ANSI/HI 5.1–5.6-2010

Approved American National Standard

ANSI

American National Standard for

Sealless Rotodynamic Pumps

for Nomenclature, Definitions, Application, Operation, and Test

ANSI/HI 5.1–5.6-2010

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

a) To develop and publish standards for pumps;

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

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

d) To support educational and research activities; and

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

Purpose of Standards

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

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

Definition of a Standard of the Hydraulic Institute

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

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

Comments from users

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

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

Revisions

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

Disclaimer

The term *sealless* is a generic, industrial word used for pumps not employing packing or mechanical shaft seals as the prime method of sealing liquid or vapor from the atmosphere. *Hermetic* would accurately describe the construction of these types of pumps. It is understood that static seals may be used in pumps that are designated sealless. Use of the term *sealless* herein should not be construed as any type of warranty or guarantee against pump leaks.

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 sealless rotodynamic 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.

Buse Fred, Consultant
DuPont
Healy Engineering, Inc.
KBR
Malcolm Pirnie
Pentair Water - Berkley Pumps

Committee list

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

Chair – Roger Turley, Flow Solutions Group
Vice-chair – Peter Gaydon, Chempump, a Division of Teikoku USA

Committee Members	Company
Charles Cappellino	ITT - Industrial Process
Peter Brule	Iwaki America Incorporated

5 Sealless rotodynamic pumps

5.1 Types and nomenclature

5.1.1 Scope

This standard covers types and nomenclature, definitions, design and application, installation, operation and maintenance, and test of sealless rotodynamic pumps driven by canned motors or magnetic couplings.

Not included are submersible wastewater pumps that do not have external shaft seals and are therefore not susceptible to external shaft leakage. Deep well submersible pumps are also excluded.

5.1.1.1 Objective

To clearly outline the information necessary to define and describe the construction and use of sealless pumps.

5.1.1.2 Introduction

The sealless pump is used when there is a need to contain toxic, dangerous, and/or valuable fluids. Application may be dictated by space, noise, environment, or safety regulations. This section outlines types, nomenclatures, and components of sealless rotodynamic type pumps.

The driven shaft is completely contained in a pressurized vessel containing the pumped fluid. The pressurized vessel or primary containment device (chamber) is sealed by static seals, such as gaskets or O-rings.

The power required by the driven shaft is transmitted through a containment barrier. Methods include (1) the "canned motor pump," with a liner (can) placed between an induction motor's armature and stator; and (2) the "magnetic drive pump," with a shell(s) located between an outer rotating element with permanent magnet(s) and a mating inner ring that follows the driving magnets. The inner rotor may have permanent magnets or it may be an induction device.

See Figure 5.1.1.2 for a diagrammatic breakdown of the types of sealless rotodynamic pumps.

5.1.2 Canned motor pump (CMP)

5.1.2.1 Close-coupled, end suction

Figure 5.1.2.1 — In this group, the impeller(s) is mounted on the end of the shaft that is overhung from its motor bearing supports.

The impeller is mounted directly on the rotor assembly, making one rotating assembly. The bearings are supported by housings at each end of the rotor assembly. The motor components are protected from the process liquid by nonmagnetic liners (shells).

During operation, the motor section and bearings are cooled and lubricated by the process liquid. This fluid is either a flush introduced from an external source or, more commonly, taken from the pump discharge. The latter can be directed internally, or by way of an external circulation line that allows for the installation of a filter to remove particulates from the fluid before its introduction into the bearing area.

5.1.2.2 Close-coupled, in-line

Figure 5.1.2.2 — In this group, the pump and motor are mounted vertically. A single-stage overhung impeller is used in conjunction with a casing with in-line flange connections. Motor and bearings are cooled and lubricated by the process liquid.

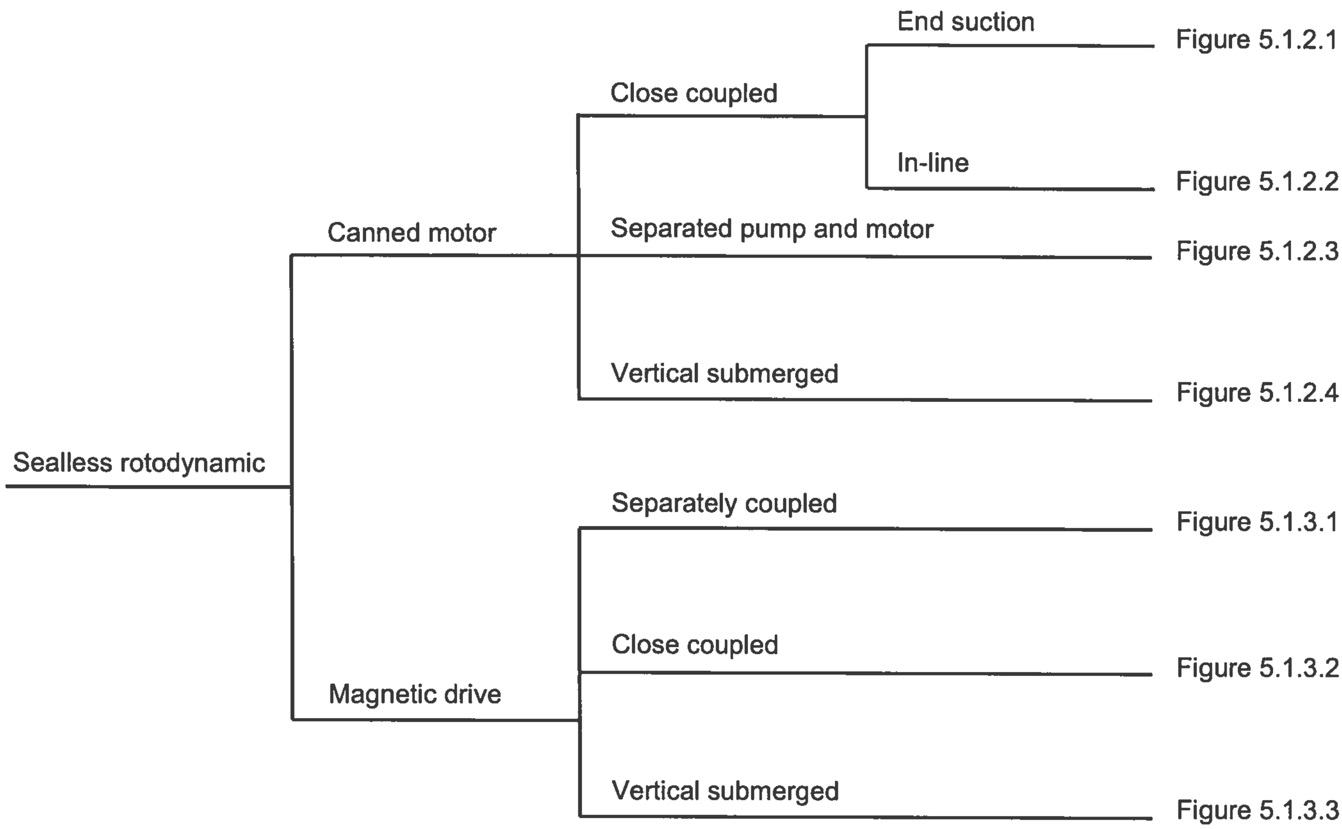


Figure 5.1.1.2 — Types of sealless rotodynamic pumps

5.1.2.3 Separated pump and motor

Figure 5.1.2.3 — This group has single or multistage overhung impellers; however, the pump and motor are separated by a thermal barrier, or air space. The impeller is mounted on the rotor assembly that is supported by bearings at each end. The rotor assembly contains an auxiliary impeller that circulates the process liquid in the motor section through a heat exchanger for control of the fluid temperature.

5.1.2.4 Vertical submerged canned motor pump

Figure 5.1.2.4 — This group of pumps is of the single-stage overhung impeller design that is suspended from a cover plate. The complete pump and motor is immersed in the process fluid. This method of installation provides sealless pump application inside a sealed vessel.

5.1.3 Magnetic drive pump (MDP)

5.1.3.1 Separately coupled

Figure 5.1.3.1 — This group of pumps is end suction, single-stage or multistage, overhung impeller design. The impeller is mounted on a rotor assembly that contains the inner magnet ring of a magnetic drive. The process fluid is retained by a containment shell that separates the inner magnet ring and the outer magnet ring.

The outer magnet ring is mounted on the shaft of a frame that is coupled to a motor or power device. All of the above is mounted on a common baseplate.

5.1.3.2 Close coupled

Figure 5.1.3.2 — This group of pumps is of the same construction as described in Section 5.1.3.1, except the outer magnet ring is mounted directly on the driver shaft.

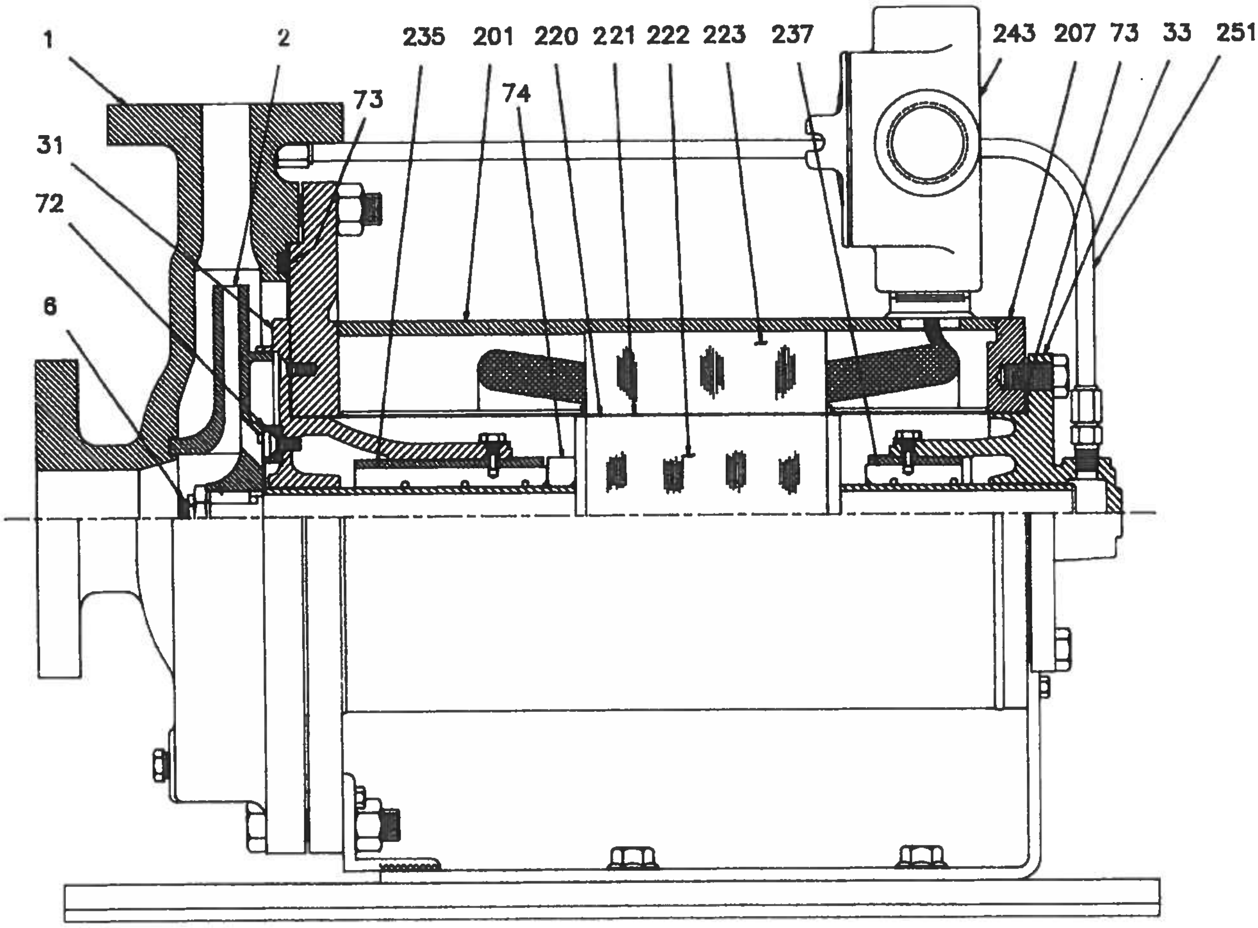
5.1.3.3 Vertical submerged

Figure 5.1.3.3 — In this group of pumps, the impeller is mounted on the end of a shaft that is overhung from its drive bearing supports. The drive section uses permanent magnets or an eddy current drive system to transmit power to the pump. This type of sealless pump uses a standard motor to drive the outer magnet ring, which in turn drives an inner magnet ring. A containment shell that contains the process fluid separates the magnet components.

The containment shell in the drive permits sealless pumping from a sealed vessel using a submersible pump.

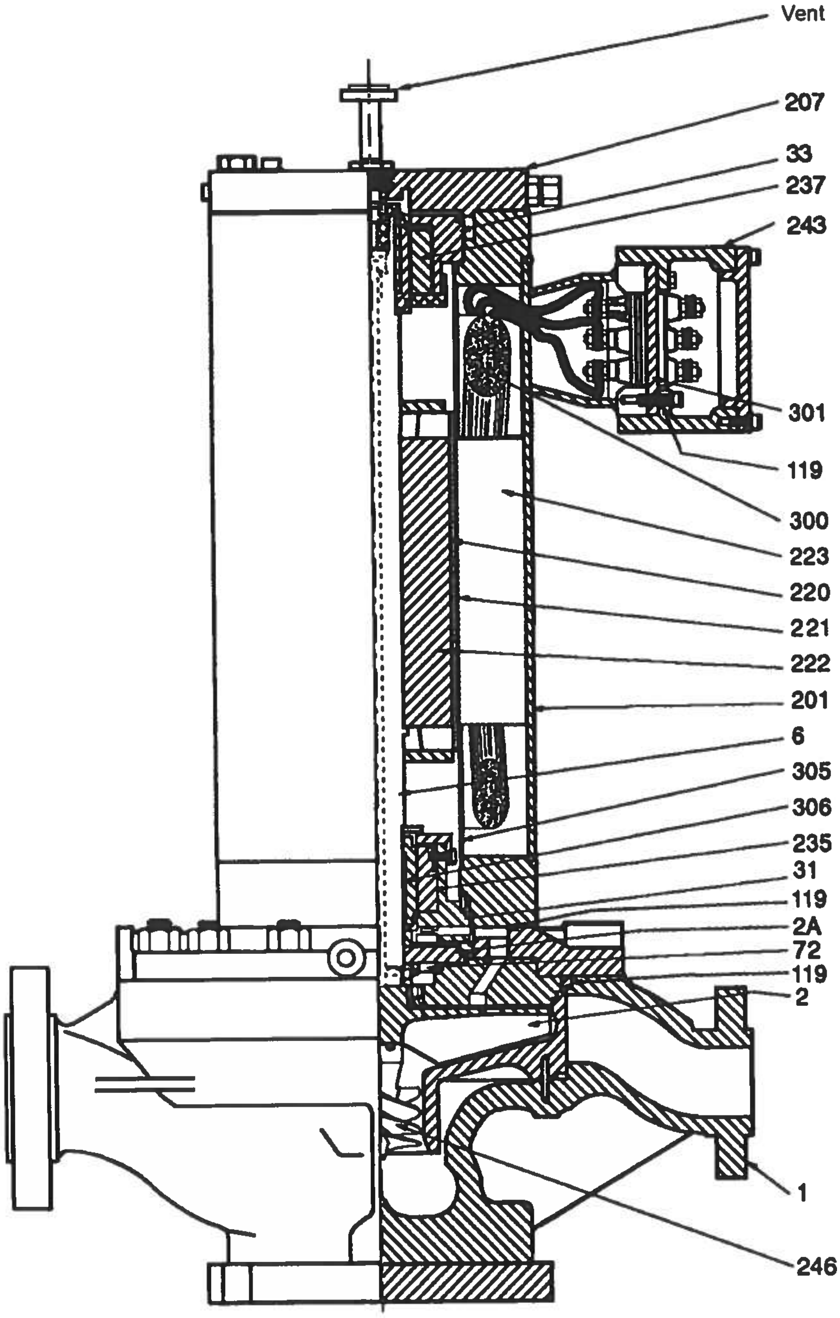
5.1.4 Sealless pump part names

Table 5.1.4 lists the names of most parts that go into the construction of sealless rotodynamic pumps. The reference numbers are the same as those shown in Figures 5.1.2.1 through 5.1.3.3.



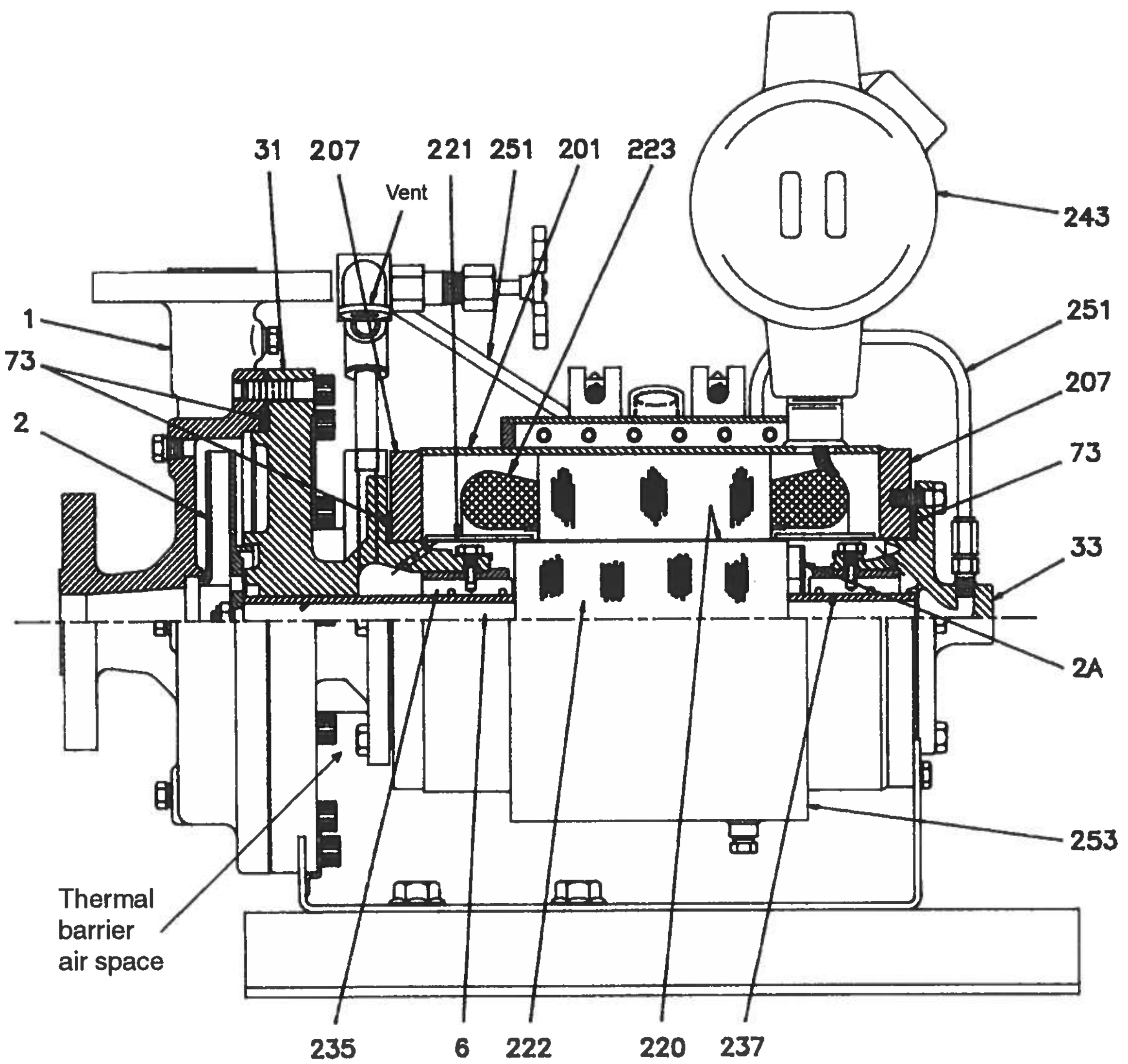
1	Casing	207	Cover, motor end
2	Impeller	220	Can, rotor
6	Shaft, pump	221	Liner, stator
31	Housing, bearing, inboard	222	Assembly, rotor
33	Housing, bearing, outboard	223	Assembly, stator
72	Bearing, axial thrust, inboard	235	Bushing, bearing, inboard
73	Gasket	237	Bushing, bearing, outboard
74	Collar, axial thrust, outboard	243	Box, electrical connection
201	Housing, stator	251	Tube, circulation

Figure 5.1.2.1 — Canned motor pump: close-coupled, end suction, overhung impeller



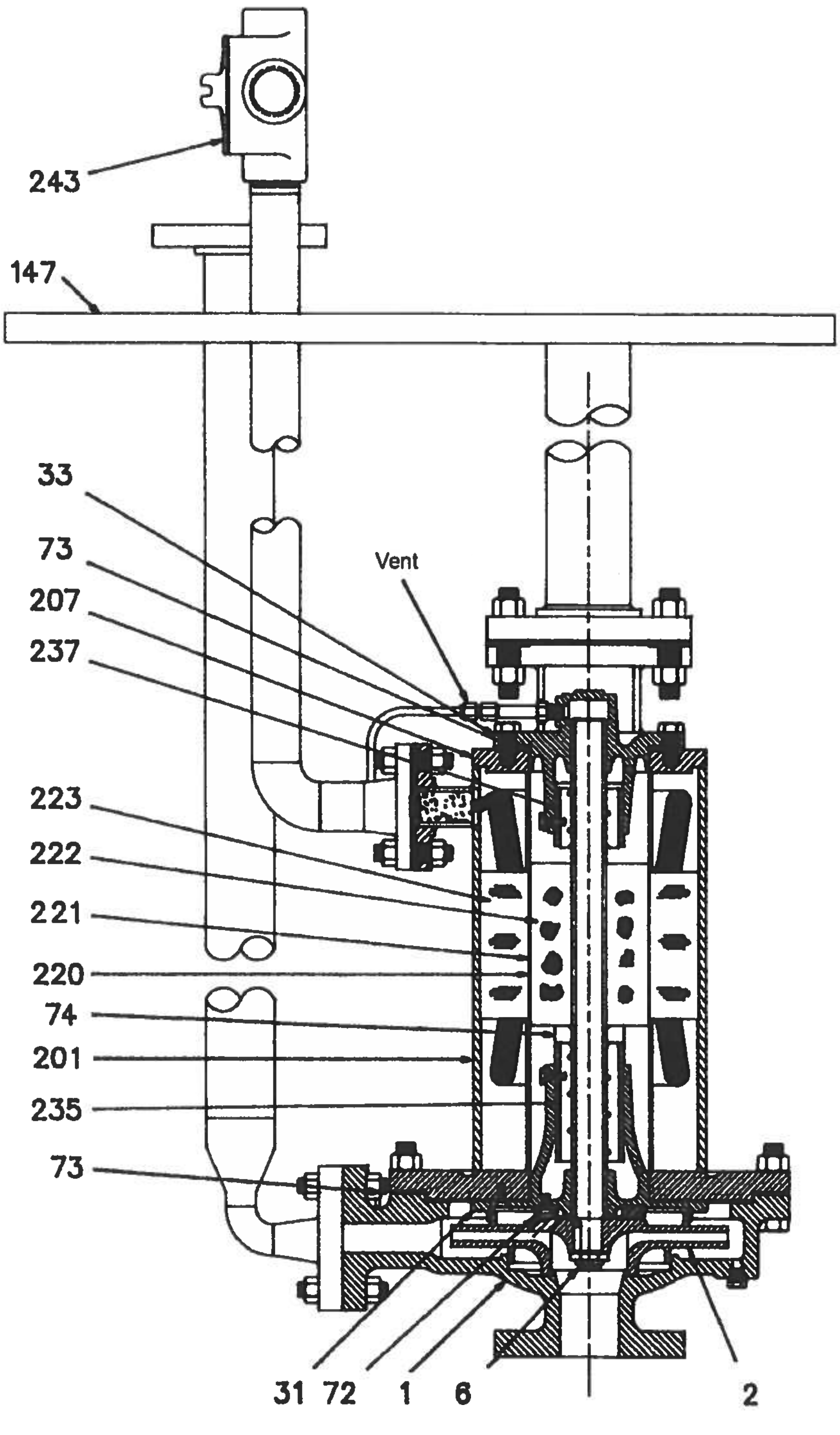
1	Casing
2	Impeller
2A	Impeller, auxiliary
6	Shaft, pump
31	Housing, bearing, inboard
33	Housing, bearing, outboard
72	Bearing, axial thrust, inboard
119	O-ring
201	Housing, stator
207	Cover, motor end
220	Can, rotor
221	Liner, stator
222	Assembly, rotor
223	Assembly, stator
235	Bushing, bearing, inboard
237	Bushing, bearing, outboard
243	Box, electrical connection
246	Inducer
300	Switch, thermal
301	Plate, terminal
305	Sleeve, backup
306	Sleeve, journal

Figure 5.1.2.2 — Canned motor pump: close-coupled, vertical in-line



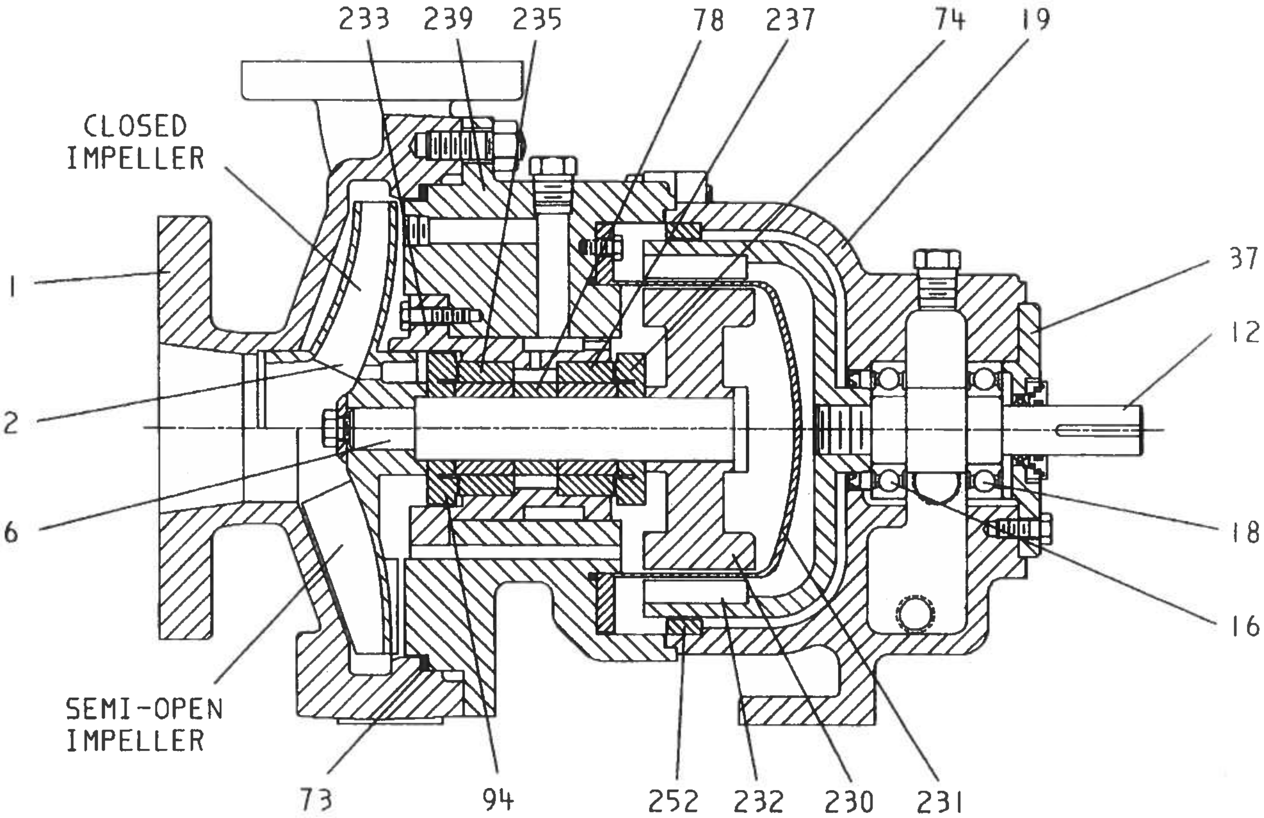
1	Casing	220	Can, rotor
2	Impeller	221	Liner, stator
2A	Impeller, auxiliary	222	Assembly, rotor
6	Shaft, pump	223	Assembly, stator
31	Housing, bearing, inboard	235	Bushing, bearing, inboard
33	Housing, bearing, outboard	237	Bushing, bearing, outboard
73	Gasket	243	Box, electrical connection
201	Housing, stator	251	Tube, circulation
207	Cover, motor end	253	Exchanger, heat

Figure 5.1.2.3 — Canned motor pump: motor and pump separated by thermal barrier



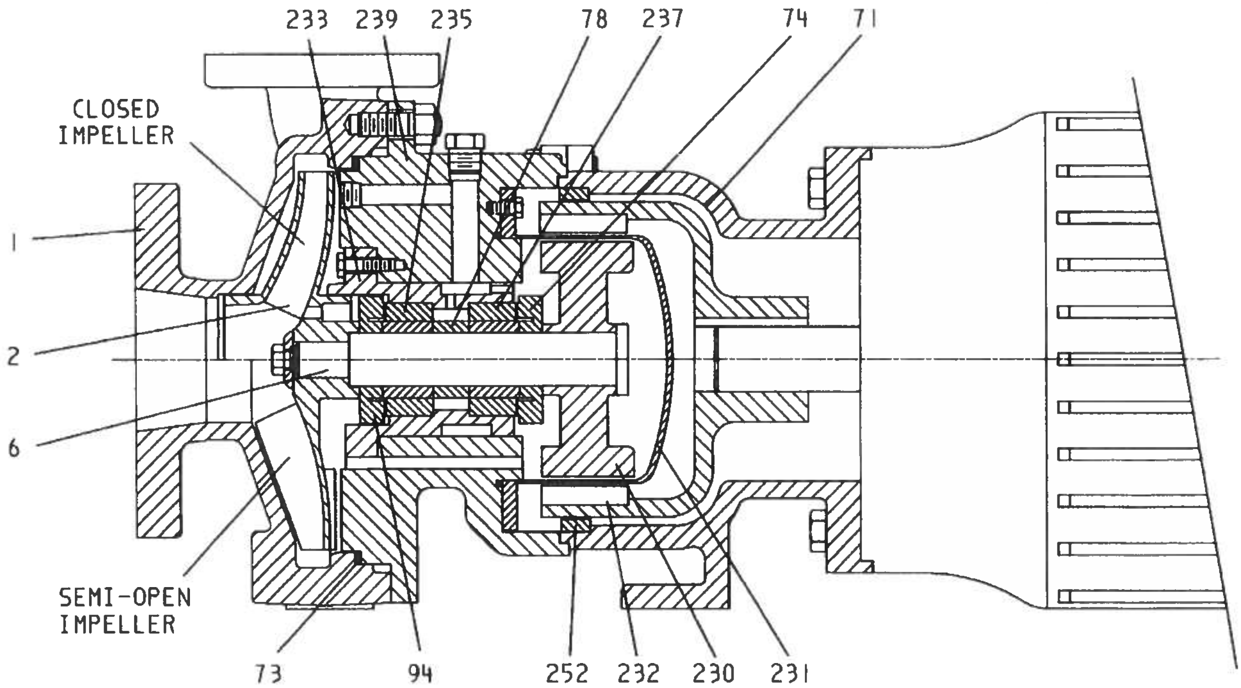
1 Casing
2 Impeller
6 Shaft, pump
31 Housing, bearing, inboard
33 Housing, bearing, outboard
72 Bearing, axial thrust, inboard
73 Gasket
74 Collar, axial thrust, outboard
147 Cover, tank or vessel
201 Housing, stator
207 Cover, motor end
220 Can, rotor
221 Liner, stator
222 Assembly, rotor
223 Assembly, stator
235 Bushing, bearing, inboard
237 Bushing, bearing, outboard
243 Box, electrical connection

Figure 5.1.2.4 — Canned motor pump: vertical – submerged



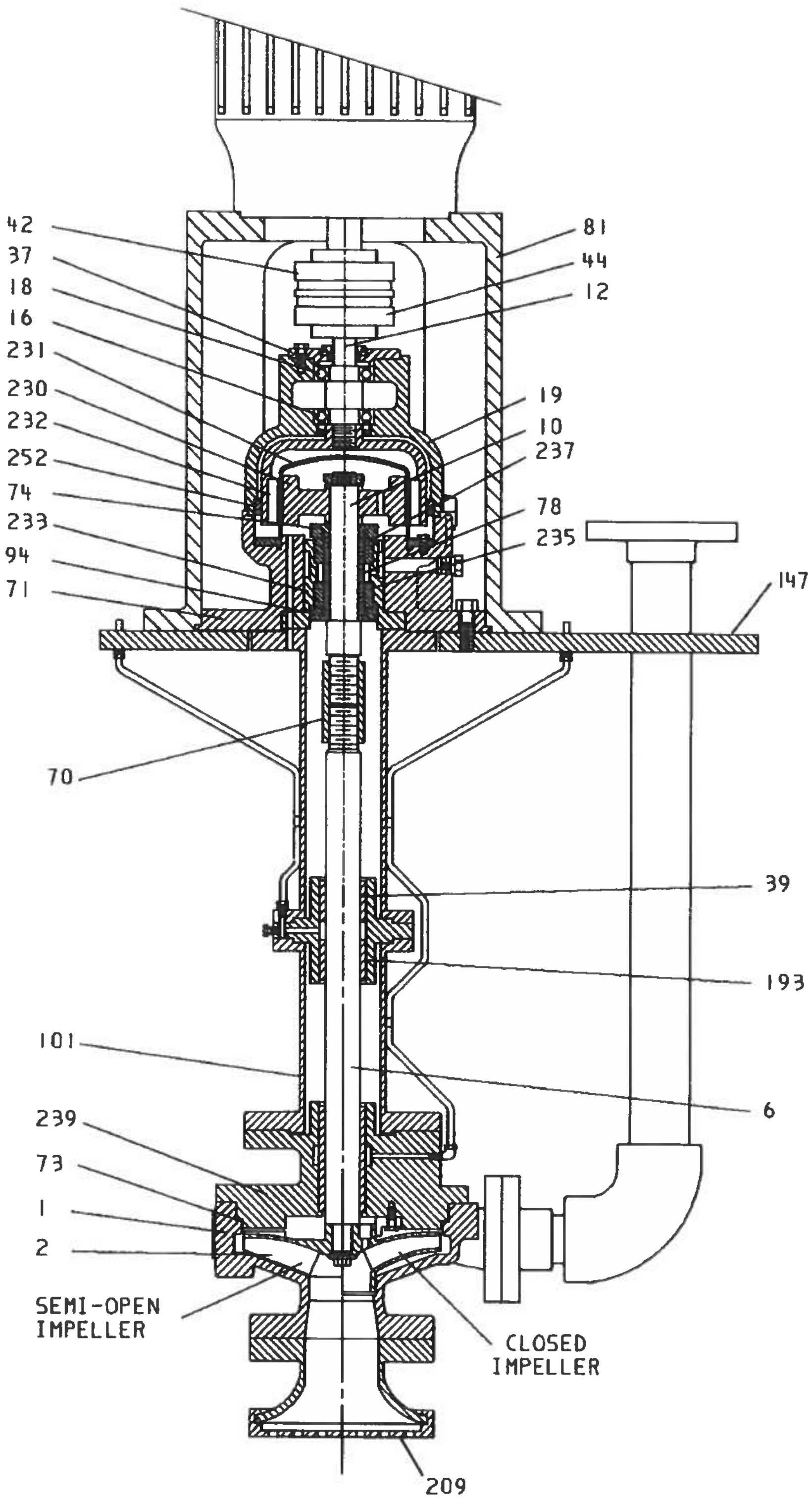
1	Casing	78	Spacer, bearing
2	Impeller	94	Collar, axial thrust, inboard
6	Shaft, pump	230	Magnet assembly, inner
12	Shaft, drive	231	Shell, containment
16	Bearing, inboard	232	Magnet assembly, outer
18	Bearing, outboard	233	Housing, bearing, bushing
19	Frame	235	Bushing, bearing, inboard
37	Cover, bearing, outboard	237	Bushing, bearing, outboard
73	Gasket	239	Cover, casing
74	Collar, axial thrust, outboard	252	Ring, rub

Figure 5.1.3.1 — Magnetic drive pump: separately coupled (closed or semi-open impeller)



1	Casing	230	Magnet assembly, inner
2	Impeller	231	Shell, containment
6	Shaft, pump	232	Magnet assembly, outer
71	Adapter	233	Housing, bearing, bushing
73	Gasket	235	Bushing, bearing, inboard
74	Collar, axial thrust, outboard	237	Bushing, bearing, outboard
78	Spacer, bearing	239	Cover, casing
94	Collar, axial thrust, inboard	252	Ring, rub

Figure 5.1.3.2 — Magnetic drive pump: close coupled (closed or semi-open impeller)



1	Casing
2	Impeller
6	Shaft, pump
10	Shaft, head
12	Shaft, drive
16	Bearing, inboard
18	Bearing, outboard
19	Frame
37	Cover, bearing, outboard
39	Bushing, bearing, intermediate
42	Coupling half, driver
44	Coupling half, pump
70	Coupling, shaft
71	Adapter
73	Gasket
74	Collar, axial thrust, outboard
78	Spacer, bearing
81	Pedestal, driver
94	Collar, axial thrust, inboard
101	Pipe, column
147	Cover, tank or vessel
193	Retainer, bearing
209	Strainer, suction
230	Magnet assembly, inner
231	Shell, containment
232	Magnet assembly, outer
233	Housing, bearing, bushing
235	Bushing, bearing, inboard
237	Bushing, bearing, outboard
239	Cover, casing
252	Ring, rub

Figure 5.1.3.3 — Magnetic drive pump: vertical submerged (closed or semi-open impeller)

Table 5.1.4 — Sealless pump parts names

Part name	Number	Definition
Adapter	71	A machined piece used to permit assembly of two other parts, or for a spacer, or for a heat barrier on a high-temperature sealless motor pump.
Assembly, rotor	222	The rotating assembly of an electrical machine containing laminations and conductors, that, when interacting with stator core assembly, produces torque.
Assembly, stator	223	The stationary portion of the electric machine containing laminations and conductors. Energizing these conductors creates an interaction with the rotor assembly, producing torque.
Bearing, axial thrust, inboard	72	Bearing that supports load parallel to the axis of revolution, which is lubricated by the pumpage.
Bearing, inboard	16	Rolling element bearing in the frame nearest the pump.
Bearing, outboard	18	Rolling element bearing closest to the motor.
Box, electrical connection	243	Electrical box in which the motor leads are joined with the power source.
Bushing, bearing, inboard	235	Sleeve type bearing in the drive section closest to the impeller, which is lubricated by the pumpage.
Bushing, bearing, intermediate	39	The removable portion of a sleeve bearing in contact with the journal.
Bushing, bearing, outboard	237	Same as 235 but farther from pump impeller.
Can, rotor	220	Liner that isolates rotor core from process fluid.
Casing	1	The portion of the pump that includes the impeller chamber and volute or diffuser.
Collar, axial thrust, inboard	94	A circular collar mounted on the shaft to absorb unbalanced axial thrust in the pump.
Collar, axial thrust, outboard	74	A circular collar mounted on a shaft to absorb the unbalanced axial thrust in the pump.
Coupling, shaft	70	A mechanism used to transmit power from the drive shaft to the pump shaft, or to connect two shafts.
Coupling half, driver	42	The coupling half mounted on the driver shaft.
Coupling half, pump	44	The coupling half mounted on the pump shaft.
Cover, bearing, outboard	37	An enclosing plate for either end of the outboard bearing of double suction or multistage pumps, or for the coupling end of the bearing of end suction pumps.

Table 5.1.4 — Sealless pump parts names (*continued*)

Part name	Number	Definition
Cover, casing	239	The portion of the pump that encloses the outboard side of the impeller. It may be integral with the containment shell, integral with the bearing holder, or a separate piece.
Cover, motor end	207	A piece that encloses the end(s) of a motor stator housing.
Cover, tank or vessel	147	A removable piece used to enclose a tank or vessel, and often used to support a pump and/or piping or electrical conduit.
Exchanger, heat	253	Additional member including heat exchanger tubing for control of process and motor temperature.
Frame	19	A member of a pump to which are assembled the rotating outer magnet ring and the drive motor or element.
Gasket	73	Resilient material of proper shape and characteristics for use in joint sealing between parts to prevent leakage.
Housing, bearing, bushing	233	A device in which the bearing is mounted.
Housing, bearing, inboard	31	A part in which the inboard bearing is mounted.
Housing, bearing, outboard	33	A part in which the outboard bearing is mounted.
Housing, stator	201	A housing in which a stator core assembly is mounted.
Impeller	2	The bladed member of a rotating assembly of the pump, which imparts the principal force to the liquid pumped.
Impeller, auxiliary	2A	An additional and typically different style impeller that is part of the rotating assembly of a pump, which helps reduce fluid flashing in the motor, produces additional head for a fractional portion of the pump main flow, creates an additional circulation path for a fractional portion of the pump main flow, or serves another special purpose in the pumping system.
Indicator, bearing wear	304	Mechanical or electrical device that indicates bearing wear.
Inducer	246	A high specific speed impeller installed in the front of the first-stage impeller of a rotodynamic pump to reduce NPSHR.
Liner, stator	221	A member that isolates the stator from the process fluid.
Magnet assembly, inner	230	The permanent magnet or induction device assembly attached to the pump shaft, located within the containment shell and driven by the outer magnet assembly.
Magnet assembly, outer	232	The permanent magnet assembly attached to the power drive shaft, located outside of the containment shell and driven by a driver.
O-ring	119	A radial or axial type seal.

Table 5.1.4 — Sealless pump parts names (*continued*)

Part name	Number	Definition
Pedestal, driver	81	A support for the driver of a vertical pump.
Pipe, column	101	A vertical pipe by which the pumping element is suspended.
Plate, terminal	301	An assembly that provides sealing of electrical feedthroughs as a part of the secondary containment system.
Retainer, bearing	193	A device used to support the lineshaft bearing.
Ring, rub	252	A replaceable ring mounted in or on the bearing housing and/or outer magnet assembly. It is used to prevent the outer carrier from hitting the containment shell if the antifriction bearings in the power end fail.
Shaft, drive	12	The cylindrical member that transmits power from the driver to the outer magnet assembly.
Shaft, head	10	The upper shaft in a vertical pump that transmits power from the driver to the drive shaft (sometimes referred to as *shaft, top*).
Shaft, pump/rotor assembly	6	The cylindrical member on which the impeller is mounted and through which power is transmitted to the impeller.
Shell, containment	231	The member that separates the inner and outer magnet assemblies. It also forms the barrier between the pumpage and the secondary containment.
Sleeve, backup	305	Sleeves used to provide structural support of the containment shell of a CMP.
Sleeve, journal	306	A removable sleeve that provides a rotating journal-bearing surface.
Spacer, bearing	78	A cylindrical piece that fits over the shaft to space or locate bearings.
Strainer, suction	209	A device used to prevent large objects from entering the pump.
Switch, thermal	300	Embedded in stator winding to sense motor temperature and actuate a control or signal when limits are reached.
Tube, circulation	251	A tube through which process fluid is piped from discharge of pump to outboard bearing housing for cooling of drive section.

5.2 Definitions

5.2.1 Scope

To develop the definitions and define construction for sealless pumps that are driven by canned motors or magnetic couplings.

5.2.1.1 Objective

To clearly outline the information necessary to define and describe the construction of sealless pumps.

5.2.1.2 Introduction

Sealless rotodynamic pumps are typically used when there is a need to contain toxic, dangerous, or valuable fluids, or where specific applications warrant their use. Application may be dictated by environmental, safety, noise, or space concerns.

The power to drive the rotating members is transmitted through a containment shell (liner, canister). Two methods are used: canned motor pumps (CMPs) and magnetic drive pumps (MDPs).

5.2.2 Sealless pumps — general

A pump design in which the impeller shaft is directly driven by either a canned induction motor or by a synchronous or an asynchronous magnetic drive. In all designs, a portion of the pumped liquid shall be in the drive section for lubrication and cooling. The design does not use a dynamic shaft seal as a primary containment device. Static seals are the method for containing the liquid.

5.2.2.1 Air gap

The radial distance between the ID of the outer magnet assembly and the OD of the containment shell.

5.2.2.2 Axial load

Net force parallel to the pump shaft caused by hydraulic forces acting on the impeller shrouds and rotor assembly.

5.2.2.3 Close coupled

A coupling arrangement in which the motor is supplied with a flange adaptor that mounts directly to the casing or body of the pump, eliminating the need for a flexible coupling. The outer magnet ring is mounted directly on the motor shaft.

5.2.2.4 Hydraulic axial thrust balance

A method to equalize axial thrust. The most common methods of equalizing axial loads are impeller design, impeller balance holes, or by balancing through variable orifices in the drive section.

5.2.2.5 Liquid end

Term used for overhung pumps to describe the wetted parts, specifically the casing, cover, stuffing box or seal chamber, impeller, and associated fasteners and gaskets.

5.2.2.6 Liquid gap

In MDP, the radial distance between the ID of the containment shell and the OD of the inner magnet assembly. In CMP, the radial distance between the ID of the containment shell and the OD of the rotor can.

5.2.2.7 Lubrication and cooling

Lubrication is a technique used to reduce wear of components in close proximity where at least one component has motion and load is exerted between the components. This is accomplished by supplying a lubricant between the components that support load between the two surfaces, and dissipates heat that is generated by friction.

Cooling is the transfer of energy from a higher temperature to a lower temperature.

Due to inherent eddy current losses in metallic containment shells and frictional heat generation from bearings, cooling and lubricant flow is necessary in the area between the inner magnet and containment shell in a magnetic drive, or between rotor and stator of a canned motor, for heat dissipation and lubrication of bearings.

Lubrication and cooling is provided by the pumped fluid or an external compatible flushing fluid. Loss of lubrication for any reason will result in premature pump failure.

5.2.2.8 Parasitic losses

Energy lost due to internal fluid friction from the rotation of the inner magnet assembly circulating the liquid within the containment shell of a magnetic drive, or losses due to the liquid circulating through the canned motor.

5.2.2.9 Power drive end

The end of the pump that provides the mechanical energy necessary for the operation of the hydraulic end.

5.2.2.10 Product-lubricated bearings

Sleeve/journal bearings and thrust bearings that operate in a pumpage-lubricated environment and support both the radial and axial loads.

5.2.2.10.1 Ceramic

A hard, generally chemically inert material used as a bearing or journal material for the shaft of a sealless pump.

5.2.2.10.2 Graphite

A composite of carbon graphite and filler material used for bearings of a sealless pump shaft.

5.2.2.10.3 Silicon carbide

A hard ceramic material capable of high unit loads (pressure velocity value) for the bearings, journals, and thrust bearings of a sealless pump shaft.

5.2.2.11 Radial load

Force perpendicular to the pump shaft created by hydraulic loading on the impeller, mechanical and magnetic rotor imbalance, and the weight of the rotor assembly.

5.2.2.12 Separately coupled

An arrangement in which the motor shaft is attached to the power frame of the MDP by means of a flexible or rigid coupling; thus the motor is mounted on the same base and must be aligned with pump driving components.

The outer magnet ring is mounted on a separate shaft and supported by rolling element bearings.

5.2.2.13 Strainer or filter

An internal or external device to remove or limit solids circulation within a drive section.

5.2.2.14 Temperature limits

The maximum and minimum allowable liquid temperatures in the hydraulic and drive sections for which it is rated.

5.2.2.15 Temperature rise in drive section

Temperature increase of the liquid circulated through the drive section for cooling and/or lubricating purposes. It is the difference between the temperature of the liquid leaving and entering the drive.

5.2.2.16 Torque

A turning force applied to a shaft tending to cause rotation.

5.2.2.17 Total gap

In MDP, the radial distance between the ID of the outer magnet assembly and the OD of the inner magnet assembly. In CMP, the total distance between the ID of the stator laminations and the OD of the rotor.

5.2.3 Canned motor pump (CMP)

A type of sealless pump that has a common shaft to link the pump and motor in a single sealed unit. The pumped liquid is circulated through the motor but is isolated from the motor components by a corrosion-resistant containment shell.

5.2.3.1 Eddy currents

Random electrical currents generated in a conductive material when strong magnetic fields are rotated around it.

5.2.3.2 Induction motor

An induction motor is an asynchronous machine composed of a magnetic circuit interlinked with two electrical circuits, or sets of circuits, rotating with respect to each other and in which power is transferred from one circuit to another by electromagnetic induction.

5.2.3.3 Locked rotor torque

The maximum torque that a motor will develop when prevented from turning when rated voltage and frequency is applied.

5.2.3.4 Motor insulation

A motor insulation system is an assembly of electrical insulating materials in association with the conductors, supporting structural parts, and the stationary winding.

5.2.3.5 Starting torque

The maximum net torque transmitted to the driven components during a hard (full voltage) start-up of the unit. It is affected by the inertia of the pump and motor rotors, the starting torque capacity of the motor, and the torque versus speed requirements of the liquid end.

5.2.4 Magnetic drive pump (MDP)

A type of sealless pump that uses an outer ring of permanent magnets or electromagnets to drive an internal rotating assembly consisting of an impeller, shaft, and inner drive member (torque ring or inner magnet ring) through a corrosion-resistant, nonmagnetic containment shell.

5.2.4.1 Alnico magnet

A permanent magnet made from aluminum, nickel, and cobalt. Usually considered the weakest of the practical magnets, but having the highest temperature limit.

5.2.4.2 Curie temperature

The transition temperature above which the magnetic material permanently loses its magnetic properties.

5.2.4.3 Decouple

Failure of a synchronous coupling to rotate synchronously.

5.2.4.4 Demagnetization

Loss of magnetic attraction due to excessive temperature or modification of the field.

5.2.4.5 Eddy current drive

A nonsynchronous magnetic coupling consisting of a permanent outer magnet ring and an inner torque ring. The rotating outer magnet ring generates eddy currents in the inner torque ring that convert it to an electromagnet. The electromagnet follows the rotating outer magnet ring but at a slightly slower speed due to slip.

5.2.4.6 Eddy current losses

Power loss due to random electrical current generated in a conductive material when a magnetic field is rotated around it. These currents are normally dissipated as heat due to the electrical resistance of the material.

5.2.4.7 Inner magnet assembly

Rows of permanent magnets securely fixed to a carrier, evenly spaced to provide a uniform magnetic field. It operates within the containment shell and is mounted on the same rotating element as the pump impeller. The outer magnet assembly, while rotating, transmits power through a containment shell, driving the inner magnet assembly.

5.2.4.8 Magnet

A material that contains a considerable amount of magnetism with minimal loss at ambient temperatures over a long period of time.

5.2.4.9 Magnetic coupling

A device that transmits torque through the use of magnet(s) attached to the drive and driven shafts.

5.2.4.10 Neodymium magnet

A rare earth magnet considered to have the greatest strength, depending on the material grade.

5.2.4.11 Outer magnet assembly

Rows of permanent magnets securely fixed to a carrier, evenly spaced to provide a uniform magnetic field. The outer magnet assembly, while rotating, transmits power through a containment shell, driving the inner magnet assembly.

5.2.4.12 Pole (N-S)

Magnets exhibit the ability to repel the like end of an identical magnet and attract the opposite end.

5.2.4.13 Rows of magnets

The circumferential arrangement of magnets in a drive assembly or in a conducting ring.

5.2.4.14 Samarium cobalt magnet

A rare earth magnet of considerable strength, however, rated for higher temperature applications than neodymium.

5.2.4.15 Slip

The speed differential between the torque ring and outer magnet ring in an eddy current drive pump.

5.2.5 Containment

5.2.5.1 Bolt-proof load

The load at which the bolt begins to yield (approximately 80% of the tensile yield strength of specific material).

5.2.5.2 Containment shell

The shell or "can" that separates the inner and outer magnet assemblies (MDP) or the liner that protects the basic motor components (CMP). It forms the primary barrier between the pumped fluid and the environment. Materials may be metallic or nonmetallic.

5.2.5.3 Driven component liner

Protective covering of the rotor armature or the inner magnet assembly to prevent corrosive attack on the basic components.

5.2.5.4 Maximum working pressure

The maximum working pressure is the highest pressure at the specified pumping temperature for which the pump is designed.

5.2.5.5 Secondary containment

A backup pressure-containing system including housing, shaft, sealing, electrical feedthroughs, and any other components necessary to contain leakage in the event of failure of the primary containment shell.

5.2.5.6 Suction pressure

External system liquid pressure acting on the pump at the inlet.

5.2.6 Monitoring equipment

Devices or instruments that indicate the condition in the sealless pump to preclude misoperation or damage to the unit. These devices may be internal or external, depending on the type of monitoring device and the application.

5.3 Design and application

5.3.1 Scope

The design portion of this standard provides minimum requirements for sealless rotodynamic pumps of the canned motor and magnetic drive types. Also included are guidelines for application of sealless rotodynamic pumps considering safety, emissions, and reliability.

The pumping portion of sealless rotodynamic pumps is similar to units having shaft seals. ANSI/HI 1.1–1.2 *Rotodynamic (Centrifugal) Pumps for Nomenclature and Definitions* and ANSI/HI 1.3 *Rotodynamic (Centrifugal) Pumps for Design and Application* provide definitions and application data for all rotodynamic pumps that are applicable to sealless pumps. There are differences, however, in design and application considerations that concern the drive portion of sealless pumps. This section concentrates on design and application considerations that are unique to sealless pumps and presumes that background knowledge exists relative to the more general subject of rotodynamic pumps. Even though the pumps described by this section are sealless, leakage could occur as a result of certain types of wear, misoperation, or misapplication.

5.3.1.1 Introduction

Sealless rotodynamic pumps are normally used when there is a need to contain toxic, dangerous, or valuable liquids or where specific applications warrant their use. Application may be dictated by environmental, safety, noise, or space concerns.

For either the magnetic drive or canned motor type sealless pump, the driven shaft is completely contained in a pressurized vessel containing the pumped liquid. Impeller shaft loads are supported by product or external flush liquid-lubricated bearings. This arrangement minimizes chances for leakage, because there is no shaft penetration of the pressure containment boundary.

5.3.1.2 Alternative designs

Designs not included in this standard may be considered, provided they meet the intent and cover construction features of this standard. Deviations from this standard should be described by the manufacturer for the purchaser's review. It is also important for both the purchaser and manufacturer to note that the terms *canned motor* and *magnetic drive* only describe general types of equipment. Proper selection and application requires detailed understanding of the specific design being considered to ensure that safety and reliability can be achieved.

5.3.1.3 Definition of terms

Terms used in this portion of the standard are defined in Section 5.2.

5.3.1.4 Special considerations for sealless pumps

Shaft seals are a principal source of leakage in conventional rotodynamic pumps. Sealless pumps avoid use of shaft seals for primary containment. The impeller shaft is driven through a liquid containment barrier either by a rotating electromagnetic field, in the case of a canned motor pump, or mechanical rotation of an outer magnetic field, in the case of a magnetically driven pump. Both types have a common need for removal of heat generated by the drive section energy losses and for providing the proper environment for satisfactory liquid film-lubricated bearing life.

Attention shall be given to selecting designs, including circulation plans, which meet these needs for specific applications. Also, for most designs, it is necessary to avoid zero flow and dry-running operation. These considerations are discussed in more detail in the design and application sections of this standard.

5.3.2 Basic design

5.3.2.1 General

5.3.2.1.1 The pumps covered by this standard shall be designed for a minimum of three years mean time between repair (work requiring pump shut-down that is done to prevent the deterioration of, restore, or maintain pump performance), with proper application. No warranty shall be implied by this design objective.

5.3.2.1.2 The pump manufacturer shall assume responsibility for the engineering coordination of the pump and all auxiliaries included in the scope of the purchase order. In cases where the pump manufacturer supplies equipment manufactured by others, the pump manufacturer shall determine whether or not the application of these items is compatible with each other and with the manufactured equipment.

5.3.2.1.3 The purchaser shall supply data on net positive suction head available (NPSHA), vapor pressure, specific heat, viscosity, density, and temperature of the pumped liquid for the intended operating range. For volatile fluids, ranges of rate of flow, total head, suction pressure, and vapor pressures at temperatures beyond the operating temperatures and other appropriate application data shall be provided for the analysis of temperature rise through the pump. The manufacturer shall specify on the data sheets the net positive suction head required (NPSHR) based on ANSI/HI 14.6 *Rotodynamic Pumps for Hydraulic Performance Acceptance Tests.* Additional NPSH may be required compared to NPSHR on water when pumps are used for more volatile liquids, depending on the type of circulation plan used for a specific application. See circulation plans in Figure 5.3.2.12.1. The purchaser shall also supply specific heat, viscosity, and vapor pressure information for external flush liquid when used.

5.3.2.1.4 Pumps that handle liquids more viscous and different in density than water shall have their performance corrected in accordance with ANSI/HI 9.6.7 *Effects of Liquid Viscosity on Rotodynamic (Centrifugal and Vertical) Pump Performance.* Additional corrections may be necessary for viscosity effects on the motor or magnetic coupling, and, if so, the manufacturer shall provide details for these corrections.

5.3.2.1.5 Motors, electrical components, and electrical installations shall be suitable for the area electrical classification (class, group, and division), as well as local codes specified by the purchaser. Although codes do not specify requirements for magnetic coupling type units, caution should be used because high temperatures may be produced during certain abnormal operating conditions, such as dry-running and magnetic decoupling.

5.3.2.2 Liquid containment shells

5.3.2.2.1 The primary design consideration for sealless pumps is to prevent leakage to the atmosphere. Because the primary containment shell may develop leakage as a result of wear by adjacent rotating parts, corrosion, or abrasion, secondary leakage containment may be required if specified by the purchaser. The method of providing secondary leakage containment is different for CMP and MDP. With the CMP, the motor housing and electrical lead sealing shall provide secondary containment. With the MDP, secondary containment shall be provided either by a double-walled containment shell or by the outer housing and appropriate sealing of input shaft. For either type, emphasis shall be on prevention of leakage to the atmosphere in the event of primary containment shell failure.

5.3.2.2.2 When primary or secondary containment shells are metallic, they shall be designed for the maximum allowable working pressure within stress values for the materials in Section VIII of the ASME *Boiler and Pressure Vessel Code.* The manufacturer shall indicate whether Division 1 or Division 2 was used.

The manufacturer shall substantiate design and test capability for nonmetallic primary or secondary containment shells. There shall be a minimum ratio between bursting pressure and design pressure of 2:1 for the pressure/temperature range.

5.3.2.2.3 For CMP, if specified by the purchaser, secondary containment shell and electrical feedthroughs are to be designed to contain allowable working pressure for a minimum of 48 hours in the event of primary shell leakage and shall have a minimum standby life of three years. If an oil-filled stator with pressure relief valve is used, then provision shall be made for safe containment of any leakage past the primary containment shell. A means for checking secondary containment periodically shall be provided by the manufacturer when specified by the purchaser.

The purchaser shall be responsible for providing shut-down devices and procedures required for safety.

⚠ **CAUTION: The electrical leads from the motor stator shall be sealed between the terminal box and the stator electrical core. However, in the possible event of the combined failure of these seals and rupture of the stator liner, it is possible that the process liquid being pumped can migrate into the atmospheric side of the terminal box. For this reason it is recommended that electrical conduit lead seals shall be used to provide further seal redundancy against process liquid migration, or that the atmospheric side of the terminal box shall be vented to a suitable safe location. Additionally, caution should be exercised when opening the terminal box in light of this possibility.**

5.3.2.2.4 For MDP, secondary containment shall be designed to contain leakage for a minimum of 48 hours in the event of primary shell leakage and shall have a minimum standby life of at least three years. A means for periodically checking function of secondary containment shall be provided when specified by the purchaser. The purchaser shall be responsible for providing shut-down devices and procedures required for safety.

5.3.2.2.5 Induced eddy currents in metallic containment shells create heat in proportion to the thickness and the electrical properties of material used. These thermal changes shall be allowed for in clearances between rotating and stationary parts and in the sizing of magnets to ensure required torque transmission. Cooling shall be required to control temperature and to avoid flashing or solids formation.

5.3.2.2.6 Primary and secondary containment shells, static seals, and mechanical seals used for secondary containment shaft sealing shall have design pressure ratings equal to, or greater than, the maximum working pressure of the pump at rated conditions. See Section 5.2.5.5.

5.3.2.3 Gaskets and joint bolting

5.3.2.3.1 All assembly gaskets shall be confined on the atmospheric side to prevent blowout. Design shall consider thermal cycling that may occur as a condition of service.

5.3.2.3.2 The pressure containment fastener load shall not exceed bolt-proof load at 1.5 times the rated working pressure, considering all loading conditions.

5.3.2.4 Casing

5.3.2.4.1 Suction and discharge flanges shall have equal ratings and shall comply with ANSI B16.5.

5.3.2.4.2 Casings shall withstand hydrostatic test pressure without permanent distortion. See ANSI/HI 14.6 *Rotodynamic Pumps for Hydraulic Performance Acceptance Tests*. The corrosion allowance shall be agreed on between purchaser and manufacturer by consideration of corrosion rates for liquids and materials involved.

5.3.2.4.3 Vent and drain bosses shall be sized for a minimum of 9.5-mm (0.375-in) diameter pipe, 12-mm (0.5-in) preferred.

5.3.2.4.4 Hydrostatic testing shall be done on each casing after completion of welding of any auxiliary piping.

5.3.2.4.5 For MDP, centerline-supported casing shall be used for horizontal magnetic drive pumps that use flexible coupling when pumped fluid liquid temperature exceeds 315 °C (600 °F) for nonpetroleum services, or 177 °C (350 °F) for petroleum services.

5.3.2.4.6 Centerline support of CMP or close-coupled MDP is not required; because flexible couplings are not used, there is no concern with driver alignment.

5.3.2.5 Venting and draining

5.3.2.5.1 The entire unit, including casing, drive section, and manufacturer-supplied piping shall be self-venting or furnished with vent connections.

5.3.2.5.2 All pumped liquid-containing areas, including vendor-supplied piping, shall be drainable to a residual of a maximum 30 mL (1.8 in^3) and shall be suitable for flushing before disassembly.

5.3.2.6 Internal bearings

5.3.2.6.1 Impeller shaft-supporting bearings are usually lubricated and cooled by process or separate flush liquid for both CMP and MDP and are typically of the liquid-lubricated type. For satisfactory life, control of environment of bearings by proper design and application is essential to prevent flashing and air or vapor collection and to avoid solids.

5.3.2.6.2 Pressure and temperature at bearings shall be maintained to prevent flashing of lubricating liquid at maximum operating conditions. Consideration shall be given to minimum operating flow, minimum NPSHA, and temperature rise through drive section.

5.3.2.6.3 When conditions of service require filtration of bearing lubricating liquid, a self-cleaning internal design may be used. If external filtration is required, the filter system should allow for indicating when filter change is required. Loss of flow to drive section shall be avoided.

5.3.2.6.4 Bearings are to be designed and applied considering fluid characteristics, unit loading, corrosion, erosion, wear, heat transfer, fits, and friction characteristics.

5.3.2.6.5 Bearing loading, alignment, shaft deflection, surface finish, and wear-in characteristics of bearing materials shall be taken into account to prevent local surface failure.

5.3.2.6.6 Materials used for journal sleeves, thrust collars, and bearings often have significantly different thermal expansion characteristics than shafts and other mating parts. Application guidelines and limits shall be established by the manufacturer for specific designs to avoid breakage or looseness under specified operating temperatures.

5.3.2.6.7 Active magnetic bearing systems are being developed by several organizations for use in sealless pumps. These systems maintain the rotor in a levitated state, so that no contact is made between rotating and stationary parts.

The design of a sealless pump with magnetic bearings shall also provide for an auxiliary bearing system to support the rotor when the active bearing system is de-energized, and for start-up and shut-down. The number of uncontrolled rundowns allowed before inspection of auxiliary bearings shall be specified by the manufacturer. Sensors used for positioning of bearings and the bearing components shall be protected from contact by the process liquid and shall not compromise pressure containment integrity.

Bearings shall be selected to have a load capacity higher than static and dynamic loads under the most adverse operating conditions. Active magnetic bearings have a lower inherent transient overload capacity than hydrodynamic bearings, so attention shall be given to determine loads that will result from anticipated operating conditions.

Cooling shall be required to remove heat from electrical losses in windings and heat generated by windage losses.

5.3.2.7 External bearings (MDP)

5.3.2.7.1 Two rolling contact bearings shall be selected to support the imposed radial and axial loads on the outer magnet assembly for 24,000 hours L-10 life based on the largest outer magnet assembly that can be put on the drive frame. See AFBMA-9 and -11.

The frame with outer bracket design shall be designed to allow withdrawal from the pump as a subassembly without need to break the fluid containment boundary.

5.3.2.7.2 A replaceable rub ring of a nonsparking material to delay wear of the containment shell by the outer magnet ring, in the event of rolling contact bearing failure, shall be provided. Atmospheric corrosive conditions shall be considered in the selection of materials.

5.3.2.7.3 Bearing lubrication can be grease, oil splash, or oil mist. Oil splash lubricated, nonpressure fed bearings shall have vent and drain openings and an oil level indicator, or a constant level oiler. When oil mist is used, provision shall be made to prevent oil from entering the magnetic drive section.

5.3.2.7.4 Close-clearance rotating labyrinth seals, lip seals, or face seals on the outboard of each bearing shall be used to provide bearing protection from the environment.

5.3.2.8 Integral motors (CMP)

5.3.2.8.1 Canned motors are normally cooled by circulation of pumped liquid or by use of external coolant fluid to remove heat generated by containment shell eddy current losses, rotor windage loss, and motor electrical losses. Stator winding temperatures shall be maintained at, or below, values established for the grade of insulation used.

5.3.2.8.2 Thermal protection indication shall be provided, and the manufacturer shall also provide the value of the temperature setting.

5.3.2.8.3 When explosion-proof units are required, the manufacturer and purchaser shall select the approved design that meets temperature, pressure, and appropriate division, group, and class requirements. Information on external motor temperatures for specified operating conditions shall be provided by the manufacturer upon request.

5.3.2.8.4 The manufacturer shall specify external cooling requirements when required.

5.3.2.8.5 Material used for parts that will come into contact with pumped liquid in the event of failure of the primary containment shell or rotor liner shall be identified when requested by the purchaser.

5.3.2.9 Magnetic couplings (MDP)

5.3.2.9.1 Magnetic couplings are defined in Sections 5.2.4.5, 5.2.4.7, 5.2.4.9, and 5.2.4.11.

5.3.2.9.2 Permanent magnets have high attraction forces to ferrous metals and high attraction or repulsion forces to companion magnets, depending on polar position. Extreme care shall be exercised when disassembling or assembling the drive unit to prevent damage to components and injury to personnel. Methods of piloting and separating flanges shall be provided in the design to allow for safe disassembly and reassembly of magnet drive section.

5.3.2.9.3 Allowance for torque required to accelerate impeller rotor assembly, considering acceleration rate of drive motor, shall be made by the manufacturer. Allowance shall also be made for maximum specified specific gravity, viscosity, temperature, and flow. Deterioration of magnetic strength shall also be considered. Application guidelines for specific designs considering these factors shall be established by the manufacturer.

5.3.2.9.4 Heat generated by eddy current losses and windage losses shall be removed by pumped liquid or by supply of external cooling liquid. Torque capacity is dependent on the coupling mechanical design, temperature, and magnet material used. Magnetic material temperature shall be maintained at or below rated values for the material used.

5.3.2.9.5 Loss of cooling flow or decoupling will result in very rapid heating of the metallic containment shell. When the pump rotor becomes decoupled, continued turning of the outer magnet assembly will cause rapid heating of the inner magnet assembly. Even though explosion-proof rating of magnetic couplings is not normally required, precautions shall be taken if potentially flammable vapors are present that might contact the containment shell. See Section 5.4.3.2 Decoupling (MDP).

5.3.2.9.6 Handling of liquids containing magnetically attracted particles shall be avoided unless particles can be effectively removed by a magnetic filter, since such particles are collected by the permanent magnetic fields and can cause erosion and blockage of liquid flow passages.

5.3.2.9.7 Materials used for parts that come into contact with pumped liquid in the event of failure of the primary containment shell or inner magnet liner shall be identified by the manufacturer.

5.3.2.9.8 The outer magnet carrier (the outer steel portion of the outer magnet assembly) shall be coated with a corrosion/heat-resistant paint or coating, with the exception of any close-clearance register fits. If the outer magnets are neodymium, they shall also be coated or painted to prevent corrosion. The outer magnet assembly shall be designed to be easily cleaned of stray ferrous particles during assembly.

5.3.2.10 Dynamic balance

5.3.2.10.1 Impeller, inner and outer rotating assemblies, or components shall be balanced to a minimum ISO 1940, Grade G 6.3. Refer to ANSI/HI 9.6.4 *Rotodynamic Pumps for Vibration Measurements and Allowable Values.*

5.3.2.11 Materials

5.3.2.11.1 Careful consideration of corrosion is important. The manufacturer should offer guidance to the purchaser regarding selection of materials particular to the design involved (such as containment shell and rotor encapsulation members).

5.3.2.11.2 The purchaser shall specify any corrosive chemicals that need specific consideration for the particular design or application involved. Included should be compounds that may cause stress corrosion cracking or hydrogen embrittlement.

5.3.2.11.3 If austenitic stainless-steel parts exposed to conditions that promote intergranular corrosion are to be fabricated by welding, then they shall be made of low carbon or stabilized grades.

5.3.2.11.4 Minor wetted parts that are not usually identified, such as nuts, bolts, springs, washers, and keys, shall have corrosion resistance at least equal to that of major parts.

5.3.2.11.5 When requested, the manufacturer shall supply chemical and physical certifications for pressure-containing parts, impeller, and shaft.

5.3.2.11.6 No repair by plugging, peening, or impregnation shall be allowed on any pressure-containing, wetted metal parts.

Welding of piping, pressure-containing parts, or wetted parts, and any weld repairs, shall be performed by operators and procedures qualified in accordance with Section VIII, Division 1, and Section IX of the ASME *Boiler and Pressure Vessel Code.*

Weld repairs shall be inspected to the same level of quality used for inspection of castings.

5.3.2.12 Circulation plans

5.3.2.12.1 General

For satisfactory life it is necessary to control the temperature of motor windings or magnetic drive components through design of the unit, selection of circulation plans, and applications attention to control bearing environment. Typical circulation plans are shown in Figure 5.3.2.12.1. Based on the application data supplied by the purchaser, and design of that equipment, the manufacturer shall recommend the most suitable circulation plan.

5.3.2.12.2 A combination of factors shall be controlled and selected to provide:

a) Clean liquid (not vapor) for internal bearing lubrication and cooling over the intended pump operating range and conditions.

b) The temperature of magnetic coupling or motor winding components that is within proper application range for materials selected.

5.3.2.12.3 It shall be necessary through design, application, and circulation plan selection for sealless pumps to avoid the items listed below.

- Dry-running (unless a separate external flush liquid is provided in the drive section)
- Flashing in drive section
- Excessive temperature rise in drive section
- Collection of air or gas at bearings
- Formation of precipitants or polymerization in the drive section
- Wear of bearings by abrasive particles
- Wear of containment shell or clogging by magnetically attracted particles when using permanent magnet (synchronous) designs
- Insufficient cooling flow with high-viscosity liquids
- Insufficient or excessive viscosity
- Excessive thrust load caused by cavitation or operation outside intended flow range
- Clogging of lube, cooling passages, or strainers

5.3.2.13 External couplings and guards (MDP)

5.3.2.13.1 Removable coupling guards shall be furnished and shall be in accordance with ANSI B15.1.

5.3.2.13.2 When a spacer coupling is used, the spacer shall be of sufficient length to allow removal of the outer magnetic coupling without disturbing the containment shell.

5.3.2.14 Mounting of pumps

5.3.2.14.1 Horizontal mounting base (CMP)

Refer to installation and operation section.

5.3.2.14.1.1 Vertical mounting

For reasons of space, piping, or system configuration, the pump may be mounted vertically (casing up or casing down). Sufficient support shall be provided to minimize piping loads. Hydraulic thrust balance shall be provided to compensate for weight of the rotating element. Provision shall also be made for safe venting.

5.3.2.14.1.2 Submerged mounting (CMP)

CMPs may be suspended from a cover plate for complete immersion in a vessel or sump. Mounting may be horizontal or vertical, depending on vessel size and available opening for pump insertion and removal.

Material of construction for pump and motor externals, piping, and support extensions shall be compatible with the liquid in the sump.

The application of CMP as submerged units should follow the parameters outlined in Hydraulic Institute Standards for submerged pumps.

5.3.2.14.2 Mounting base (MDP)

5.3.2.14.2.1 For close-coupled configurations (magnetic drive housing mounted to motor flange), a rigid mounting base is not required, because piping strains do not affect shaft alignment. Allowable flange loading shall be specified by the manufacturer but is not related to coupling deflection.

5.3.2.14.2.2 For magnetic drive designs using flexible shaft couplings, the baseplate design shall be suitable for grouting to a rigid foundation if necessary to handle rated flange loading with acceptable misalignment at the flexible coupling. Allowable flange loading to avoid malfunction of internal components shall be specified by the manufacturer.

Mounting pads or contact surfaces of the baseplate shall be provided for pump and drive train components, shall be flat and parallel, and should be larger than the feet of the mounted equipment.

Pads or contact surfaces for drive train components shall allow for installation of shims at least 3 mm (0.125 in) thick under the driver. A set of stainless-steel shims at least 3 mm (0.125 in) thick shall be furnished.

The pump and its baseplate shall be constructed with sufficient structural stiffness, when properly grouted, to limit the displacement of the drive end of the pump shaft to 0.25 mm (0.010 in) using the most severe combination of forces and moments for which the manufacturer rates the product. Refer to Section 5.4.

When epoxy grout is specified on the data sheet, the manufacturer shall precoat all surfaces of the baseplate that will be in contact with the grout with a catalyzed epoxy primer, applied according to the paint manufacturer's recommendations.

Anchor bolts shall be furnished by the purchaser.

5.3.2.14.2.3 A magnetic drive may be used for a vertical submerged pump. Design and application requirements of this standard shall apply. Particular attention shall be given to venting the containment shell.

5.3.2.15 Auxiliary piping

5.3.2.15.1 Auxiliary piping handling process or external flush liquid shall be of materials having corrosion properties that are equal to or better than casing material.

5.3.2.15.2 The manufacturer shall supply all piping, tubing, and fittings associated with closed systems for bearing lubrication, cooling, and axial balance. Systems with external connections shall have terminal points identified and dimensionally located on drawings or in manuals.

5.3.2.15.3 Threaded connections handling process or external flush liquid shall not be used when thermal cyclic variations during operation exceed 38 °C (100 °F) (not considering startup).

5.3.2.15.4 Design of auxiliary piping shall include:

- Adequate support and protection to prevent damage from vibration or shipment
- Adequate space for normal maintenance and installation
- Elimination of air pockets at high points
- Provision for drainage without disassembly of piping to not more than 30 mL (1.8 in^3) residual, or to a value agreed on by the manufacturer and purchaser

5.3.2.15.5 Seal welding of threaded connections may be done with proper preparation and if exposed threads are covered by weld metal and if agreed to by the purchaser and the manufacturer.

5.3.2.16 Instrumentation options

5.3.2.16.1 Internal flow is critical for maintaining proper bearing environment and proper temperature of motor windings or magnet assemblies. Instrumentation and controls to detect loss of flow through the drive unit may be desirable. Refer to ANSI/HI 9.6.5 *Rotodynamic (Centrifugal and Vertical) Pumps for Condition Monitoring*.

5.3.2.16.2 Optional auxiliary devices for detection of axial and radial bearing wear prior to contact between rotating element and stationary pressure-containing parts may be desirable.

5.3.2.16.3 Some types of equipment distress and wear can be detected by vibration analysis. Use of appropriate sensors may be desirable.

5.3.2.16.4 Sensing of motor current or power can detect high flow or no flow, decoupling, binding of shaft, and rubs of rotating parts. Use of current or power sensors may be desirable.

5.3.2.16.5 Provision for detecting leakage into the stator enclosure of canned motor pumps or the outer housing of magnetically coupled pumps may be desirable.

5.3.2.16.6 A device for detecting temperature of the metallic containment shell of magnetically coupled units may be desirable.

5.3.2.16.7 Provisions for measuring liquid pressure and temperature as close as practical to the highest temperature point within drive circulation path may be desirable.

5.3.2.16.8 Provisions for determining direction of rotation under power may be desirable.

5.3.3 Guidelines for applications

5.3.3.1 General

Understanding the differences between sealless pumps and mechanically sealed rotodynamic pumps is necessary for proper application. Information is presented within this section to point out such differences.

5.3.3.1.1 Reasons for use

Sealless pumps are normally used where it is considered essential to reduce the possibility of emissions of pumped liquid that is hazardous, damaging to the environment, or valuable, or when specific applications warrant their use.

5.3.3.1.2 Containment expectations

Sealless pumps are usually purchased with the expectation that emissions will be substantially reduced or eliminated. Fulfilling these expectations requires careful consideration of specific design, associated circulation plans, and attention to application and quality details. Although sealless pumps do not leak during normal operations, leakage can occur in some failure modes, and appropriate supplemental precautions shall be taken.

5.3.3.1.3 Unit design and circulation plan selection and application (see Figure 5.3.2.12.1)

It is recognized that the liquid-lubricated bearings' design and application considerations are essentially the same for CMP and MDP.

Factors internal to the unit design, such as pressures, temperatures, flows, and heat transfer characteristics within the drive section and hydraulic performance of the pump end, must be understood in order to properly select circulation plans and assess application questions. Also to be considered are possible advantages and limitations.

5.3.3.1.4 Sealless pump advantages

Properly designed, applied, and operated sealless pumps may offer the following advantages:

a) No leakage through primary containment to the environment during normal operation.

b) Optional backup secondary containment.

c) No loss of valuable liquids.

d) Lower noise level (CMP designs).

e) Suction pressure usually does not affect the axial thrust.

f) No periodic shaft seal replacement cost.

5.3.3.1.5 Limitations

a) Temperature of motor windings (CMP) or magnet components (MDP).

b) Control of bearing environment is required to provide clean liquid, not vapor, for good bearing life.

c) Primary containment shell is relatively thin and corrosion potential shall be carefully considered.

d) Retraining of maintenance personnel may be required.

e) With some circulation plans for volatile liquids, drive-generated heat may affect the NPSH required.

f) There is potential for higher repair cost if bearings fail before detection.

g) Overheating of drive section may occur with loss of flow or loss of suction.

h) Check of rotation direction at startup may be necessary.

5.3.3.2 Safety considerations

Sealless pumps can provide safe operation when properly designed and applied. However, because they are typically used for hazardous services, potential application hazards should be considered.

5.3.3.2.1 Toxicity

Liquids can be categorized according to their toxicity. A brief guide is presented below.

- *Toxicity Rating 0*: No harmful effects under normal conditions
- *Toxicity Rating 1*: May cause irritation but only minor residual injury with short exposure
- *Toxicity Rating 2*: May cause temporary incapacitation or possible residual injury with short exposure
- *Toxicity Rating 3*: May cause serious temporary or residual injury with short exposure
- *Toxicity Rating 4*: May cause death or major residual injury even after short exposure to only small quantities

Liquids of toxicity rating 0 can normally be controlled with single seals or packing.

Liquids of toxicity rating 1 may be contained with a sealless pump or a single mechanical seal backed up by an auxiliary device or a double/tandem seal. The sealing method is normally based on the end purchaser's experience, along with local and national health and safety requirements. Supplementary safety procedures for the area surrounding the unit are also important.

Liquids of toxicity ratings of 2, and especially 3 and 4, require the highest integrity containment. One choice is a sealless pump with attention to secondary containment and to supplementary safety procedures for the surrounding area.

5.3.3.2.2 Flammability

The risk of fire is an important consideration. Fluid and vapor containment capability of sealless pumps is often a reason for their selection for flammable services. Also, assessment of supplemental safety considerations shall be made for the area surrounding the pump.

5.3.3.2.3 Environmental considerations

A significant reason for using sealless equipment is the increased control of fugitive emissions to the environment, which may cause environmental damage or other concerns.

5.3.3.2.4 Legal requirements

Reduction or elimination of fugitive emissions is often necessary for compliance with environmental requirements and is a major factor in obtaining construction permits and for continued operation.

5.3.3.3 Circulation piping plan selection

Selection of an appropriate circulation piping plan depends on knowledge of liquid properties such as cleanliness, volatility, specific heat, viscosity, specific gravity, toxicity, melting point, temperature, corrosiveness, and any tendency to form solids. Also to be considered are intended flow rates, NPSHA, frequency of starts, cooling or heating availability, and potential loss of suction liquid.

Typical circulation plans are shown in Figure 5.3.2.12.1 and are grouped by application type considering pumped liquid cleanliness, volatility, and temperature. Additional plans specific to design and application requirements may be offered by the manufacturer. A detailed analysis should be conducted for each application.

5.3.3.3.1 Clean liquids

Clean liquids are those with no solid particles.

5.3.3.3.2 Dirty liquids

Dirty liquids include solid particles. Rotodynamic separation, mechanical filtration, or separate, clean external flush liquid may be used. Also, volatility and temperature shall be considered.

5.3.3.3.3 High temperature

The temperature of motor windings or magnetic drive components can be controlled by using a variety of circulation piping plans. Volatility and cleanliness should be considered in selecting a plan.

5.3.3.3.4 Volatile liquids

Circulation to suction vessel or pressurized circulation may be used to avoid thermal effect of drive heating on pump NPSH requirements. Consideration of vapor pressure increase with temperature and of specific heat of liquid shall be required. Use of a separate low-volatility drive external flush liquid is also possible. Liquid cleanliness and temperature shall also be considered.

5.3.3.3.5 Liquids that solidify

Jacketed pumps may be required for high melting point liquids and easily polymerized or crystallized liquids. External flush liquids may also be used. Figure 5.3.2.12.1 does not include plans for jacketed pumps.

5.3.3.3.6 High viscosity

Viscosities that would cause objectionable drag losses in the drive section or inadequate bearing cooling flow (usually above 200 mPa•s [200 centipoise]) may be handled with external flush liquid. Startup and operating viscosity shall be considered.

5.3.3.3.7 External flush

External flush shall be used where there is potential loss of suction, zero flow, or entrained vapor. Separate compatible external flush liquid supply with appropriate cooling may be used to provide lubrication and cooling of the drive section. Precautions still apply for normal rotodynamic pump operation.

5.3.3.4 Pump selection

Attention shall be given to the following items.

5.3.3.4.1 Hydraulic sizing

Excessive oversizing of pump (higher than necessary head or flow) may require similar oversizing of the drive section and result in unnecessary heat input. Minimum flow requirements and bearing loads may also increase. The pump model that has the best efficiency point close to selected design point is preferred.

5.3.3.4.2 Driver sizing (CMP)

Effect of motor load on winding temperature and rotational speed shall be considered over anticipated performance range. Motors shall conform to specified area classification.

5.3.3.4.3 Magnetic drive and driver sizing (MDP)

The drive motor needs to be selected to cover projected operating range, but oversizing may be a factor in decoupling during acceleration. Decoupling shall be avoided because rapid overheating may occur when the inner and outer magnets decouple during operation. Excessively large drives, however, have higher losses that result in liquid heating.

Motors shall conform to specified area electrical classification.

5.3.3.4.4 Thermal effects on NPSH and drive section

Heat from the drive section of a sealless pump may cause cavitation and loss of flow if liquid is recirculated to the pump suction. Circulation to intermediate or discharge pressure points or recirculation to supply tank minimizes this problem. Heating of liquid at the suction eye can also occur with internal recirculation within the pump impeller at low flow rates. Volatile liquids may require higher minimum flows and use of appropriate circulation piping.

Cavitation at the pump impeller may also result in excessive thrust towards suction and should be avoided.

Design and circulation piping plans shall provide a margin of safety between vapor pressure and the lowest pressure/highest temperature within the drive area over the projected operating range.

5.3.3.4.5 Operation range

Operation at excessively high or low flows may result in cavitation and in increased thrust and should be avoided.

5.3.3.4.6 Pressure rating

Selection of models having rated working pressure in excess of anticipated operating conditions shall be required.

5.3.3.4.7 Material selection

Material selection is the responsibility of the purchaser, but the manufacturer also has a responsibility to inform the purchaser of unusual corrosion requirements, such as affect on pressure containment shells and rotor encapsulation.

The purchaser shall identify any potentially corrosive agents, such as chlorides or hydrogen sulfide, which should be given special consideration.

The manufacturer shall describe materials of construction sufficiently so that the purchaser has the information required to make the proper selections.

Allowance shall also be made for the temperature rise within the drive section when corrosive characteristics vary significantly with temperature.

5.3.3.4.8 Entrained, noncondensable gas

Collection of vapors in the liquid-lubricated bearing area shall be avoided by use of appropriate circulation piping.

5.3.3.4.9 Efficiency

For direct comparison of efficiencies of magnetic drive versus canned motor pumps versus mechanically sealed pumps, consideration shall be given to overall efficiency from motor input power (P_{mot}) to the pump output power (P_w). This overall efficiency shall also include energy used for auxiliary piping, seals, or other optional components. It is necessary to know the pump efficiency for proper drive selection. It is also necessary to know the efficiency of the drive section and separate motors (when used) to predict overall efficiency.

5.3.3.5 Canned motor or magnet component temperature

The temperature of magnetic components (magnets, adhesives, and motor windings) shall be maintained within maximum limits for proper life and function. The temperature of these components is affected by the following factors:

- Circulation piping used
- Temperature of pumped liquid
- Temperature of circulated liquid
- Power transmitted
- Insulation of the drive section
- Use of cooling jackets
- Circulation flow rate

The combined effect of these factors shall be considered in the proper selection and application of sealless pumps.

For MDP, the maximum allowable liquid temperatures for which the magnet power drive is rated, depending on the type and grade of magnet used, are listed in the chart below with the compound used to secure the magnets. Exceeding allowable temperature of the magnet material will result in irreversible loss in torque capabilities of the drive.

Magnet temperature limits

Alnico (isotropic)	450 °C	842 °F
Neodymium	121 °C	250 °F
Samarium Cobalt	300 °C	572 °F

For CMP, the maximum liquid temperatures for which a canned motor insulation system is rated, based on Institute of Electrical and Electronic Engineers (IEEE) ratings for various classes of motor insulation, are listed in the chart below.

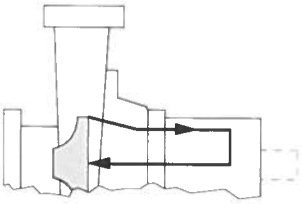
Motor insulation temperature limits

Class		
B	130 °C	266 °F
F	155 °C	311 °F
H	180 °C	356 °F
N	200 °C	392 °F
R	220 °C	428 °F
C	250 °C and above	482 °F and above

Motor windings in a CMP and magnets in the MDP may operate at higher temperatures than the process fluid.

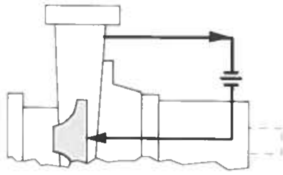
Consideration shall also be given to the corrosion rate and thermal expansion of the wetted materials due to elevated temperatures.

i) Clean liquid – nonvolatile – moderate temperature



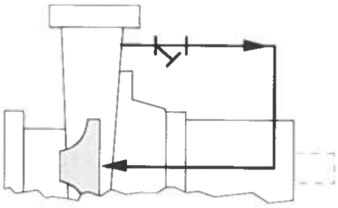
Plan 101

1) Internal circulation through drive section to suction.
2) Bearing pressure almost at suction pressure.



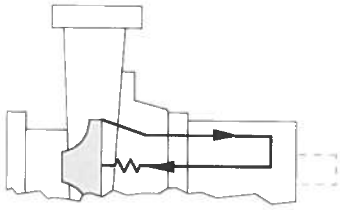
Plan 111

1) Recirculation from discharge through optional orifice through drive section to suction.
2) Bearing pressure almost at suction pressure.



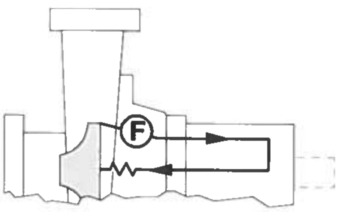
Plan 112

1) Recirculation from discharge through strainer into drive section and to suction.
2) Bearing pressure almost at suction pressure.



Plan 114

1) Internal recirculation from discharge through drive section and internal restriction to suction.
2) Bearing pressure substantially higher than suction pressure.



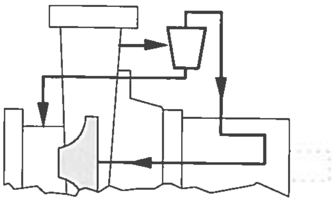
Plan 115

1) Internal recirculation through centrifugal or mechanical filter through drive section through internal restriction to suction.
2) Bearing pressure substantially higher than suction pressure.

Ⓕ Filter
Internal flow resistor
Orifice or internal restriction
Strainer
Heat exchanger
Ⓟ Pressure gauge
Ⓠ Flow indicator
Valve
Centrifugal separator

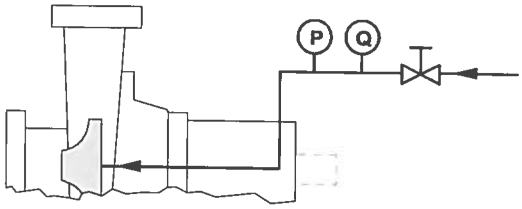
Figure 5.3.2.12.1 — Typical circulation piping plans for canned motor and magnetic drive pumps

ii) Dirty liquid



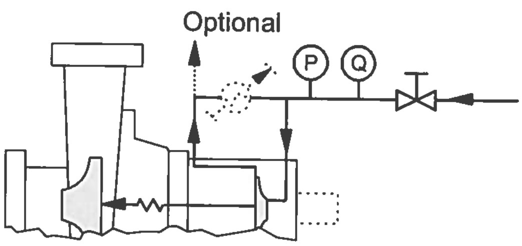
Plan 131

1) Recirculation through external or internal centrifugal separator through drive section to suction.
2) Bearing pressure almost at suction pressure.
3) Nonvolatile process liquid.
4) Moderate temperature.



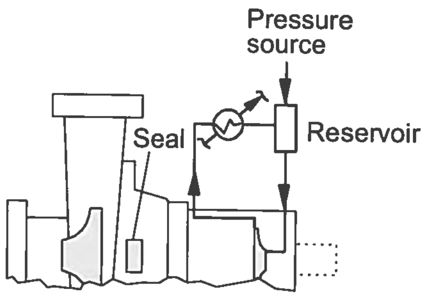
Plan 132

1) Full flush with external clean nonvolatile liquid.
2) Drive heat removed by flush liquid.
3) Bearing pressure almost at suction pressure.
4) Nonvolatile flush liquid.
5) Moderate or high temperature.
6) May inject at intermediate pressure on pump impeller as an option.



Plan 133

1) Backflush at reduced flow rate into process.
2) Supply of clean external liquid required.
3) Bearing pressure almost at suction pressure.
4) Backflush flow limited by internal restriction.
5) Moderate or high temperature.
6) Optional full flush flow to external point for cooling instead of recirculation through heat exchanger.

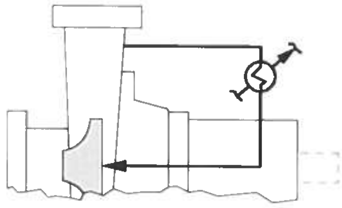


Plan 153

1) Pressurized external fluid reservoir.
2) Shaft seal between drive section and pump end.
3) Bearing pressure higher than pump suction pressure.
4) Minimum leakage of external flush liquid past seal into process.
5) Moderate or high temperature.
6) Volatile or nonvolatile process liquid.

Figure 5.3.2.12.1 — Typical circulation piping plans for canned motor and magnetic drive pumps (*continued*)

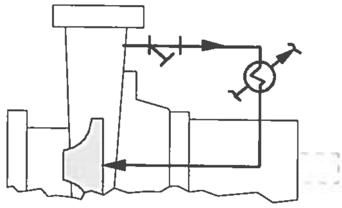
iii) Clean liquid – volatile – moderate temperature



Plan 121

1) Recirculation from discharge through heat exchanger to drive section and suction.

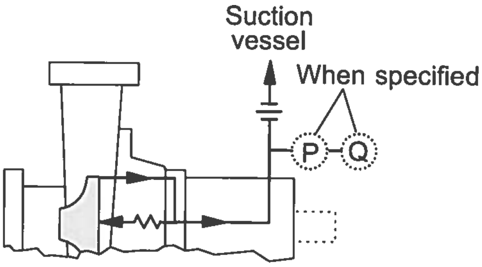
2) Bearing pressure almost at suction pressure with temperature below suction temperature.



Plan 122

1) Recirculation from discharge through strainer and heat exchanger to drive section and suction.

2) Bearing pressure almost at suction pressure with temperature below suction temperature.

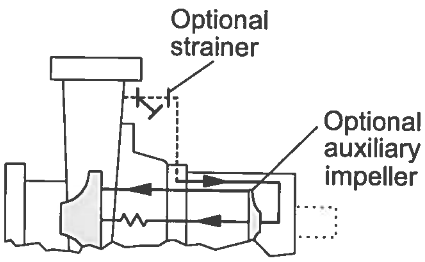


Plan 113

1) Reverse circulation through drive section to suction vessel.

2) Bearing pressure substantially above suction pressure through use of internal restriction.

3) Drive heat not returned to suction.



Plan 125

1) Internal circulation from impeller discharge to intermediate pressure on pump impeller.

2) May use circulating auxiliary impeller.

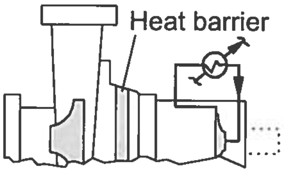
3) Bearing pressure substantially higher than suction pressure.

4) Circulation liquid entry to process flow substantially above suction pressure.

5) May use optional internal or external strainer or filter.

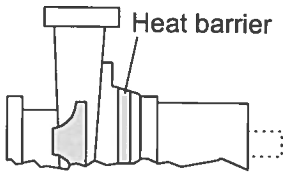
Figure 5.3.2.12.1 — Typical circulation piping plans for canned motor and magnetic drive pumps (*continued*)

iv) Clean liquid – high temperature – nonvolatile



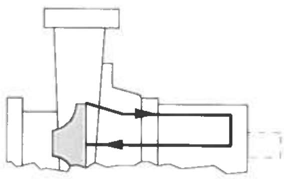
Plan 123

1) Recirculation from drive section through heat exchanger with auxiliary impeller.
2) Bearing pressure slightly above suction pressure.
3) Heat barrier between pump and drive.



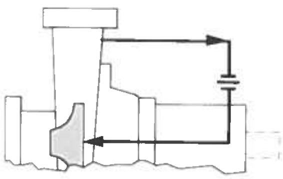
Plan 102

1) Dead-ended drive section.
2) Drive heat to atmosphere.
3) Primarily for MDP.



Plan 101

1) High-temperature drive materials.
2) Cooling (at high temperature) by internal recirculation through drive section.
3) Bearing pressure almost at suction pressure.

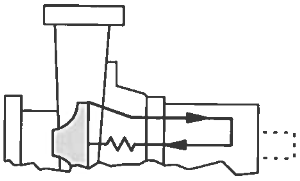


Plan 111

1) High-temperature drive materials.
2) Recirculation from discharge through orifice to drive section to suction.
3) Bearing pressure almost at suction pressure.

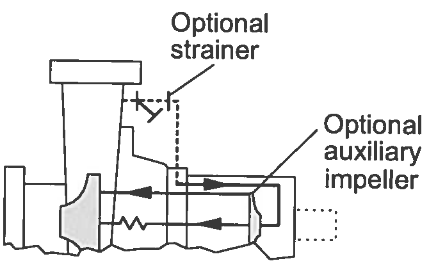
Figure 5.3.2.12.1 — Typical circulation piping plans for canned motor and magnetic drive pumps (*continued*)

iv) Clean liquid – high temperature – nonvolatile (*continued*)



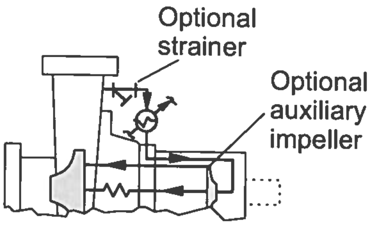
Plan 114

1) High-temperature drive materials.
2) Cooling (at high temperature) by internal recirculation through drive section and internal restriction to suction.
3) Bearing pressure substantially higher than suction pressure.



Plan 125

1) High-temperature drive materials.
2) Internal circulation from impeller discharge to intermediate pressure on pump impeller.
3) May use circulating auxiliary impeller.
4) Bearing pressure substantially higher than suction pressure.
5) Circulation fluid entry to process flow substantially above suction pressure.
6) May use optional internal or external strainer or filter.



Plan 126

1) Circulation from impeller discharge through heat exchanger to drive area to limit temperature in drive area.
2) May not require high-temperature drive materials.
3) Bearing pressure substantially higher than suction pressure.
4) Circulation fluid entry to process flow substantially above suction pressure.
5) Strainer or filter is optional.

NOTES:

1) Plan numbers used are similar to API 610.
2) Plan numbers are grouped in this text by type of application.

Figure 5.3.2.12.1 — Typical circulation piping plans for canned motor and magnetic drive pumps (*continued*)

5.4 Installation, operation, and maintenance

Sealless pumps are built in a variety of designs for different services by a number of manufacturers. The specific manufacturer's instruction manual shall be studied carefully and directions followed for the pump in question.

The following paragraphs outline the general principles that shall be considered to ensure trouble-free pump operation.

Upon receipt of the pumping unit, check to make sure all items have been received in an undamaged condition. Report any damage to the shipper and the equipment manufacturer. Do not leave the unit exposed to weather or construction hazards. Protective covers should be left on all openings until the time of installation.

⚠ **CAUTION: In spite of thorough cleaning and flushing prior to maintenance of sealless pumps, some contamination of pump internals may exist. Repair shop personnel shall be advised of the nature of the hazardous liquid handled and of the requirement for protective clothing and equipment needed during maintenance work. Care shall be taken in disposing of residue and contaminated parts being replaced. For further details, see Section 5.4.5 Maintenance.**

For MDP, the magnets in magnetically driven pumps create strong magnetic fields. Precautions to prevent harm or damage shall be taken, among which the following are the most important:

- *Pacemakers:* Magnets from these pumps can upset the timing of pacemakers and make them malfunction. This caution cannot be overstated due to the health risks involved.
- *Hands and fingers:* Magnets can cause parts and tools to slam together, injuring hands and fingers.
- *Credit cards:* Credit cards or information on the credit card's magnetic tape can be scrambled and shall be kept away from all magnets.
- *Computers, computer tapes, computer disks:* Computers, computer tapes, computer disks, or any computer memory device shall be kept away from magnets to prevent damage.
- *Watches:* All watches should be removed when handling magnets. Magnets have affected the workings of mechanical spring-driven watches as well as chip and electronically controlled watches.
- *Freight:* Special precautions may be necessary when shipping raw or bare magnet assemblies, especially by air. Usually the shipment of an assembled pump is not a problem. Consultation between the pump manufacturer, the purchaser, and the freight company is advisable.

Repair shop personnel should be made aware of the above precautions when handling sealless pumps.

5.4.1 Unit location and foundation

The pump should be as near the liquid source as possible, so that a short, direct suction pipe may be used. Adequate room shall be provided around the pump for inspection during operation and maintenance. Refer to ANSI/HI 9.6.6 *Rotodynamic Pumps for Pump Piping*.

5.4.1.1 MDP

For separately coupled MDPs, the mass of the foundation should be sufficient, preferably five times that of the pumping equipment, to form a permanent and rigid support for the baseplate. Foundation bolts should be embedded in the concrete, located by a template or drawing. A pipe sleeve larger than the bolt should be used to allow movement for final positioning of the bolts. For close-coupled MDPs, mounting on a rigid, grouted base may not be required.

5.4.1.2 CMP

Foundation requirements for canned motor pumps vary greatly depending on size. However, mounting on a rigid, grouted base (for example, for coupled units) is typically not required. A mounting base, when used, serves to correctly position and support the unit prior to connecting the suction and discharge piping. Small pumps can be supported directly by the suction and discharge pipe, but the manufacturer's recommendations should be followed.

5.4.2 Installation

The following instructions apply primarily to conventional, horizontal pumps. However, canned motor and magnetic drive pumps are also manufactured for vertical installation, in which case the manufacturer's special directions shall be followed.

5.4.2.1 Alignment

Because canned motor pumps and close-coupled magnetically driven pumps come as an integral unit, fully aligned and assembled from the manufacturer, no additional alignment is required at the time of installation.

Separately coupled MDPs with both the pump and driver mounted on a common baseplate shall be accurately aligned before shipment. However, all baseplates are flexible to some extent and shall not be relied on to maintain the factory alignment. Realignment is necessary after the complete pump has been leveled on the foundation and again after the grout has set and foundation bolts have been tightened. The alignment shall be checked after the piping is installed, and then rechecked periodically. To facilitate accurate field alignment, most manufacturers do not dowel the pumps or drivers on the baseplates before shipment, or they dowel the pump only.

When the driver is to be mounted at the place of installation, it shall be correctly aligned to the pump.

5.4.2.2 Leveling the unit

The pumping unit on its baseplate should be placed on the foundation with the baseplate supported on rectangular metal blocks and shims, or on tapered metal wedges. A gap of 25 to 50 mm (1 to 2 in) should be allowed between the baseplate and the foundation for grouting. Make the necessary adjustment until the baseplate is level. Tighten the foundation bolts evenly but not too firmly, and grout the unit in place. The foundation bolts should not be fully tightened until the grout is hardened, usually about 48 hours after pouring.

5.4.2.3 Coupling alignment (MDP)

For detailed instructions on how to align couplings and check for misalignment between the pump shaft and the driver shaft, refer to ANSI/HI 1.4 *Rotodynamic (Centrifugal) Pumps for Manuals Describing Installation, Operation, and Maintenance*. Gear type, disk type, and spacer couplings are covered in depth.

Due to the magnetic pull between the inner and outer magnet assemblies, and some looseness in the outer magnet carrier bearings when cold, slightly higher shaft runout at the coupling may be experienced before the unit reaches operating temperature.

5.4.2.4 Piping

Suction and discharge piping shall be anchored, supported, and restrained near the pump to avoid imposing forces and moments in excess of those permitted by the pump manufacturer. In calculating forces and moments, the weight of the liquid-filled pipes as well as thermal contraction and expansion shall be considered. Allowable flange loading to avoid unit damage or malfunction shall be specified by the manufacturer. Concern over coupling deflection is not applicable to canned motor pumps and close-coupled magnetically driven pumps.

The suction pipe shall be designed to provide the pump with a steady flow of liquid with sufficient pressure to provide adequate NPSH and prevent cavitation damage. For pumps operating with suction pressure below atmospheric pressure or handling liquids near their vapor pressure, the suction line shall slope constantly upwards toward the pump to avoid vapor traps. Any valves in the suction line should be installed with their stems in a horizontal position. A block valve may be installed to isolate the pump for maintenance.

The discharge pipe shall have a check valve and a block valve installed next to the pump. The check valve serves to protect the pump from reverse flow and excessive backpressure. The block valve, installed downstream from the check valve, is used in priming, starting, and shutting down the pump.

For additional details on suction and discharge piping, refer to ANSI/HI 1.4 *Rotodynamic (Centrifugal) Pumps for Manuals Describing Installation, Operation, and Maintenance* and ANSI/HI 9.6.6 *Rotodynamic Pumps for Pump Piping.*

5.4.2.5 Auxiliary connections and monitoring devices

All auxiliary connections, controls, and alarms shall be correctly connected and functioning in accordance with the manufacturer's instructions. This includes cooling water to the pump and/or motor heat exchanger on high-temperature pumps, vent connection to the suction source, clean flush injection to liquid-lubricated bearings when required, temperature and vibration detectors, and other instruments. All alarm point settings shall be verified.

Power monitors are recommended for most sealless pumps. A power monitor can help detect operation at shutoff (zero flow), dry-running operation at runout condition, rubbing, jamming of the pump, and decoupling of a magnetic drive. For canned motor pumps, direction of rotation indicators and rotor axial and radial position indication is recommended. For magnetic drive pumps, a temperature probe on the containment shell for the magnetic drive to detect temperature rise in the lubrication/cooling circuit is recommended. For canned motor pumps, a temperature indicator in the rear bearing housing is recommended to detect the fluid temperature. Monitoring of potential leakage from the magnetic drive containment shell may also be desired. Consultation with the manufacturer about all facets of monitoring is advised.

5.4.3 Starting

When the pump is installed and the piping system completed, it is recommended that the system be backflushed to remove debris and loose scale. The pump, motor, and other sensitive equipment should be protected with startup strainers, which should in turn be removed on completion of the flushing. The viscosity of the flushing liquid shall be compatible with the drive.

The pump shall not be run unless it is completely filled with liquid, as damage might occur. Typically, case and impeller rings depend on liquid for their lubrication and may seize if the pump is run dry. When required, priming may be done by using an ejector or a vacuum pump.

It is extremely important to prevent the liquid-lubricated bearings in the magnetic drive and canned motor from being operated dry because they depend on the pumped liquid for lubrication. Lack of bearing lubrication results in heat buildup, which is the most common cause of failure with sealless pumps. Silicon carbide bearings fail quickly when run dry, while carbon graphite composites may handle short periods of dry run.

Liquids with entrained air or gas may cause vapor pockets to form in the containment shell, leading to lack of lubrication, heat buildup, and bearing failure. In addition to proper venting, a special flush of clean, vapor-free liquid shall be applied to the bearings when the pumped liquid contains entrained air or gas.

For units in critical NPSH service, a continuous vent line should be provided from the highest point in the pump under suction pressure to the vapor phase of the suction source. Even though these units are typically self-venting, the vent line will help prevent inadvertent vapor locking and dry-running. The vent line shall be continuously rising to preclude air or gas traps.

When handling cold liquids, it is necessary to slowly cool down both the unit and the piping to near pumping temperature prior to startup. This can be done either with a bypass line on the discharge side or a separate, adequately sized vent line back to the supply vessel. Shocking the pump with cold liquid may cause seizure and/or vapor locking.

During initial startup the pump should be started with the discharge valve partially opened. Once the pump has reached full operating speed, open the discharge valve completely. With a variable frequency drive (VFD) or soft-start control the pump may be started with a fully open discharge valve. Prolonged operation with a closed discharge valve will damage the pump. The pump shall never be operated with a closed or partially closed suction valve.

5.4.3.1 Other precautions

When operating at flow below the manufacturer's recommended minimum, noise and vibration levels will typically increase. This may lead to reduced bearing life and potential damage to other components.

If it is necessary to operate a pump at flows below those specified by the manufacturer as permissible, then a bypass line should be installed from the pump discharge to the suction source. The bypass line shall be sized so that the system flow plus the continuous bypass flow is equal to, or larger than, the manufacturer's specified minimum.

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

For parallel operation, the pumps shall have matching head characteristics. 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.

In series operation, the pumps shall have approximately the same flow characteristics. Because each pump will take suction from the preceding pumps, the pressure-containing parts shall be designed for the resulting discharge pressure.

5.4.3.2 Decoupling (MDP)

If decoupling of the inner and outer magnets occurs, then demagnetization of the inner magnets is likely in a short span of time. In addition, temperature rise of the liquid in the containment shell or around metal-clad inner magnets may occur. Decoupling can be caused by jamming of the impeller, overloading due to rubbing, viscosity, high inertia load at startup, air entrainment, or bearing failure. In addition, decoupling can occur if an oversize motor accelerates too fast for the coupling. A power monitor on the motor can detect and shut off the pump in these cases. A temperature probe sensing metal containment shell temperature rise can also detect decoupling. The driver shall be stopped for the magnets to realign themselves. The pump manufacturer may be consulted about this subject.

5.4.4 Vibration

There are a number of factors that may cause vibration in a pump. Imbalance, looseness in the assembly, worn bearings, cavitation, decoupling, and liquid turbulence are some of the common sources. For a complete discussion of pump vibration issues, including vibration measurements and permissible vibration levels, refer to ANSI/HI 9.6.4 *Rotodynamic Pumps for Vibration Measurements and Allowable Values*.

5.4.5 Maintenance

If the unit is to be taken out of service for a prolonged period, it is recommended that the liquid be drained from the unit, paying close attention to the manufacturer's specific instructions.

Sealless pumps often handle flammable, toxic, or hazardous liquids. The user shall take caution that all such liquid is drained from the containment shell before disassembly and repair work is begun. Some designs do not allow for fully draining the containment shell when the casing is drained. When the pump is handling flammable, toxic, or hazardous liquid, the internals of the pump shall be properly decontaminated by qualified personnel before disassembly. This may include flushing the pump and system before disassembly. Before flushing, decontamination, and disassembly, the material safety data sheet (MSDS) for the pumped liquid shall be reviewed to ensure procedures and precautions as specified are adhered to. Proper attire shall be worn during disassembly and decontamination.

Pumps requiring factory repair shall not be returned or transported until a certified and documented decontamination has taken place. Decontamination certificate and MSDS shall be part of the shipment package returned for factory repair; otherwise, the manufacturer may reject the shipment.

5.4.5.1 Magnet assembly (MDP)

Extreme caution shall be used when dismantling or reassembling a magnetically driven pump. The magnets can cause parts and tools to slam together with enough force to injure the person handling the parts. The user shall refer to the manufacturer's maintenance manual for procedures and special tools. If provided for, jacking screws shall be used between mating parts during disassembly and reassembly to avoid personal injury. The use of non-magnetic tools, while not absolutely necessary, is advised to prevent injury to workers and/or pump parts. Refer to the precautions listed in the beginning of this section.

5.4.5.2 Canned motor (CMP)

By regularly monitoring the pump vibration, it can be determined whether or not the bearings are getting worn and need to be replaced.

Any problem associated with the electrical components should be corrected only by the manufacturer or a qualified repair facility.

5.4.5.3 Close running fits

Wear rings fitted in the casing and/or on the impeller provide a close running clearance to reduce the quantity of liquid leaking from the high-pressure side to the suction side. These rings will eventually wear until the clearance becomes greater and more liquid passes back to the suction. For pumps fitted with open or semi-open impellers, the running clearances between the impeller vanes and case, or liner wall, is equally critical in controlling liquid leakage. Excessively large clearances and running fits, including badly worn wear rings, will result in severe degradation of pump performance, particularly on small pumps, and should be corrected. Axial thrust may also be affected.

5.4.5.4 Maintenance considerations

The manufacturer's manual may recommend a schedule of inspection or will recommend inspection of parts based on abnormal performance. However, the frequency of inspection will often depend on the corrosive and erosive nature of the liquid, and the user should set up the inspection schedule accordingly.

Examination of wear patterns can provide valuable information in diagnosing pump problems and determining their origin. The manufacturer shall provide the inspection parameters for individual parts for determining the wear rate and the need for replacement.

5.4.6 Troubleshooting

When investigating pump trouble at the jobsite, an effort shall 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, viscosity, air entrainment, and particulates.

5.4.6.1 No discharge flow

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

- Pump not primed
- Speed too low

  NOTE: Determine whether or not motor is "across the line" and receives full voltage, or if a provision for reduced voltage starting is causing the problem.

- System head too high
- Impeller plugged
- Wrong direction of rotation
- Air leak in the suction line
- Suction lift too high
- Impeller loose on shaft
- Closed suction valve
- Magnet decoupling
- Magnets de-energized
- Vapor lock
- Broken shaft coupling

5.4.6.2 Insufficient discharge flow

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

- Air leaks on suction side
- Speed too low

  NOTE: Determine whether or not motor is "across the line" and receives full voltage, or if a provision for reduced voltage starting is causing the problem.

- System head higher than anticipated
- Inadequate submergence at suction inlet
- Insufficient NPSHA:
  - Check with gauges
  - Clogged suction line
  - Not enough suction head for hot or volatile liquids
  - Impeller partially plugged

- Mechanical defects:
  - Rings worn
  - Impeller damaged
  - Impeller loose on shaft
- Suction valve partially closed
- Impeller installed backwards
- Wrong direction of rotation

5.4.6.3 Insufficient pressure

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

- Speed too low

  NOTE: Determine whether or not motor is "across the line" and receives full voltage, or if a provision for reduced voltage starting is causing the problem.

- System head less than anticipated
- Air or gas in liquid
- Leaking pressure joints
- Mechanical defects:
  - Rings worn
  - Impeller damaged
  - Impeller diameter too small
  - Worn open impeller vanes
- Wrong direction of rotation

5.4.6.4 Loss of suction following a period of satisfactory operation

Loss of suction pressure following a period of satisfactory operation may be caused by any of the following conditions:

- Suction line drawing air
- Suction lift too high
- Insufficient NPSHA
- Air or gas in liquid
- Casing gasket defective
- Temperature rise causing loss of NPSHA

5.4.6.5 Excessive power consumption

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

- Speed too high
- System head lower than rating
- Specific gravity or viscosity of liquid pumped is too high
- Mechanical defects:
  - Shaft bent
  - Rotating element rubs or binds
  - Electrical or mechanical defect in motor (including rubbing)
- Increased motor loss due to voltage imbalance or waveshape distortion

5.5 Reference and source material

5.5.1 Bearings

ANSI/ABMA 9, *Load Ratings and Fatigue Life for Ball Bearings.*

ANSI/ABMA 11, *Load Ratings and Fatigue Life for Roller Bearings.*

American Bearing Manufacturers Association
2025 M Street, NW
Suite 800
Washington, DC 20036
www.abma-dc.org

5.5.2 Sealless pumps

API 685, *Sealless Centrifugal Pumps for Refinery Services.*

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005

5.5.3 ANSI/ASME – American Society of Mechanical Engineers

ANSI B15.1, *Safety Standards for Mechanical Power Transmission Apparatus.*

ASME B16.5, *Pipe Flanges and Flanged Fittings.*

ASME B73.I, *Specifications for Horizontal End Suction Centrifugal Pumps for Chemical Process.*

ASME B73.2, *Specifications for Vertical In-line Centrifugal Pumps for Chemical Process.*

ASME B73.3, *Specification for Sealless Pumps Horizontal End Suction Centrifugal Pumps.*

ASME, *Boiler and Pressure Vessel Code*

ASME Steam Tables

American Society of Mechanical Engineers
Three Park Avenue
New York, NY 10016-5990

AMT - The Association For Manufacturing Technology
7901 Westpark Drive
McLean, VA 22102-4206
Phone: 703-893-2900
Toll Free: 800-524-0475
Fax: 703-893-1151
AMT@AMTonline.org

5.5.4 ANSI/HI – Hydraulic Institute

ANSI/HI 1.1–1.2 *Rotodynamic (Centrifugal) Pumps for Nomenclature and Definitions.*

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

ANSI/HI 1.4 *Rotodynamic (Centrifugal) Pumps for Manuals Describing Installation, Operation, and Maintenance.*

ANSI/HI 14.6 *Rotodynamic Pumps for Hydraulic Performance Acceptance Tests.*

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

Hydraulic Institute
6 Campus Drive, 1st Floor North
Parsippany, NJ 07054-4406

5.5.5 ANSI/IEEE – Institute of Electrical and Electronic Engineers

ANSI/IEEE 4, *Standard techniques for high voltage testing.*

ANSI/IEEE 43, *Recommended practice for testing insulation resistance of rotating machinery.*

ANSI/IEEE 117, *Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound AC Electric Machinery.*

ANSI/IEEE 118, *Standard test code for resistance measurements.*

Institute of Electrical and Electronic Engineers
3 Park Avenue, 17th Floor
New York, NY 10016-5997

5.5.6 ISO – International Organization for Standards

ISO - 1940, *Balance Quality of Rotating Rigid Bodies.*

American National Standards Institute
1819 L Street, NW
Washington, DC 20036

5.5.7 ASTM – American Society for Testing and Materials

Annual Book of ASTM Standards.

ASTM
100 Barr Harbor Drive
West Conshohocken, PA

5.6 Test

5.6.1 Scope

This standard applies to tests of the pump and magnetic coupling (magnetic drive pumps), or pump and motor unit (canned motor pumps).

The types of tests performed in accordance with this standard are limited to those listed in Section 5.6.2. For other types of tests that are also applicable to sealless pumps, see ANSI/HI 14.6 *Rotodynamic Pumps for Hydraulic Performance Acceptance Tests.*

5.6.1.1 Objective

To provide uniform procedures for hermetic integrity, electrical and secondary containment testing of sealless rotodynamic pumps, and recording of the test results.

5.6.2 Types of tests

For any one of the tests to become a contractual requirement, it shall be specifically identified in the contract documents.

This standard describes the following tests:

a) Hermetic integrity test (standard test).

b) Motor winding integrity test (canned motor pumps) (standard test).

c) Secondary containment test.

d) Motor winding temperature rise test (canned motor pumps).

5.6.3 Hermetic integrity test (standard test)

5.6.3.1 Objective

To demonstrate that a sealless pump assembly does not leak when subjected to internal pressure. This test is usually a low-pressure gas (air) test and done after final assembly.

This test is typically conducted during the manufacturing of the stator assembly of a canned motor pump, and after final assembly before shipment.

5.6.3.2 Test parameters

Tests shall be conducted on completely assembled pump units. Disassembly after the test is not permitted. The primary and secondary (if so equipped) containment boundaries shall be tested separately.

Test duration – Test pressure shall be maintained for a sufficient period of time to permit a complete examination of the parts under pressure. A minimum of three minutes is considered necessary for this examination, unless acceptance criteria "c" is required.

Test fluid – The test fluid shall be air or an inert dry gas. Where specified, there shall be no water or other liquid present in the test fluid.

Test pressure - Because a compressible fluid is being used, and the test is not conducted in an isolated safety chamber, the test pressure shall not exceed 75% of maximum working pressure or 517 kPa (75 psig) with a minimum working pressure of 69 kPa (10 psig), whichever is lower.

Test temperature – Tests shall be conducted at room temperature.

This test is not conducted at or above maximum working pressure. For this reason this test does not give verification that a leak shall not occur at maximum working pressure.

5.6.3.3 Test procedure

The gas shall be introduced into the primary and secondary containment boundaries. Each area shall be tested separately. The primary boundary shall be pressurized first. Once the primary boundary has been proven, the secondary boundary shall be pressurized. (Note: if pressurizing the secondary boundary could damage the primary boundary, then it is permissible to pressurize the primary boundary during the test of the secondary boundary.) After pressure has stabilized, one of three methods can be used to determine leakage:

a) Inert gas sniffer test.

b) Pressure drop observation. After pressurization, but before starting the test, isolate the item under test from the pressure source and then disconnect the pressure source.

c) External soap bubble test.

5.6.3.4 Acceptance criteria

One of the following acceptance criteria shall be used, depending on the test method selected in Section 5.6.3.3, i.e., "a" for test method "a," etc.

a) A leakage of no more than 1×10^{-4} mL/s (6×10^{-6} in^3/s) of gas shall be observed.

b) A pressure drop of no more than 0.4 kPa (0.06 psi) shall be observed for a period of not less than 10 minutes, or a measured pressure drop rate of not more than 7×10^{-4} kPa/s (1×10^{-4} psi/s). The acceptance criteria assume no significant temperature change during the test.

c) No observable leakage for a minimum of 10 minutes.

5.6.4 Motor winding integrity test (standard test)

5.6.4.1 Objective

Verify the integrity of the motor windings during manufacturing, and check the integrity once the motor is installed in the field. This test is typically conducted by the manufacturer during the manufacture of the motor, or by the user if a motor is suspected of having a problem.

5.6.4.2 Test parameters

Motor tests shall consist of resistance measurements of the windings (ANSI/IEEE 118), a dielectric test (Hi-pot test) for shorts to ground (ANSI/IEEE 4).

In the event a motor in the field is suspected of having an issue, the user can complete resistance checks of the winding per ANSI/IEEE 118 as well as an insulation resistance check (MEGGER) per ANSI/IEEE 43. If desired, and a low MEGGER with a good resistance is measured, then a Hi-pot test can be done. Because a full voltage Hi-pot test severely stresses the motor windings and was done during manufacture, it is recommended that any subsequent Hi-pot tests be done at 80% of the previous voltage test levels.

5.6.5 Secondary containment test

5.6.5.1 Objective

To verify the integrity of the secondary containment shell, welds, and electrical lead through connections at maximum working pressure. The pump user will consider specifying a secondary containment test, if it is absolutely critical to contain the process fluid in the event of a primary containment failure. An example would be an application with highly toxic process fluids. This test will be specified in addition to a hydrostatic test of the primary containment shell (ANSI/HI 14.6).

5.6.5.2 Test parameters

The test shall be conducted on the secondary containment shell, lead through connections, and welds. Inert gas shall be pressurized in the primary and secondary containment shell beyond maximum working pressure. Because compressible fluid is the test medium, and the test pressure will exceed the maximum working pressure, the test shall be conducted in an isolated safety chamber.

EXTREME CAUTION: COMPRESSED GAS IS HAZARDOUS WHEN USED AS A TEST MEDIUM. EXERCISE EXTREME PRECAUTION TO PROTECT ALL PERSONNEL.

5.6.5.3 Test procedure

⚠ **CAUTION: If the secondary containment shell of a canned motor pump is pressurized without equally pressurizing the primary containment shell, the primary boundary will be damaged. For this reason the primary and secondary containment shell shall be pressurized equally, and at the same time.**

1) The test pressure shall be 1.1 times the design pressure.

2) Test fluid shall be inert dry gas.

3) Gradually pressurize the unit under test in 1/10th increments of test pressure, until test pressure is reached.

4) Once test pressure is reached, maintain test pressure for 10 minutes, and then reduce to design pressure.

5) Leave at design pressure for 10 minutes, and one of the following methods may be used to determine leakage:

   a) Inert gas sniffer.

   b) Pressure drop observation.

   c) External soap bubble test.

5.6.5.4 Acceptance criteria

One of the following acceptance criteria shall be used, depending on the test method selected in Section 5.6.4.3, i.e., "a" for test method "a," etc.

a) A leakage of no more than 1×10^{-4} mL/s (6×10^{-6} in^3/s) of gas shall be observed.

b) A pressure drop of no more than 0.4 kPa (0.06 psi) shall be observed during a period of no less than 10 minutes, or a measured pressure drop rate of not more than 7×10^{-4} kPa/s (1×10^{-4} psi/s).

c) No observable leakage for a minimum of 10 minutes.

5.6.6 Motor winding temperature rise test

5.6.6.1 Objective

Verify motor windings do not exceed the maximum insulation temperature (see Section 5.3.3.5) at design motor load and design motor liquid cooling temperature.

In a liquid-cooled motor, such as a canned motor, the winding temperature is equal to the winding temperature rise at a specific motor load plus the liquid temperature cooling the motor. This test shall only be specified if the user is not comfortable with the calculated margin below maximum winding insulation temperature. The manufacturer can provide typical temperature rise data for each motor as a function of load, so the winding temperature can be estimated based on the motor load and motor cooling liquid temperature.

5.6.6.2 Test parameters

The test shall be conducted at design voltage, speed, and power. The test fluid shall be water.

5.6.6.3 Test procedure

Two test procedures are acceptable.

1) Insert thermocouples into the motor windings, and read the winding temperature directly. This method will need to be addressed during the manufacturing of the motor.

2) Measure the energized winding resistance, and calculate the winding temperature based on the energized winding resistance compared to the cold winding resistance.

Method 1

1) Operate the motor at design voltage, speed, and motor load until the winding temperature (WT) stabilizes. Record the winding temperature and the fluid temperature cooling the motor (also known as *hot temperature* [TH]) every 15 minutes until the winding temperature stabilizes.

2) Winding temperature rise (WTR) is calculated by the following equation:

   $$WTR = WT - TH$$

   Where:

   WTR = Winding temperature rise

   WT = Winding temperature

   TH = Temperature of fluid cooling motor

Method 2

1) An energized resistance measurement device is needed to connect in series with the motor power leads.

2) Record the cold resistance (RC) of the motor with the energized resistance measurement device while the motor is at room temperature, before liquid is in the motor, and before the motor has been energized. Record the skin temperature of the motor (°C) at the same time the cold resistance is measured. Skin

temperature shall be assumed to be the cold winding temperature. This is also known as *temperature cold* (TC).

3) Run the motor at design speed, voltage, and motor load until the energized winding resistance stabilizes.

4) Every 15 minutes record the following until the winding resistance stabilizes:

   - Input motor power (kW).
   - Fluid temperature entering the motor (°C). This is also known as *temperature hot* (TH).
   - Energized winding resistance. Also known as the *hot resistance* (RH).

5) Once the energized winding resistance has stabilized, calculate the *winding temperature rise* (WTR) with the following equation:

$$WTR = \frac{RH}{RC}(K + TC) - (K + TH)$$

Where:

WTR = Winding temperature rise (°C)

RH = Hot resistance (ohms)

RC = Cold resistance (ohms)

TH = Liquid temperature cooling the motor (°C)

TC = Temperature cold resistance was measured (°C)

K = Constant (234.5 copper winding, 226 aluminum winding)

5.6.6.4 Acceptance

Acceptance shall be agreed upon by the manufacturer and the user. It shall be based on the user's process fluid temperature that is cooling the motor, and the winding temperature rise measured during the test. As long as the winding temperature (WT) is less than the maximum insulation temperature (refer to Section 5.3.3.5) at design load, the winding temperature rise is acceptable. Winding temperature is calculated by the following:

$$WT = WTR + PT$$

Where:

WT = Winding temperature

WTR = Winding temperature rise

PT = Process temperature cooling the motor

5.6.7 Report of test

On completion of any or all of the above tests, a certificate shall be provided to the purchaser stating that the test was completed and that the results met the contract requirements.

Appendix A

Index

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

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

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

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

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Mechanical Seals for Pumps: Application Guidelines

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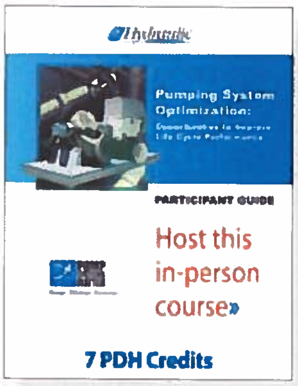

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