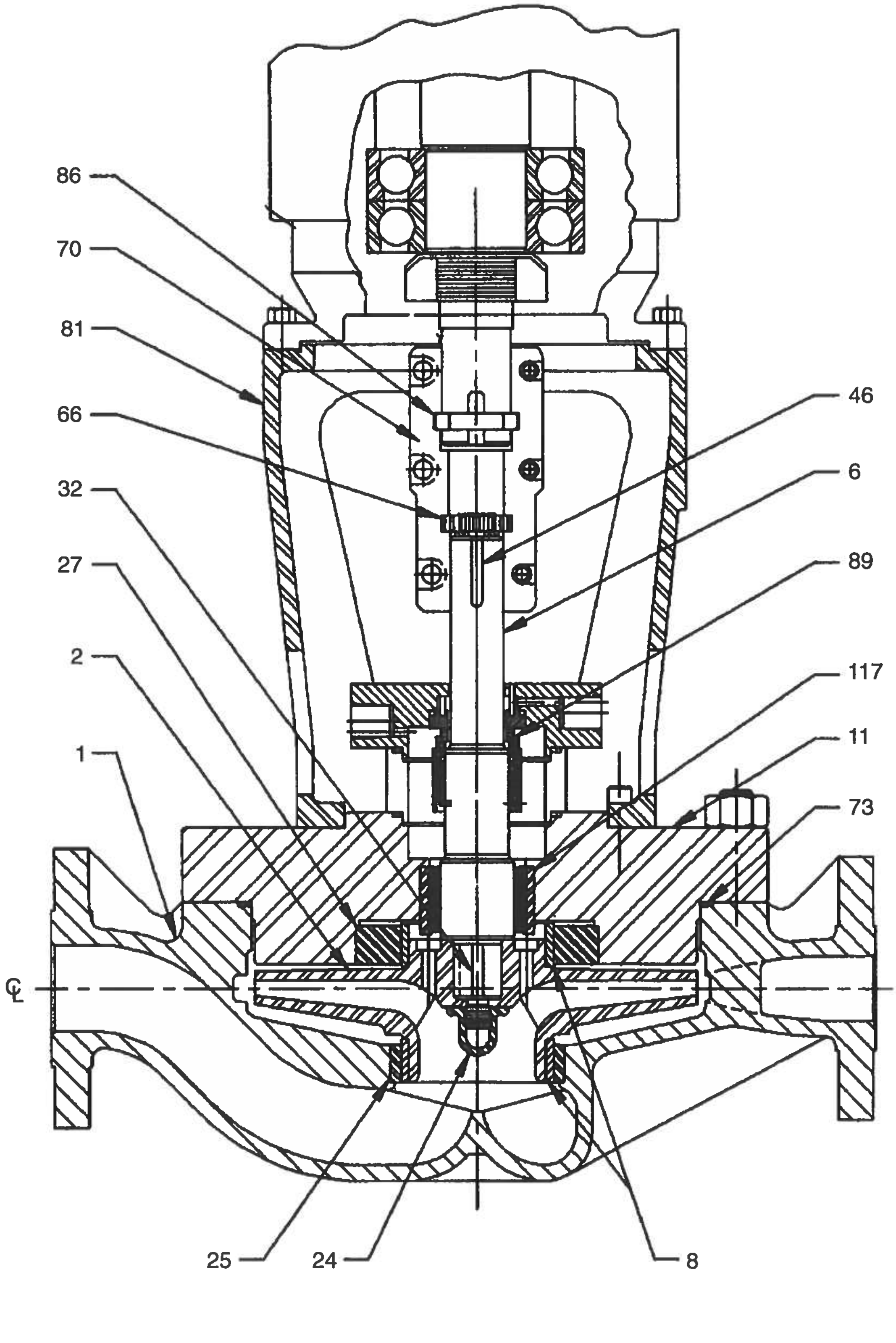
OH3A


Figure A.22 — Vertical end suction OH3A



OH4

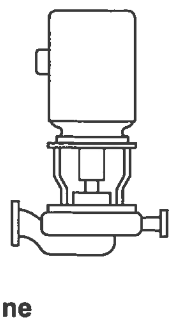


Figure A.23 — Overhung impeller – rigidly coupled – single stage – vertical in-line

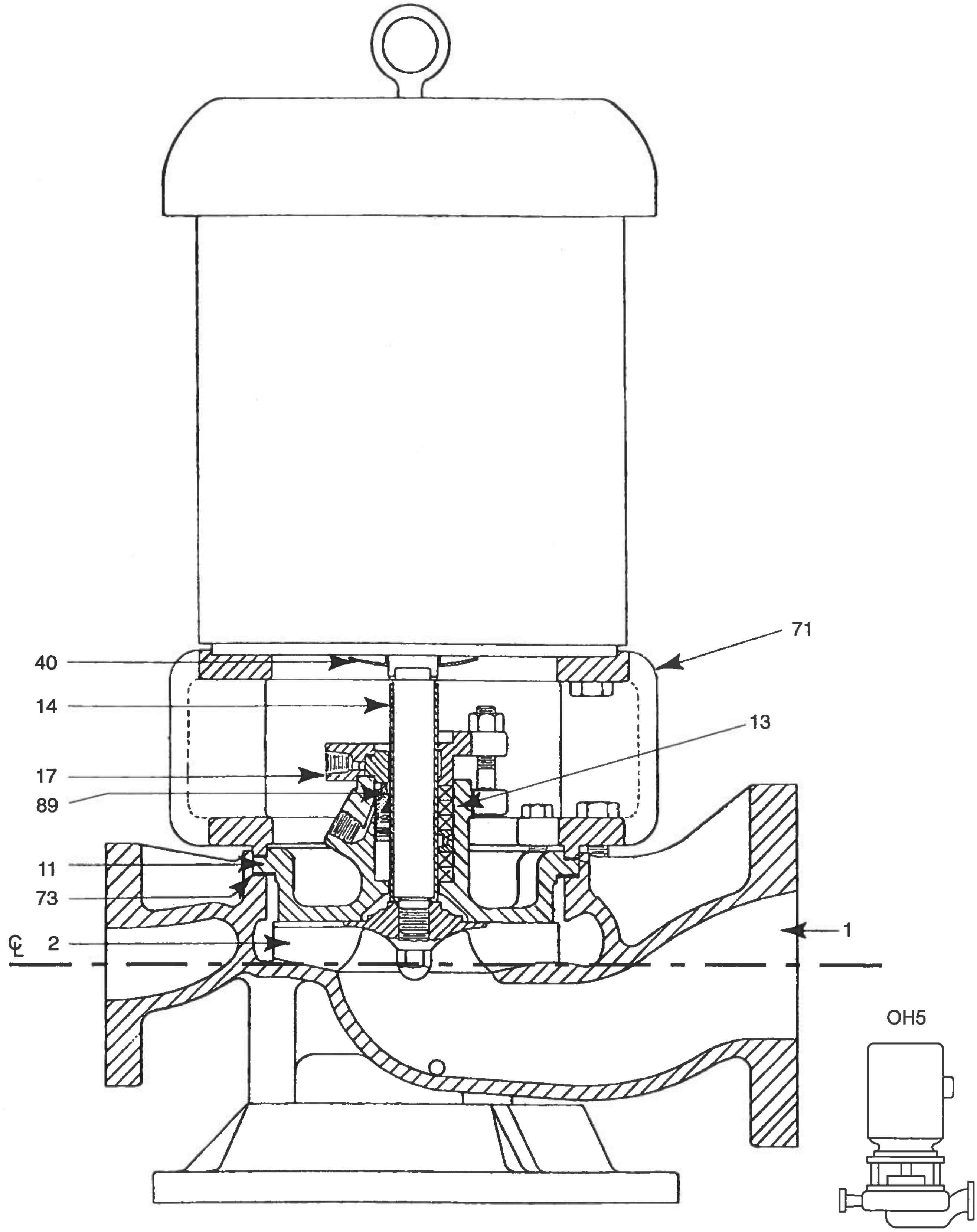
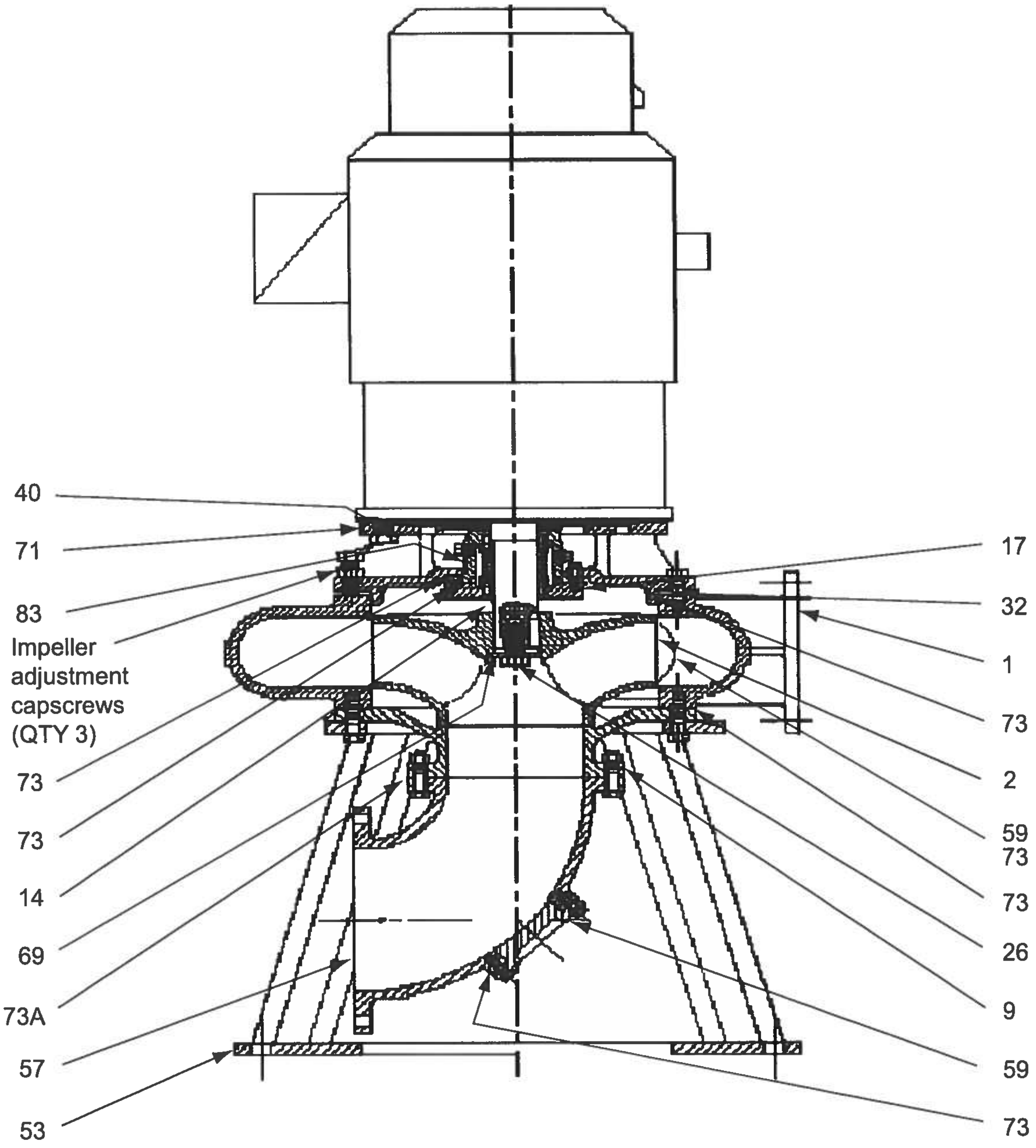


Figure A.24 — Overhung impeller – close coupled – single stage – in-line (showing seal and packing)



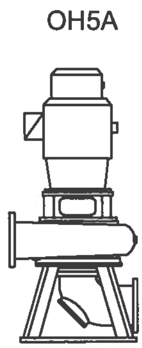
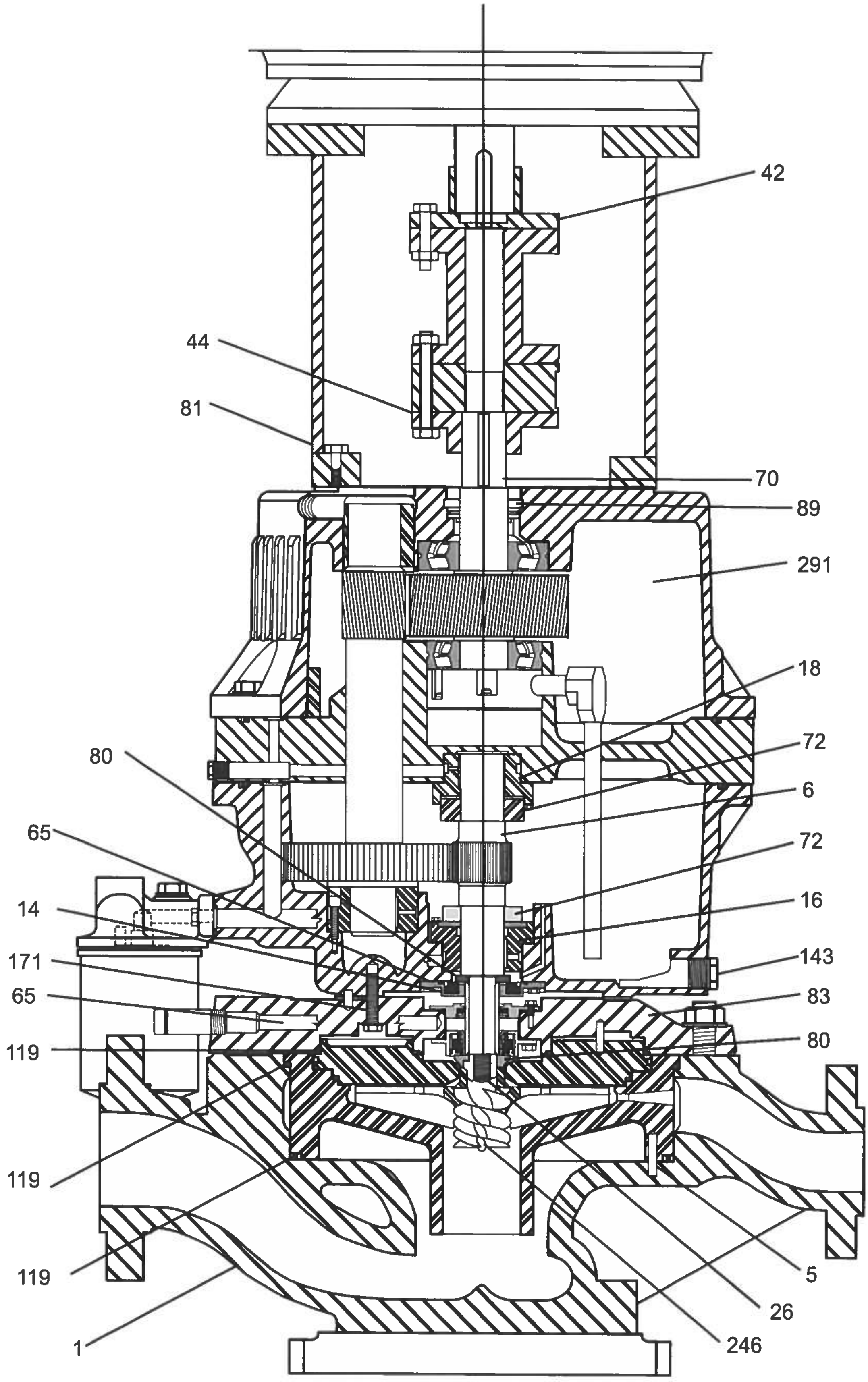


Figure A.25 — Vertical end suction OH5A – close coupled – built together



OH6

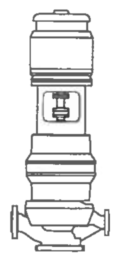


Figure A.26 — High speed – integral gear – close coupled – single stage

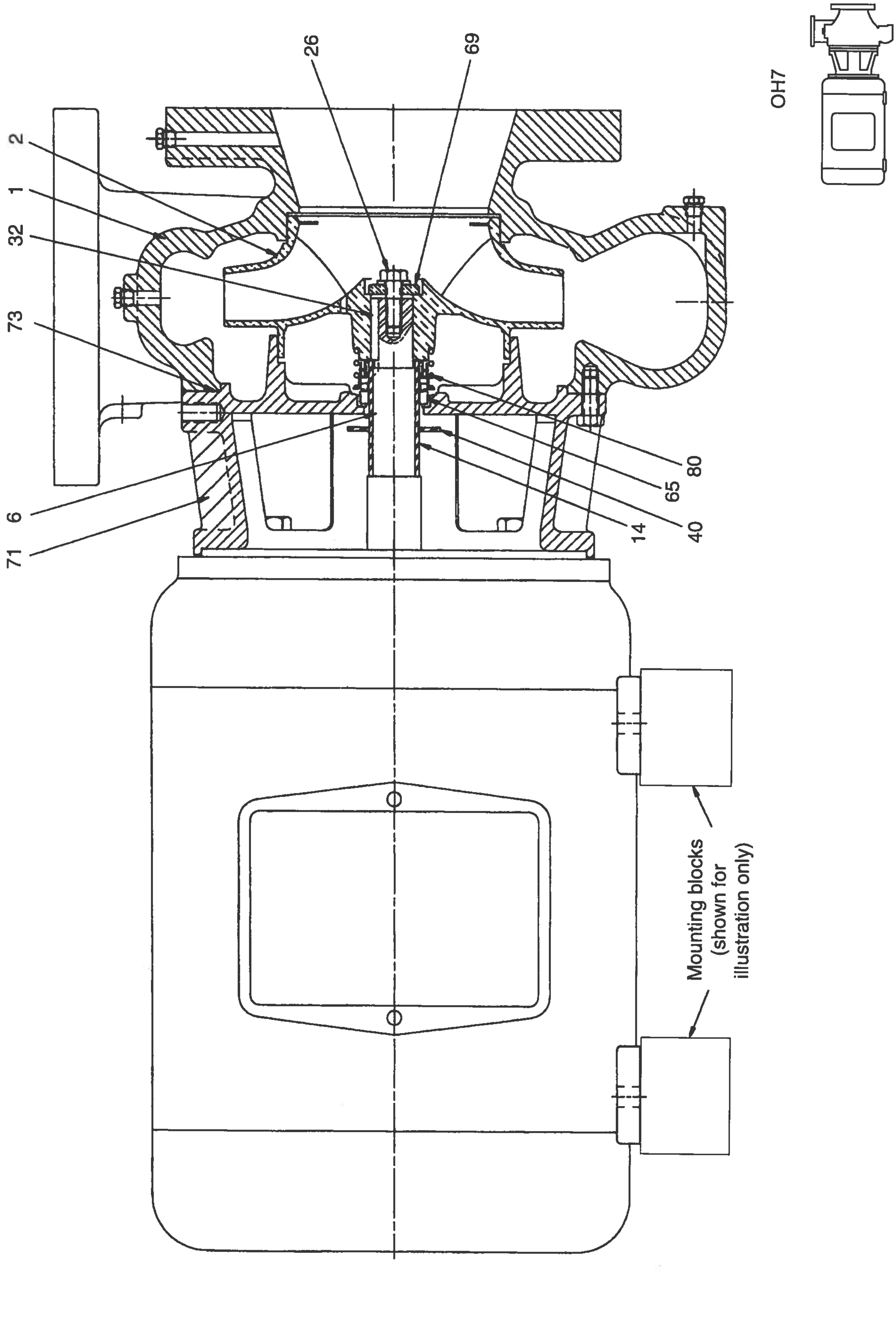
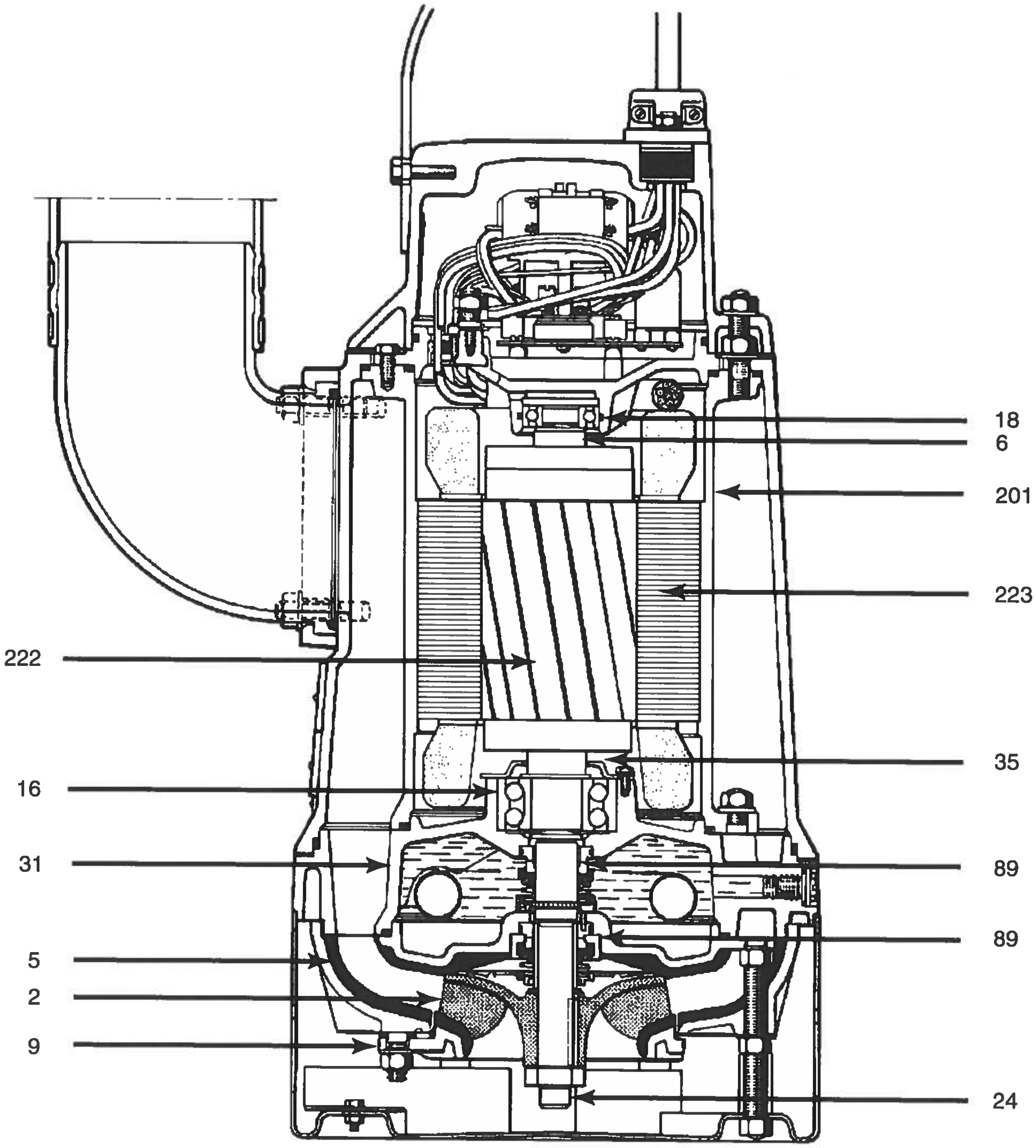


Figure A.27 — Overhung impeller – close coupled – single stage – end suction



OH8A

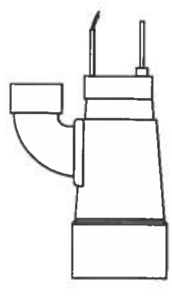
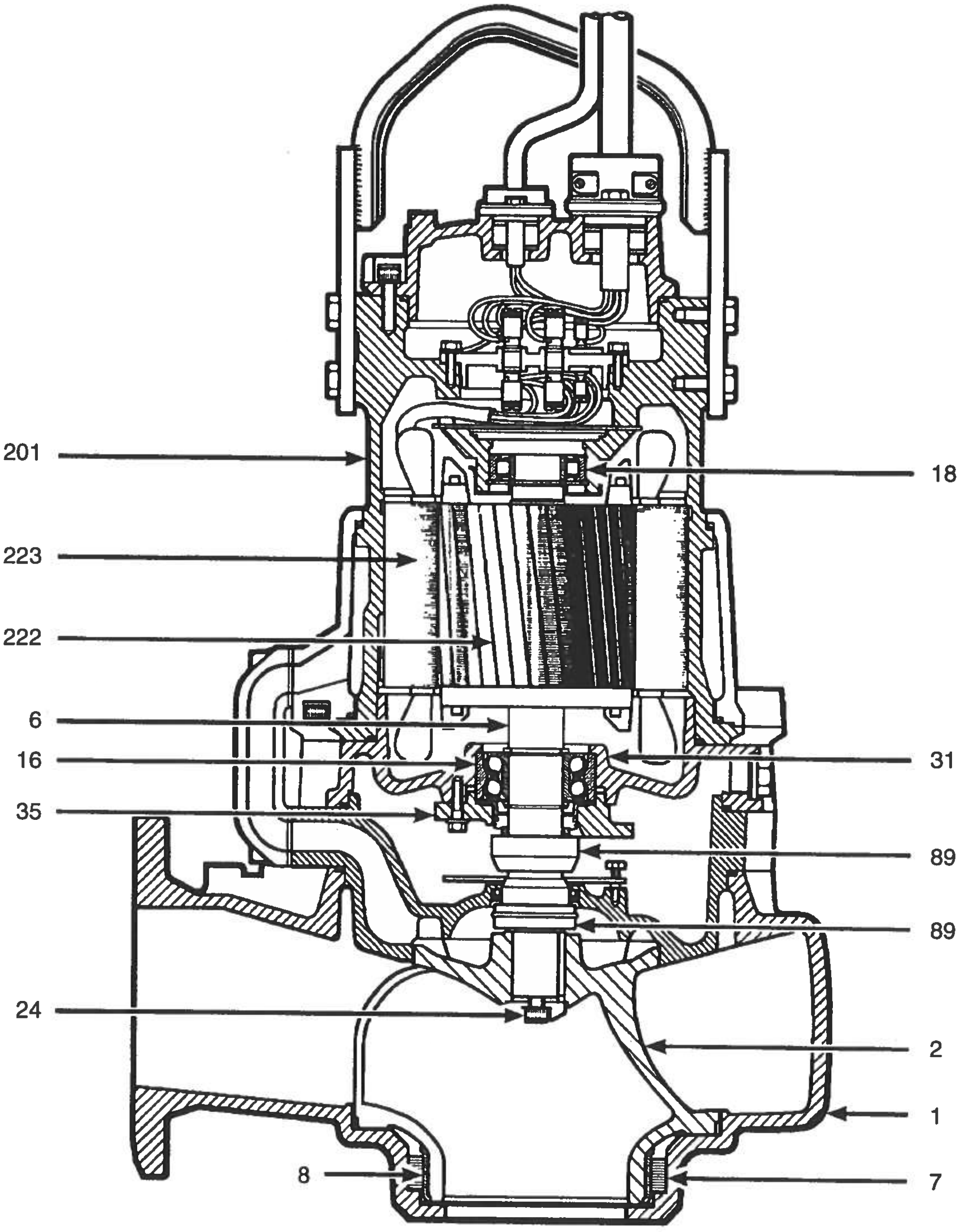


Figure A.28 — Overhung impeller – close coupled – single stage – diffuser style – end suction – submersible



OH8B

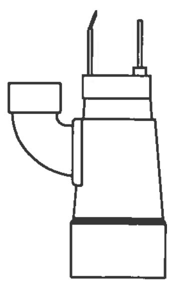


Figure A.29 — Overhung impeller – close coupled – single stage – volute style – end suction submersible

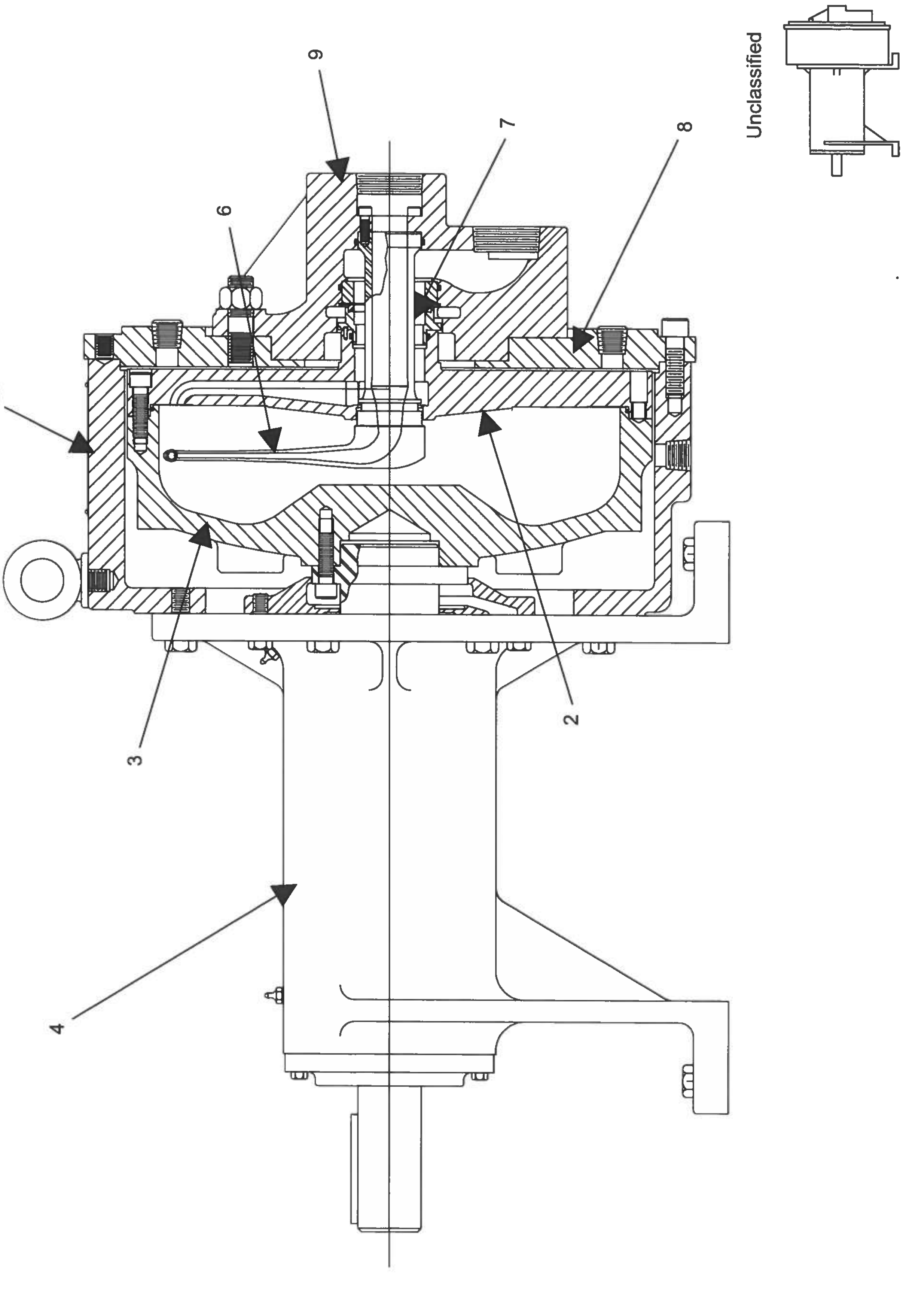


Figure A.30 — Pitot pump – flexibly coupled – single stage – frame mounted

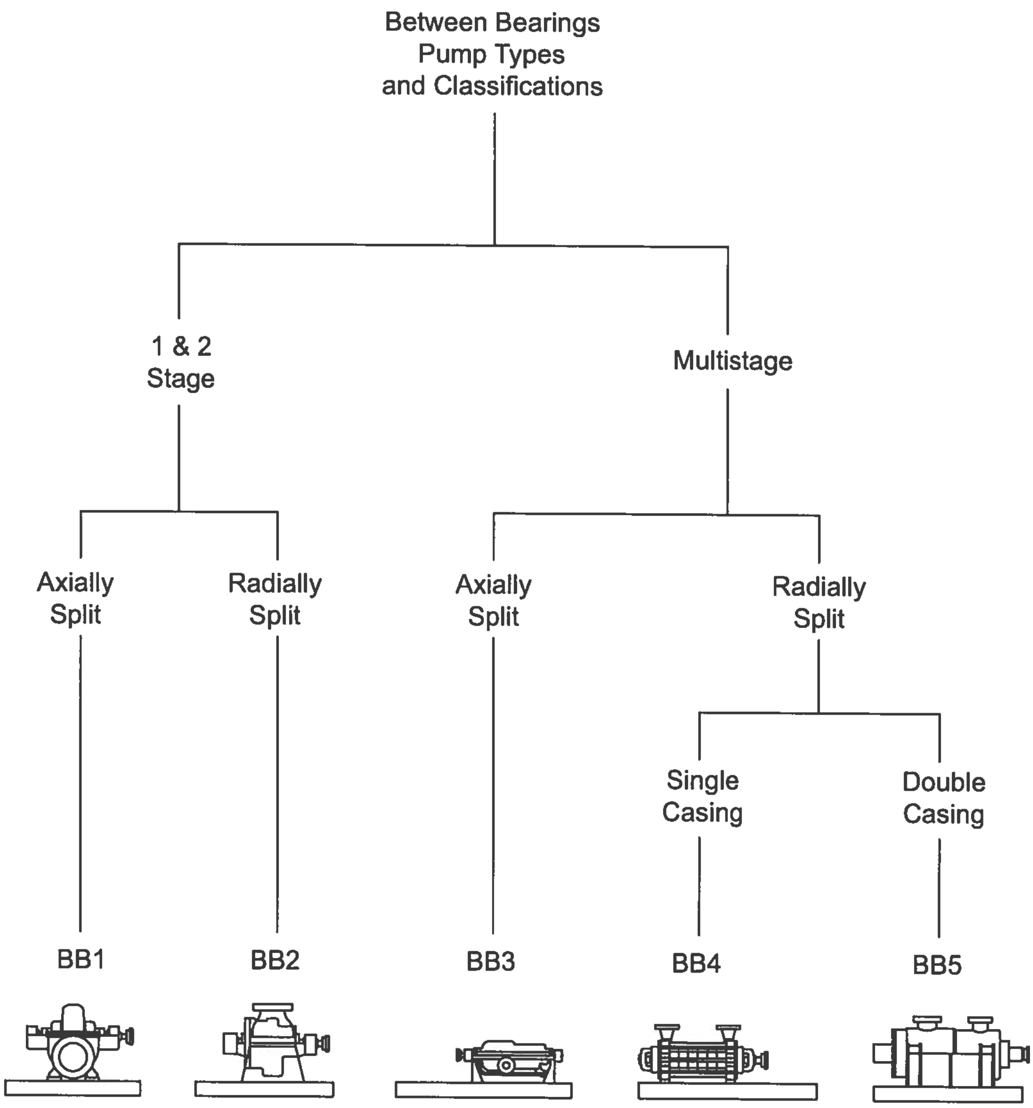


Figure A.31 — Rotodynamic pump types - between bearings

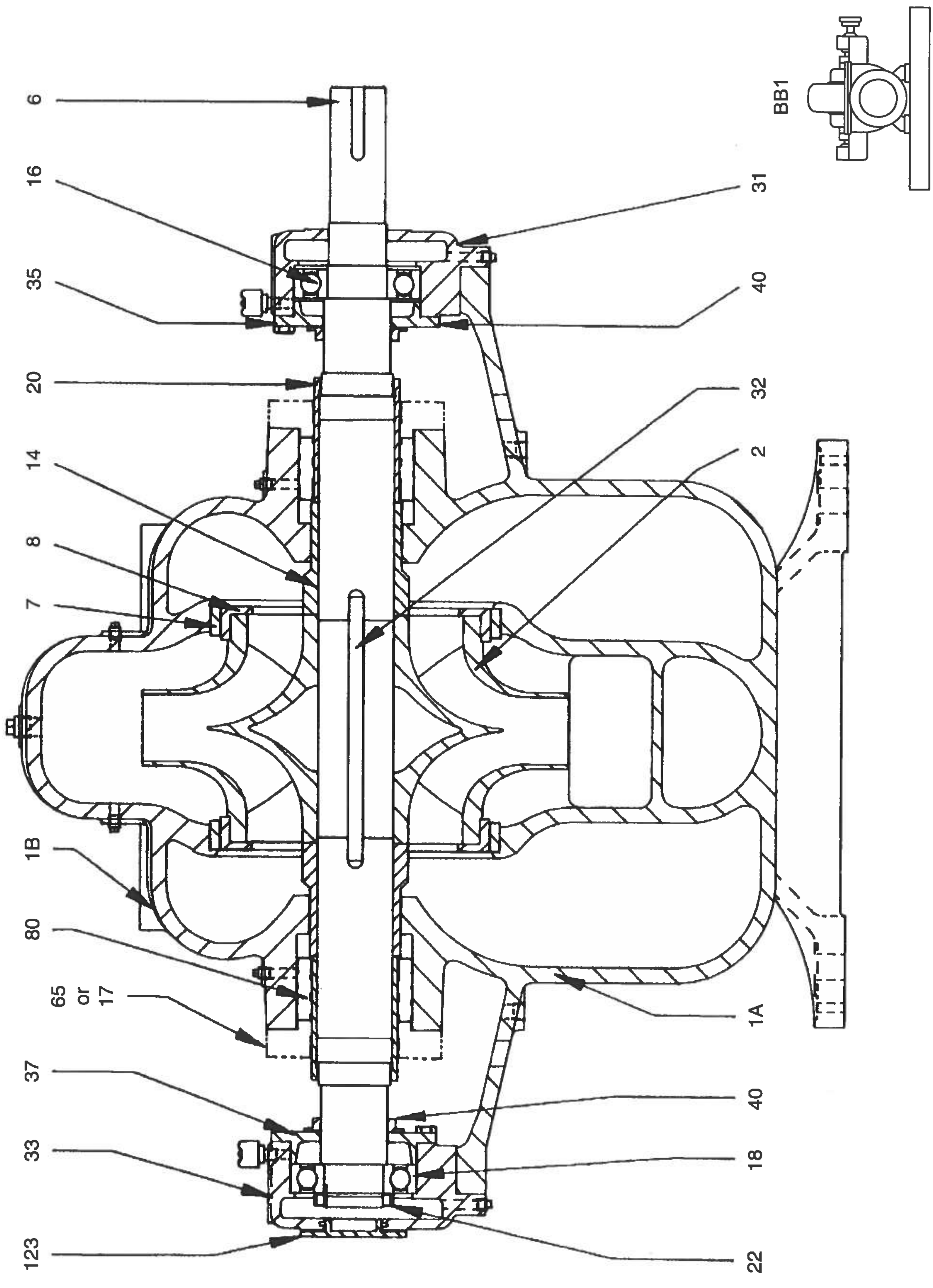


Figure A.32 — Impeller between bearings – flexibly coupled – single stage – axial (horizontal) split case

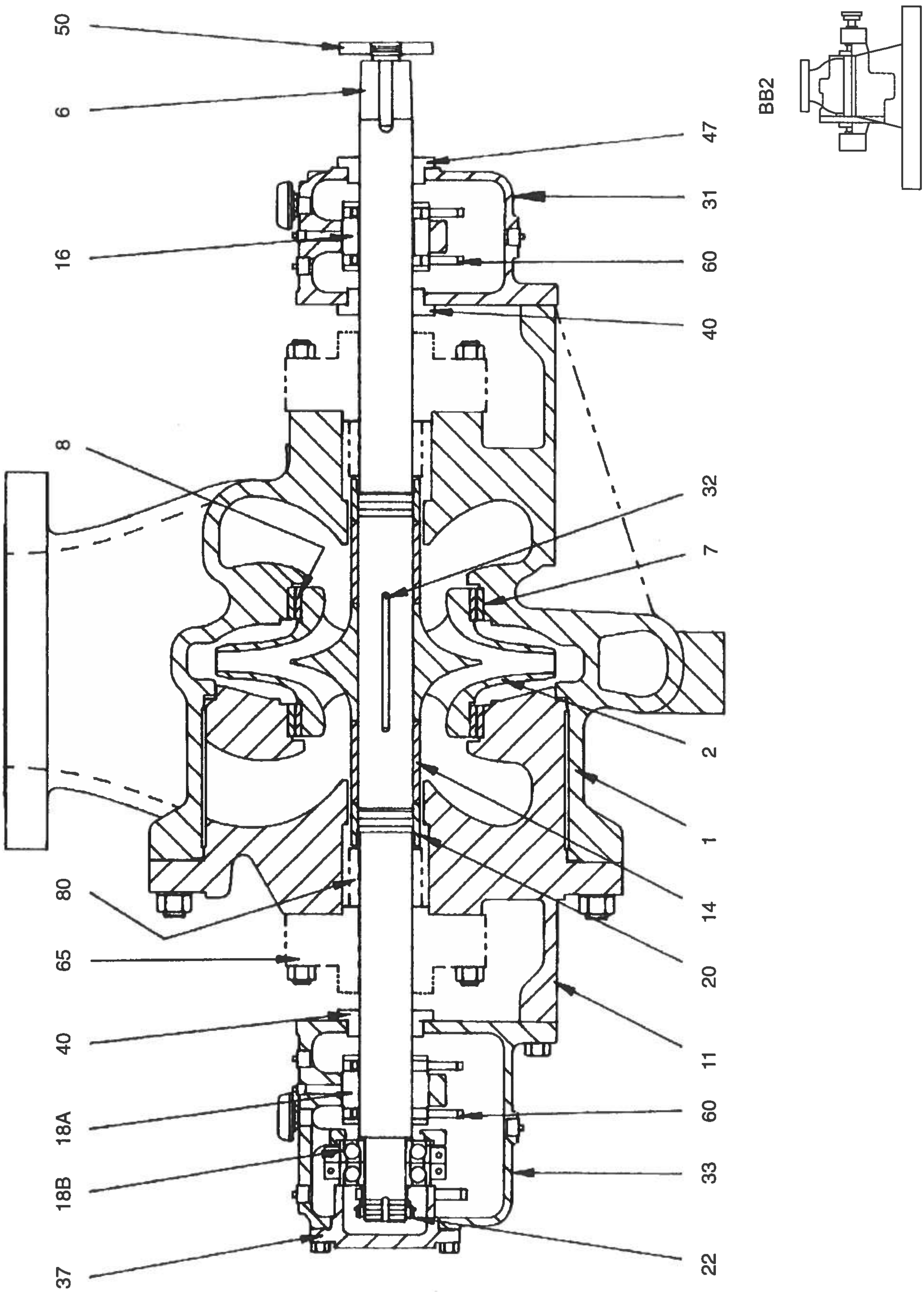


Figure A.33 — Impeller between bearings – flexibly coupled – single stage – radial split case

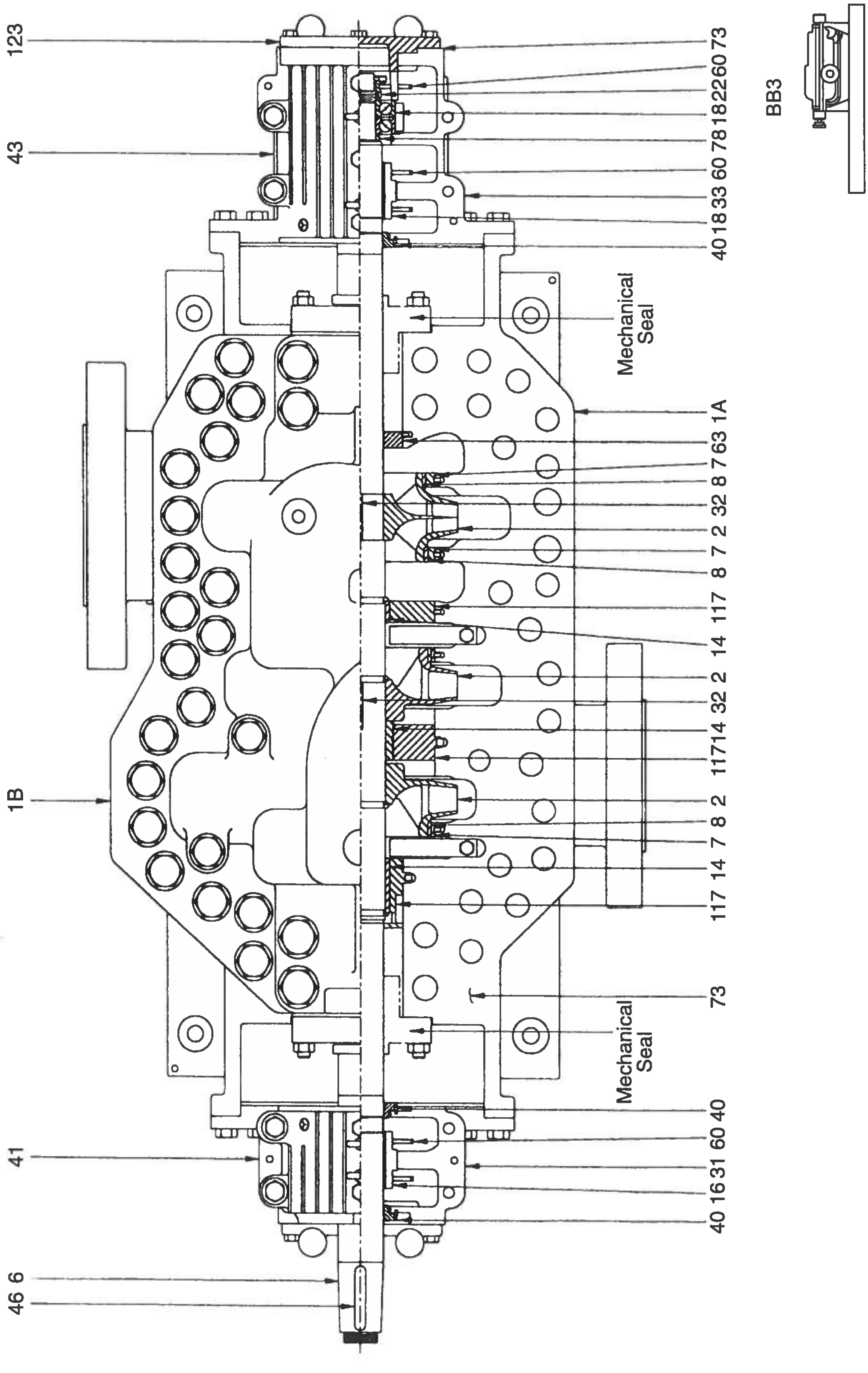


Figure A.34 — Impeller between bearings – flexibly coupled – multistage – axial (horizontal) split case

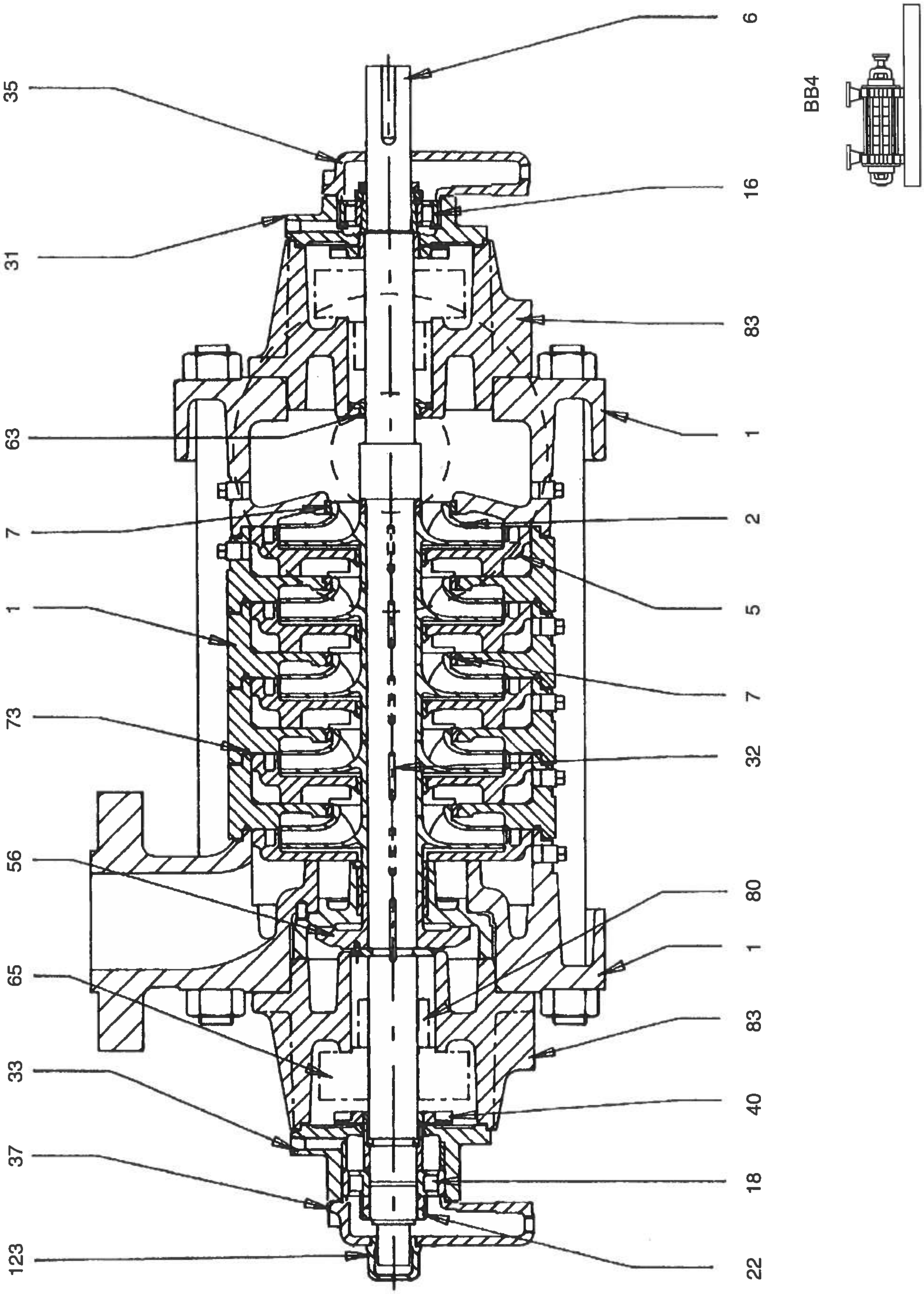


Figure A.35 — Impeller between bearings – flexibly coupled – multistage – radial split case

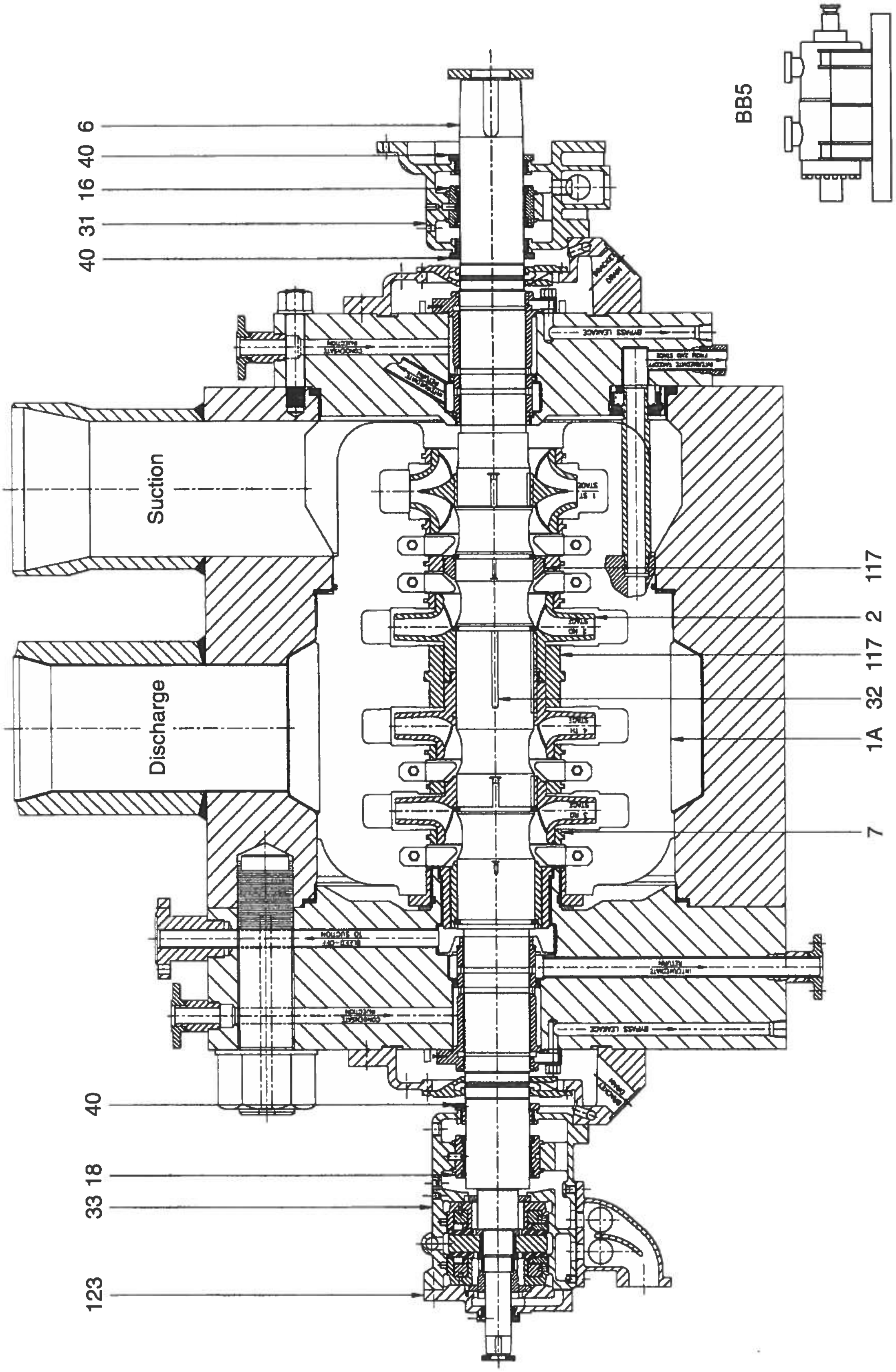
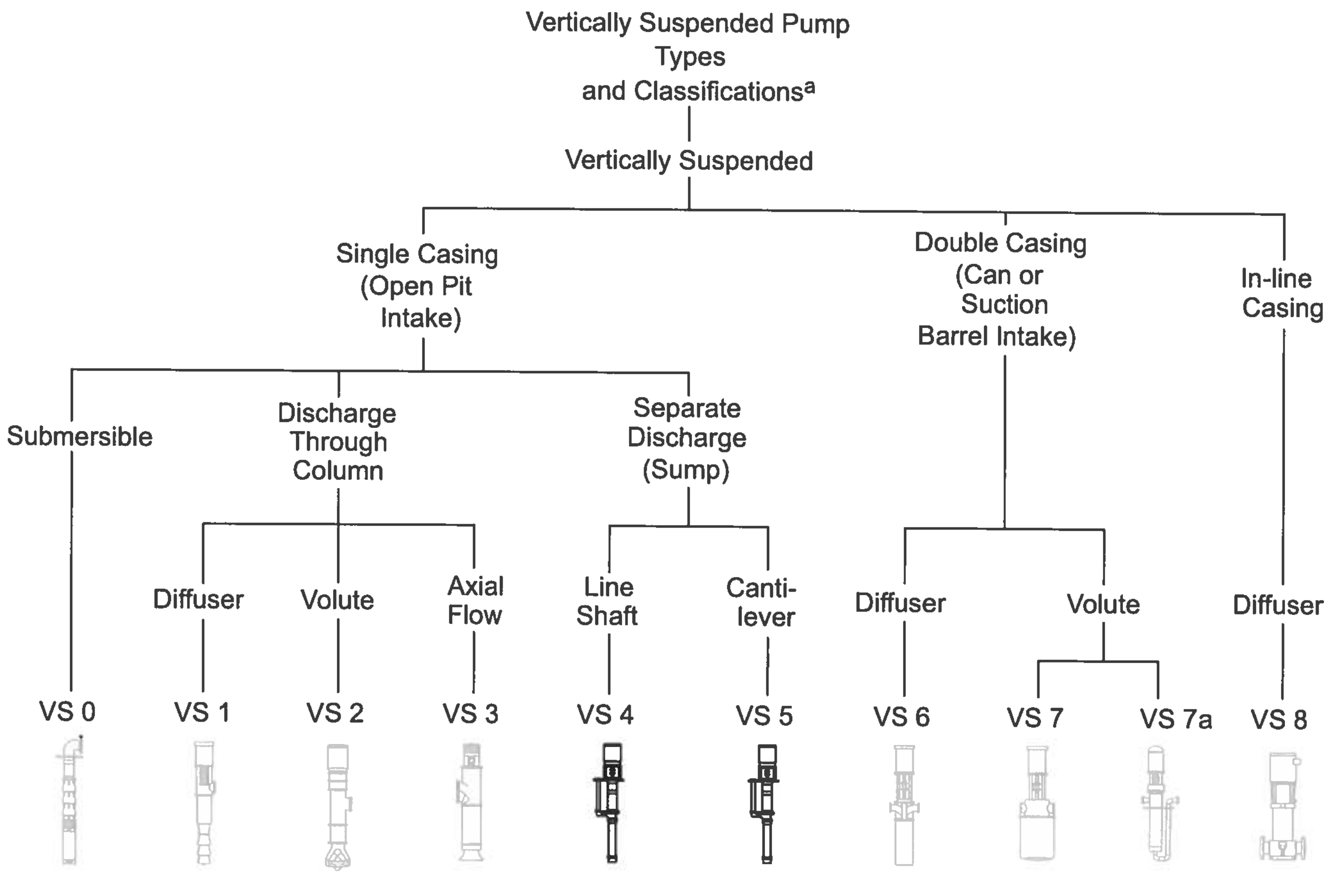
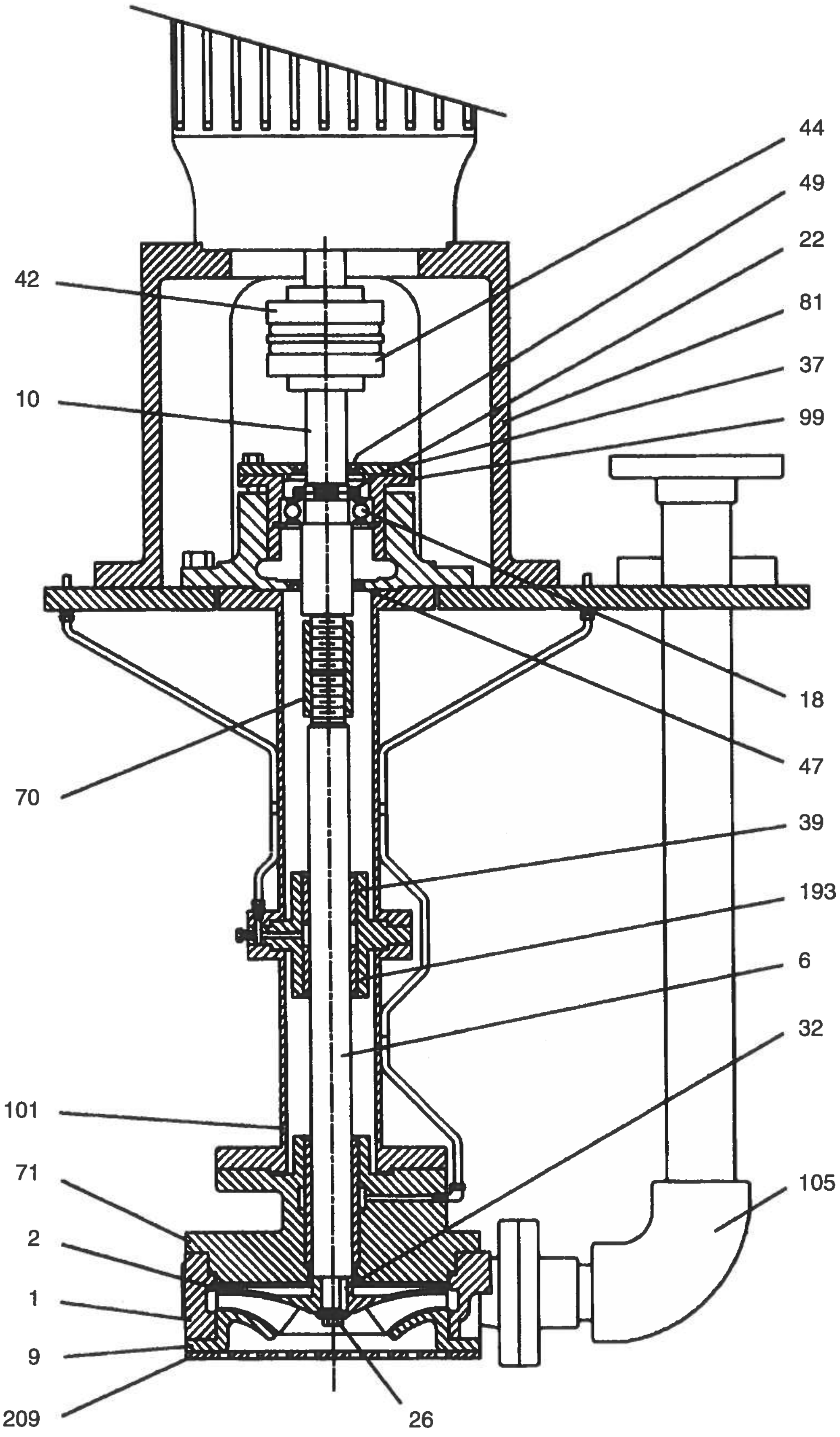


Figure A.36 — Impeller between bearings – flexibly coupled – multistage – radial split double casing



[a] VS4 and VS5 are included in this standard, for all others refer to ANSI/HI 2.4 *Rotodynamic (Vertical) Pumps for Manuals Describing Installation, Operation, and Maintenance.*

Figure A.37 — Rotodynamic pump types - vertically suspended



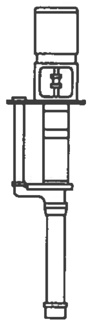
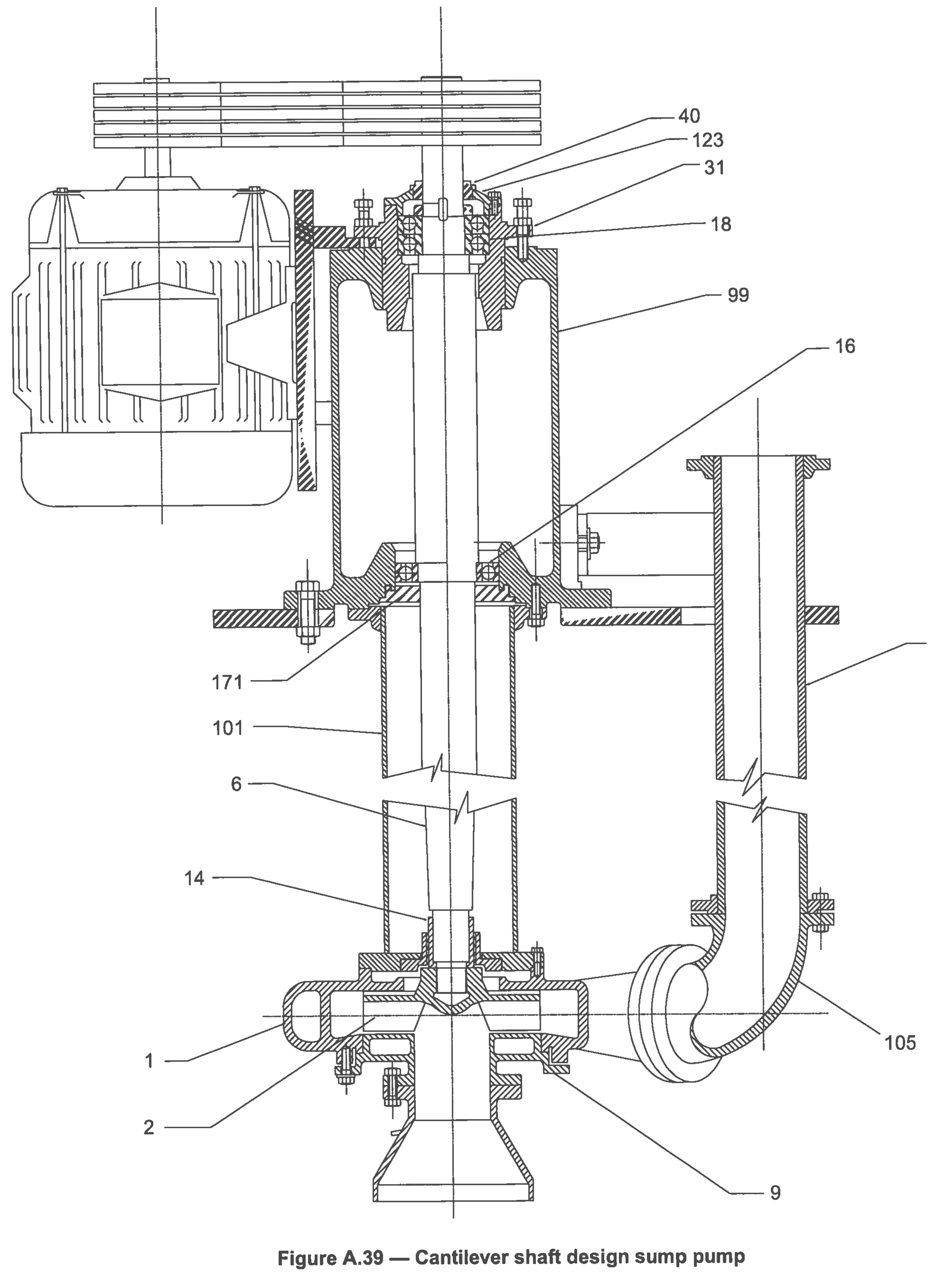


Figure A.38 — Lineshaft design sump pump



VS5

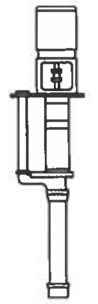


Figure A.39 — Cantilever shaft design sump pump

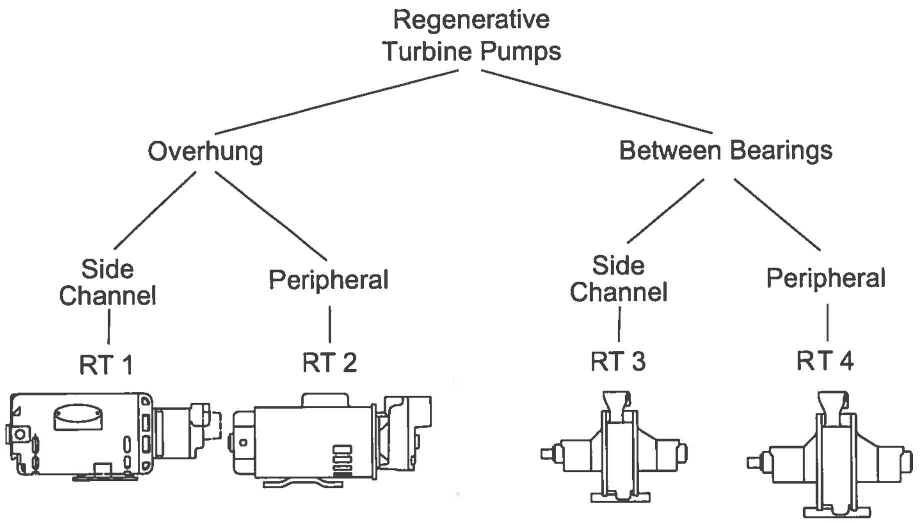


Figure A.40 — Rotodynamic pump types - regenerative turbine

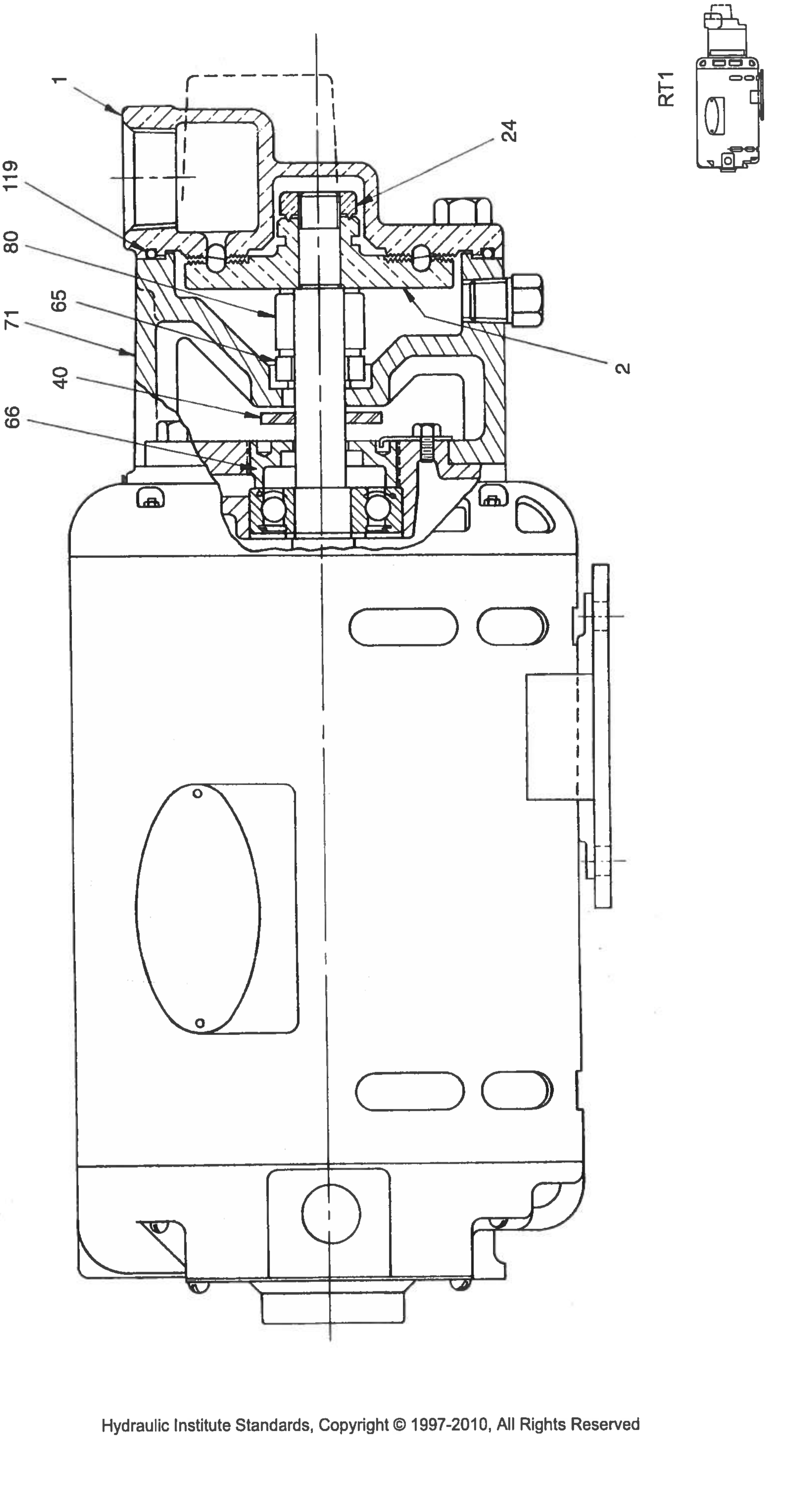


Figure A.41 — Regenerative turbine – side channel single stage

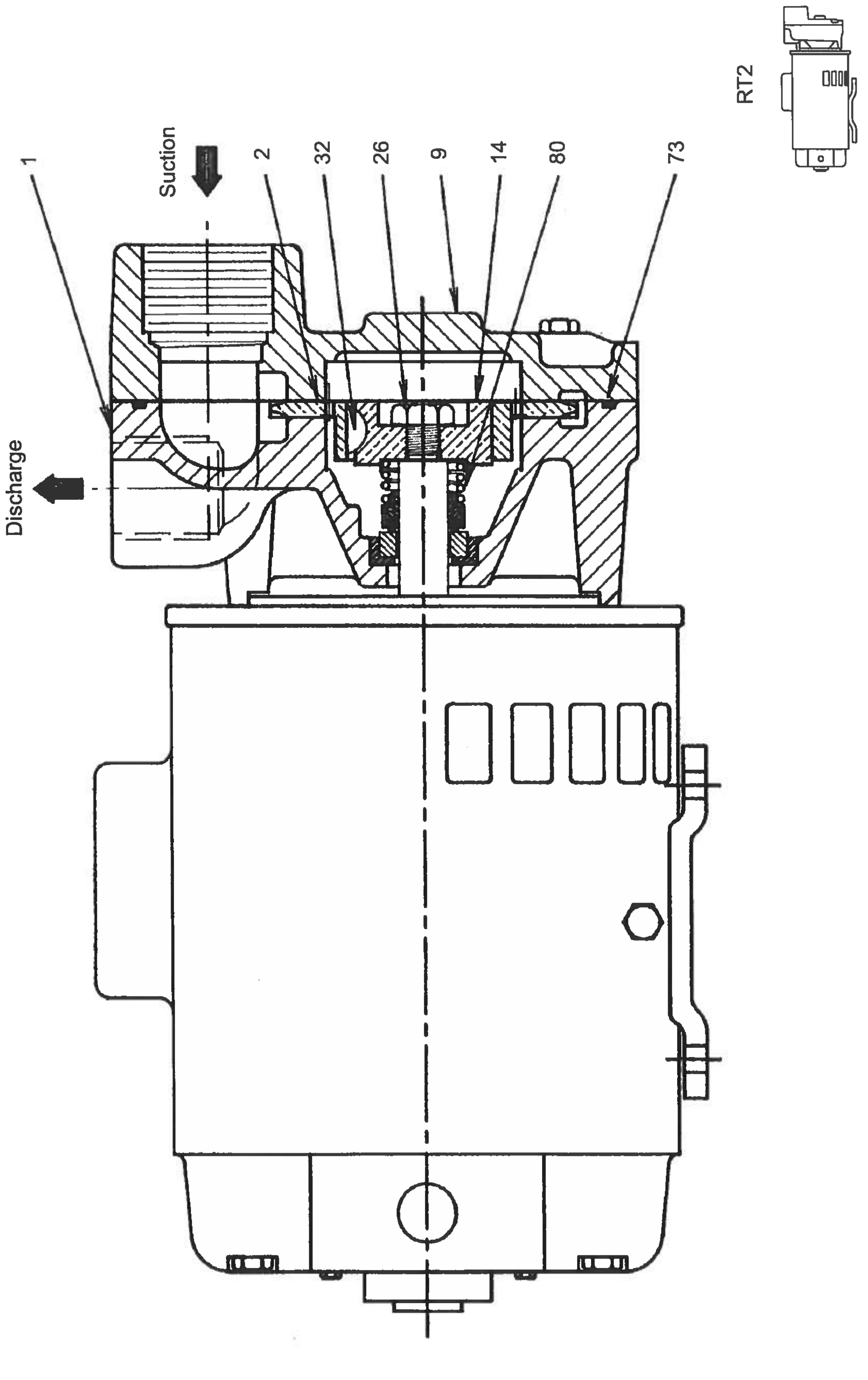


Figure A.42 — Regenerative turbine – peripheral single stage

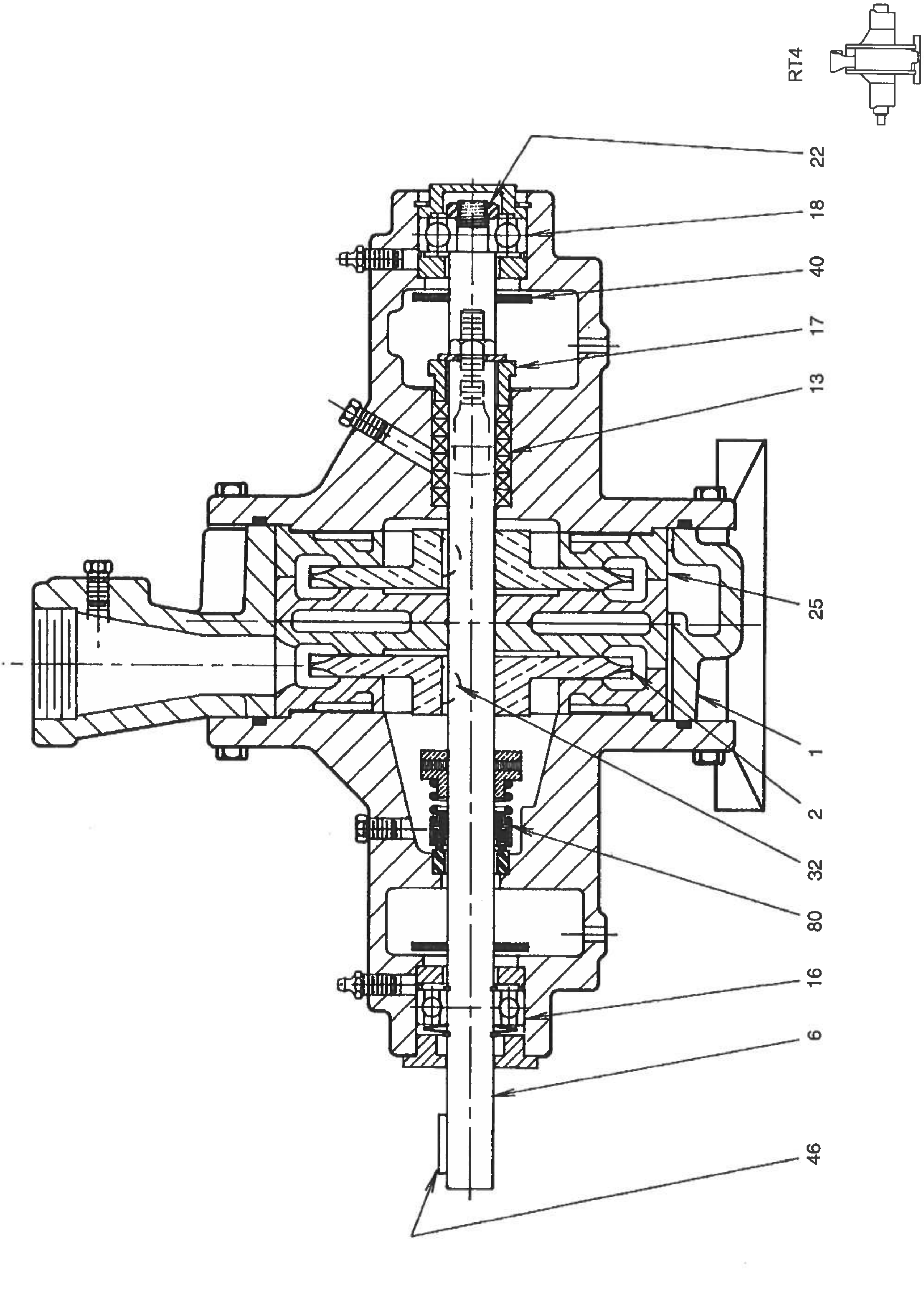


Figure A.43 — Regenerative turbine - impeller between bearings - two stages

A.9 Certification

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

A.9.1 Why product certification matters

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

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

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

A.9.2 UL and CSA-US acceptance

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

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

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

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

A.9.3 Authorized testing locations

There are two considerations to ensure testing compliance:

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

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

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

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

The certification mark provides visual evidence that the product was tested and certified to meet the applicable standard. All listed products for the US market are tested to the same standard, regardless of whether they carry a UL or CSA-US mark. Hence, the following UL and CSA marks are interchangeable and are usually equally accepted today.

A.9.3.1 Underwriters Laboratories, Inc

UL listing mark

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

C-UL US listing mark

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

Recognized Component mark and Canadian Recognized Component mark

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

Water Quality mark

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

A.9.3.2 Canadian Standards Association

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

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

C US NRTL/C

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

NSF/ANSI 61
Drinking Water

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

A.10 Other relevant documentation and manuals

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

Appendix B

Index

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

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

Hydraulic Institute
Creating Pump Standards Since 1917

Available at eStore.Pumps.org

Optimizing Pumping Systems: A Guide to Improved Efficiency, Reliability and Profitability

Pump Life Cycle Costs: A Guide to LCC Analysis for Pumping Systems

Variable Speed Pumping: A Guide to Successful Applications

Mechanical Seals for Pumps: Application Guidelines

ANSI/HI
Pump Standards

Individual Standards

- Hardcopy
- Downloadable

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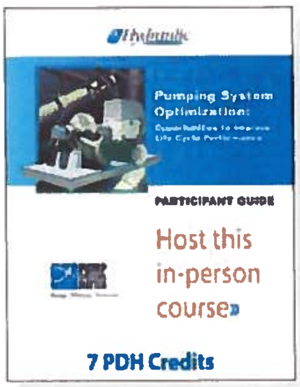

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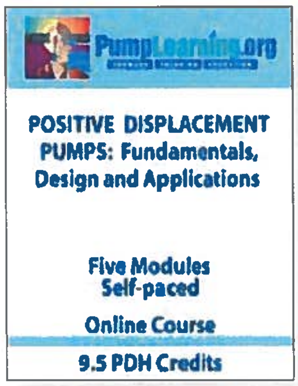

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