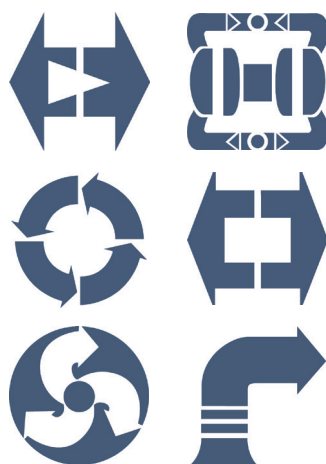




American National Standard for

Pumps General Guidelines

for Materials, Sound Testing, and Decontamination



American National Standard for

Pumps – General Guidelines for Materials, Sound Testing, and Decontamination

Sponsor
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www.Pumps.org

Approved September 28, 2021
American National Standards Institute, Inc.

American National Standard

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Consensus is established when, in the judgement of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution.

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Contents

Page

Foreword	v
9 Pumps – general guidelines for materials, sound testing, and decontamination	1
9.0 Introduction	1
9.0.1 Purpose	1
9.0.2 Scope	1
9.0.3 Units, symbols, and subscripts	5
9.1 Materials	8
9.1.1 Introduction	8
9.1.2 Data on liquids	9
9.1.3 Factors affecting material selection	9
9.1.4 Positive displacement pumps – materials – general designations	16
9.1.5 Rotodynamic pumps – materials – general designation	18
9.1.6 Materials of construction	20
9.2 Measurement of airborne sound	33
9.2.1 Purpose	33
9.2.2 Introduction	33
9.2.3 Instrumentation	33
9.2.4 Operation of pumping equipment	34
9.2.5 Test environment	34
9.2.6 Microphone locations	34
9.2.7 Measurement technique	44
9.2.8 Measurements to be taken	44
9.2.9 Calculation and interpretation of readings	45
9.2.10 Presentation of data	46
9.3 Decontamination of returned products procedure	46
Appendix A Bibliography	49
Appendix B Airborne sound pressure level test report (informative)	51

Figures

9.0.a – Rotodynamic pump types	1
9.0.b — Rotodynamic pump types – overhung impeller	1
9.0.c — Rotodynamic pump types – between bearing	2
9.0.d — Rotodynamic pump types – vertically suspended	2
9.0.e — Rotodynamic pump types – regenerative turbine	3
9.0.f — Rotodynamic pump types – circulator pump	3
9.0.g — Rotary pump types	3
9.0.h — Rotodynamic pump types – sealless	4
9.0.i — Reciprocating power pump types	4
9.0.j — Direct acting (steam) pump types	4

9.0.k — Rotodynamic slurry pump types 5

9.1.3.5.1 — Galvanic series of metals and alloys beginning with the corroded end (anodic, or least noble) 12

9.1.6.19 — General ranking of cavitation erosion resistance of common cast metals. 31

9.1.6.19.3 — General hardness of common overlay materials 32

9.2.6a — Horizontal end suction centrifugal pump 35

9.2.6b — Horizontally split rotodynamic pump. 36

9.2.6c — Vertical in-line centrifugal pump 37

9.2.6d — Double case BB5 pump 38

9.2.6e — Horizontally split multistage rotodynamic pump 39

9.2.6f — Horizontal reciprocating pump. 39

9.2.6g — Vertical reciprocating pump 40

9.2.6i — Horizontal rotary screw pump 41

9.2.6h — Horizontal rotary gear pump. 41

9.2.6j — Vertical rotary pump 42

9.2.6k — VS1-VS7 pumps 43

9.2.6l — VS8 pump 43

Tables

9.0.3 — Preferred measurement units and conversion factors 5

9.1.3.7 — Relative ranking of adhesive wear resistance of wrought materials 14

9.1.6.19 — Comparison of hard-facing application methods 32

9.2.9.1 — Corrections for background noise 45

Foreword (Not part of Standard)

Purpose and aims of the Hydraulic Institute

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

- a) Develop and publish standards.
- b) Address pump systems.
- c) Expand knowledge and resources.
- d) Educate the marketplace.
- e) Advocate for the industry.

Purpose of Standards and Guidelines

- a) HI Standards and Guidelines are adopted in the public interest and are designed to help eliminate misunderstandings between the manufacturer, the purchaser, and/or the user and to assist the purchaser in selecting and obtaining the proper product for a particular need.
- b) Use of HI Standards and Guidelines is completely voluntary. Existence of HI Standards does not in any respect preclude a member from manufacturing or selling products not conforming to the standards.

Definition of a Standard of the Hydraulic Institute

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

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

Definition of a Hydraulic Institute Guideline

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

Comments from users

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

Revisions

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

Disclaimer

This document was prepared by an HI committee and approved by following ANSI essential requirements. Neither the HI, HI committees, nor any person acting on behalf of the HI: 1) makes any warranty, expressed or implied, with respect to the use of any information, apparatus, method, or process disclosed in this document or guarantees that such may not infringe privately owned rights; 2) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this guideline. The HI is in no way responsible for any consequences to an owner, operator, user, or anyone else resulting from reference to the content of this document, its application, or use.

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

Units of measurement

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

Consensus

Consensus for this American National Standard was achieved by use of the canvass method. The following organizations, recognized as having an interest in the standardization of pumps, were contacted prior to the approval of this revision of the standard. Inclusion in this list does not necessarily imply that the organization concurred with the submittal of the proposed standard to ANSI.

Hydraulic, Measurement, & Inspection Consulting	Summit Pump, Inc.
Parametrix, Inc.	Xylem Inc. - Applied Water Systems
Hidrostal	Peerless Pump Company
Intelliquip, Inc.	Leistritz Advanced Technologies Corp.
Stantec	CB&I
West Yost Associates	Irving Oil
Moving Water Industries (MWI)	LVVWD- Las Vegas Valley Water District
Sulzer Pumps Solutions Inc.	Lincus Inc.
Patterson Pump Company	TRWD - Tarrant Regional Water District

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 – Michael Mueller, Flowserve Corporation
Vice-chair – Randy Bennett, Leistritz Advanced Technologies

Committee members

Michael Coussens
Frank Ennenbach
Benjamin Madison
Aleksander Roudnev
Paul Ruzicka
David Skinner
Robert Slattery
Andrew Wolf

Company

Peerless Pump Company
Sulzer Pumps
Grundfos USA
Weir Minerals
Xylem Applied Water Systems
ITT - Industrial Process
Kop-Flex Inc., Regal Beloit America
TACO, Inc.



9 Pumps – general guidelines for materials, sound testing, and decontamination

9.0 Introduction

9.0.1 Purpose

This standard provides general guidelines for rotodynamic and positive displacement pump type classifications, materials of construction, airborne sound measurement, and procedures for decontamination of returned product.

9.0.2 Scope

This standard applies to all industrial/commercial pumps of positive displacement and rotodynamic types. This document covers pump type classifications, materials of construction, airborne sound measurement, and decontamination. Refer to ANSI/HI 14.1 – 14.2 *Rotodynamic Pumps for Nomenclature and Definitions*, ANSI/HI 3.1 – 3.5 *Rotary Pumps for Nomenclature, Definitions, Application, and Operation*, ANSI/HI 6.1 – 6.5 *Reciprocating Power Pumps for Nomenclature, Definitions, Application, and Operation*, ANSI/HI 7.1 – 7.5 *Controlled-volume Metering Pumps*, and ANSI/HI 8.1 – 8.5 *Direct Acting (Steam) Pumps* for the pumps covered in the scope of this document. Figures 9.0.a through 9.0.k show pump type tree diagrams.

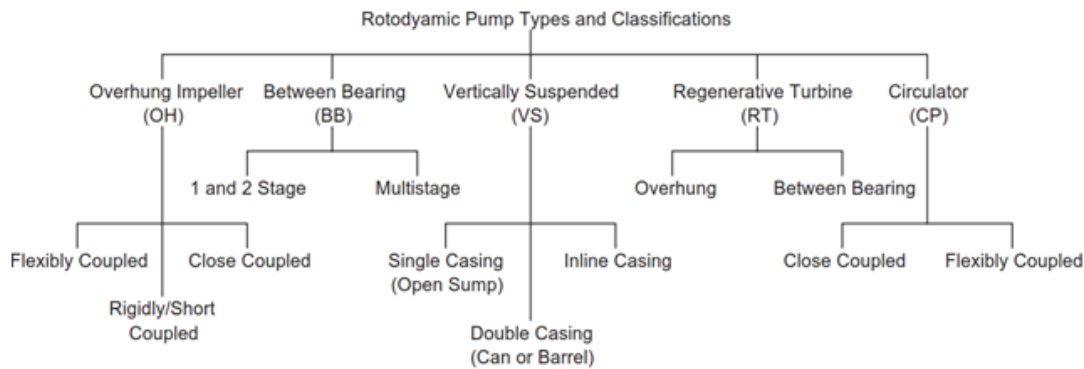


Figure 9.0.a – Rotodynamic pump types

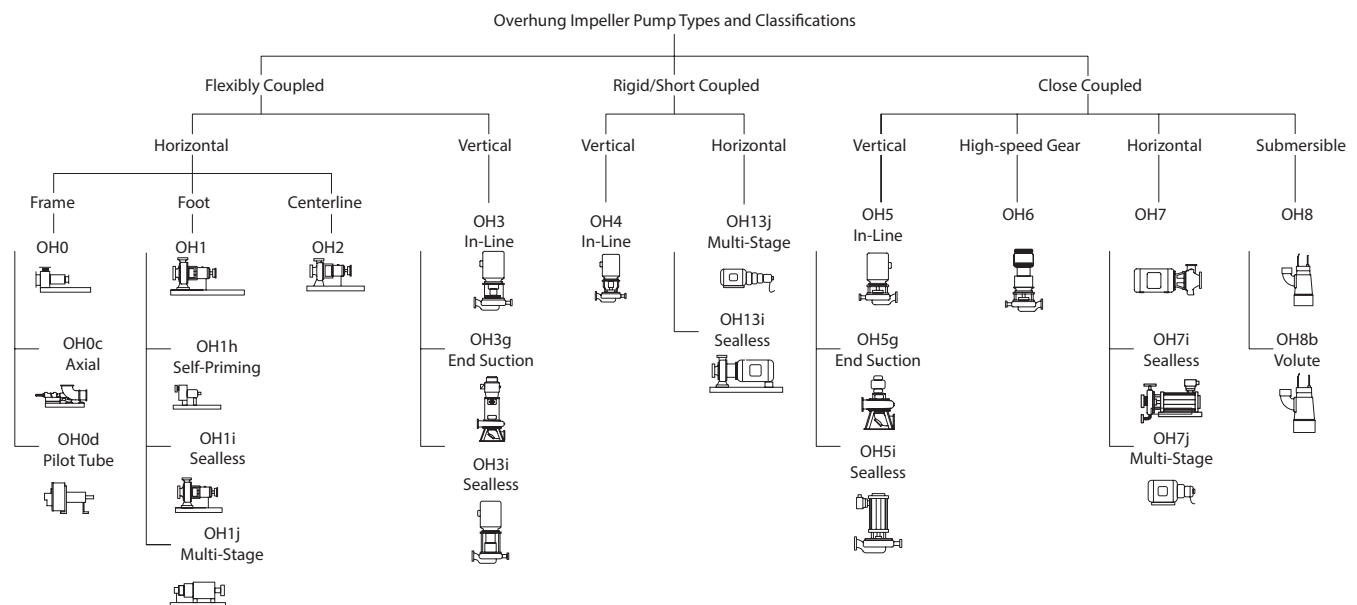


Figure 9.0.b — Rotodynamic pump types – overhung impeller



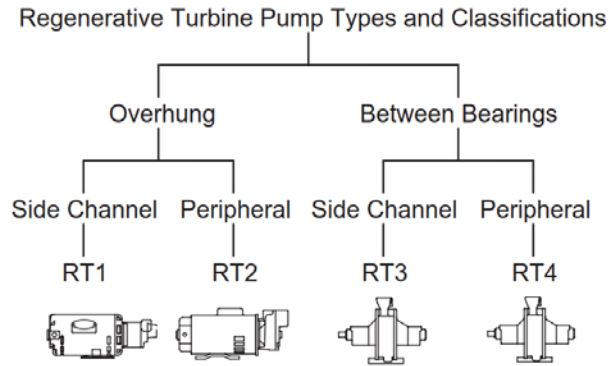


Figure 9.0.e — Rotodynamic pump types – regenerative turbine

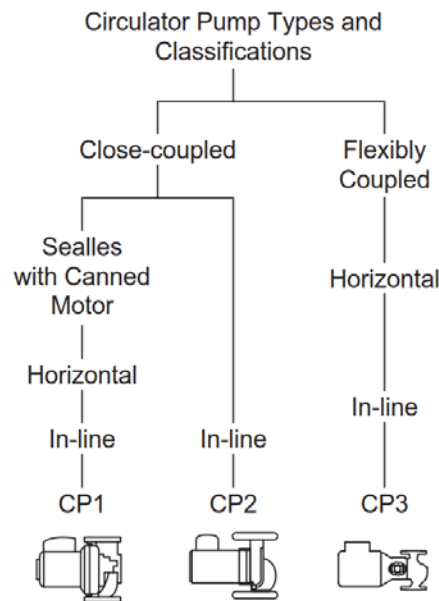


Figure 9.0.f — Rotodynamic pump types – circulator pump

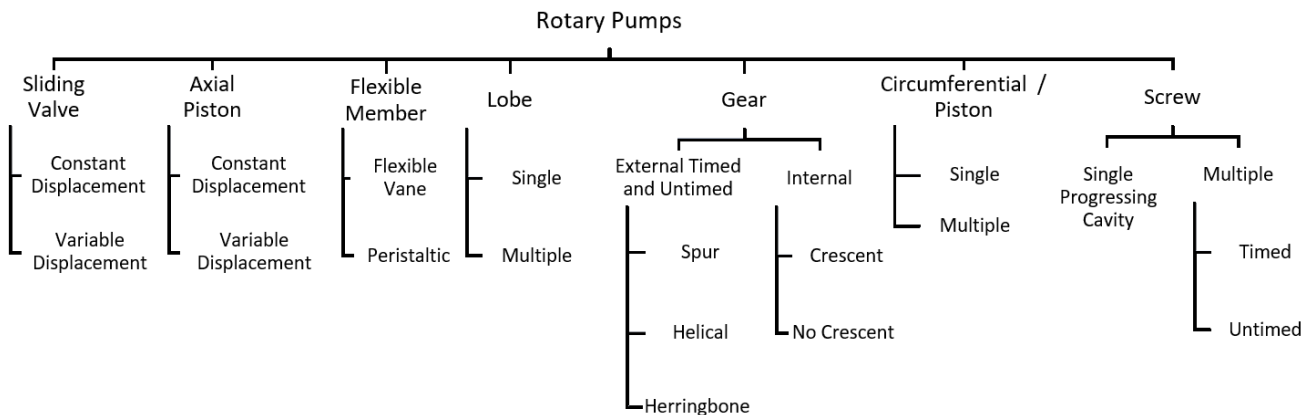


Figure 9.0.g — Rotary pump types

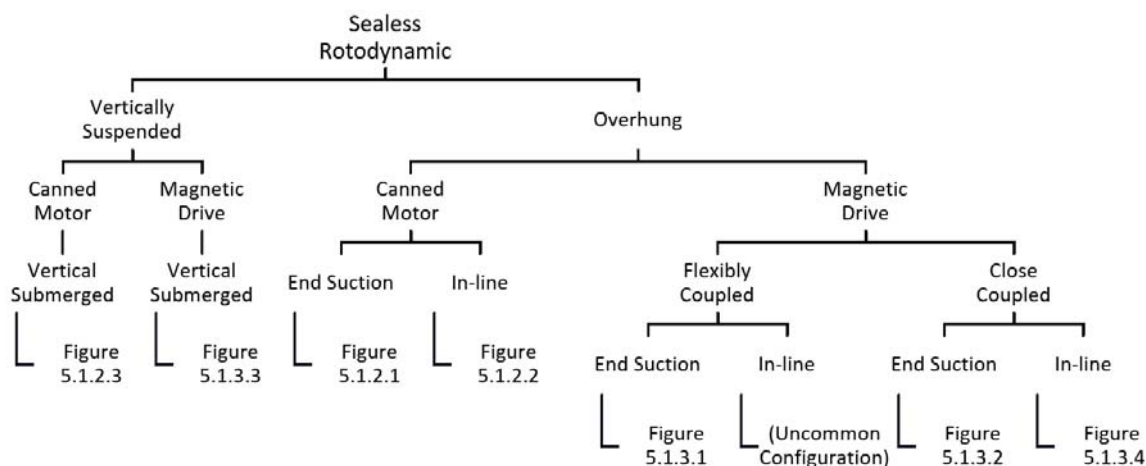


Figure 9.0.h — Rotodynamic pump types – sealless

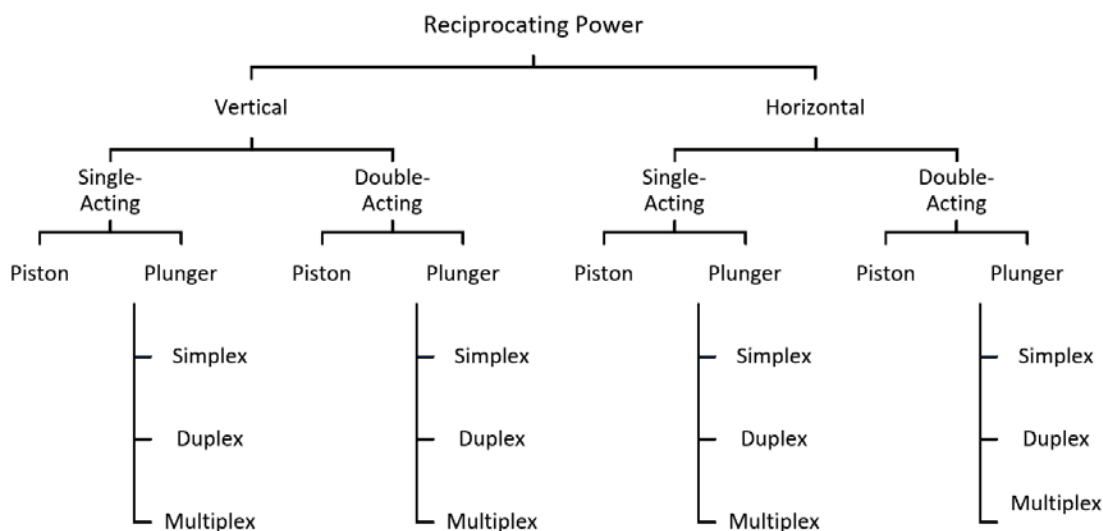


Figure 9.0.i — Reciprocating power pump types

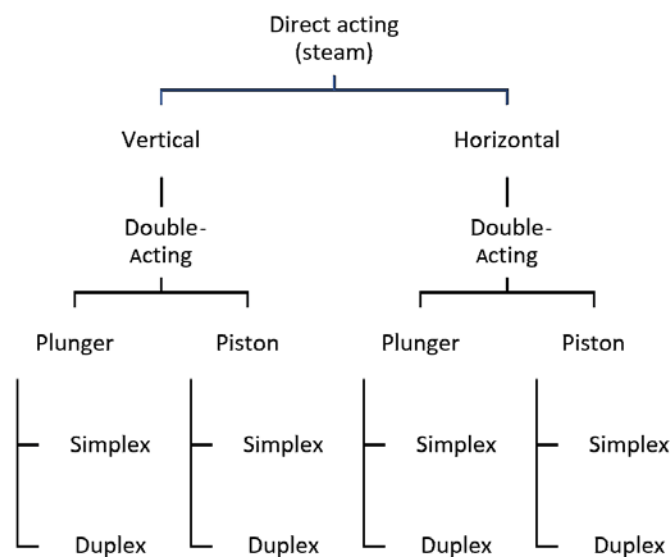


Figure 9.0.j — Direct acting (steam) pump types

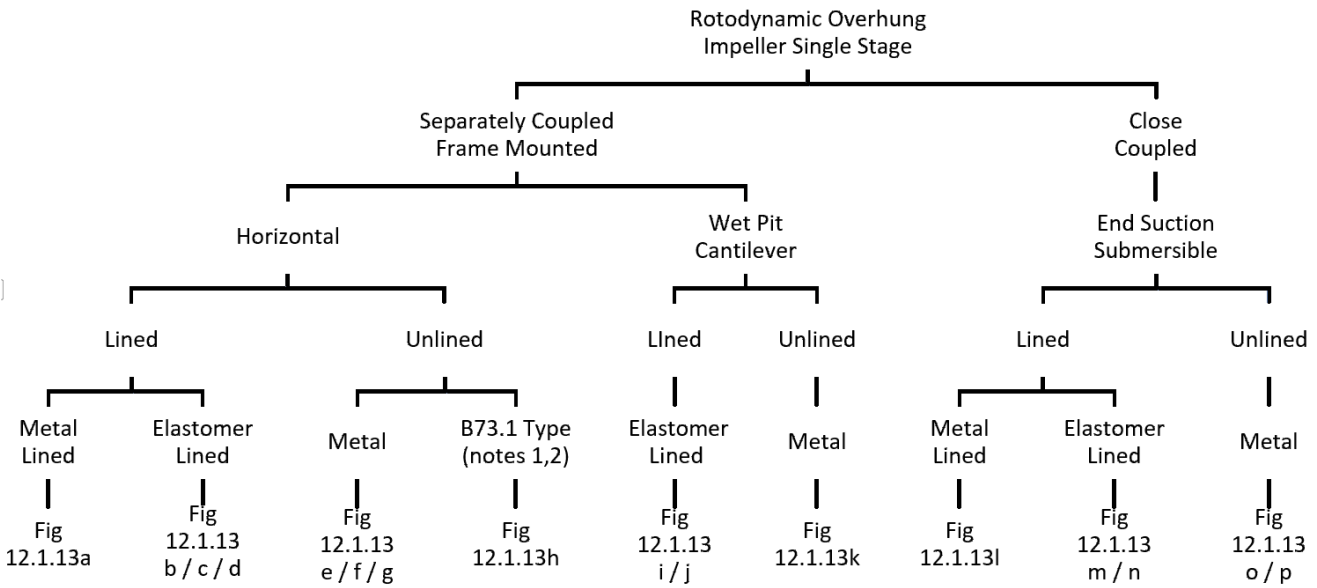


Figure 9.0.k — Rotodynamic slurry pump types

9.0.3 Units, symbols, and subscripts

HI prepared Table 9.0.3 to aid those wishing to convert US customary units to metric units and vice versa.

Table 9.0.3 — Preferred measurement units and conversion factors

Quantity ^a	Typical applications	Metric unit	Abbr.	US customary unit	Abbr.	Conversion factors - multiply by	
						Metric to US unit	US unit to metric
1. Space and time							
plane angle	fluid flow angle	degree	°	degree	°	1 ^b	1 ^b
length	dimensions of sumps and pits	meter	m	foot	ft or ′	3.281	0.3048
		meter	m	inch	in or ″	39.37	0.0254 ^b
	mechanical engineering drawings	millimeter	mm	inch	in or ″	0.03937	25.4 ^b
	coating thickness, surface finish, filter particle size	micrometer	μm	thousandths of inch	mil	0.03937	25.4 ^b
		micrometer	μm	microinch	μin	39.37	0.0254 ^b
		micrometer	μm	micron	μm	1 ^b	1 ^b
area	surface area, flow area	square meter	m ²	square foot	ft ²	10.76	0.09290
		square centimeter	cm ²	square inch	in ²	0.155	6.452
volume	fluid volume rate of flow	milliliter (cm ³) ^c	mL ^d	cubic inch	in ³	0.06102	16.39
		cubic meter	m ³	cubic foot	ft ³	35.31	0.02832
		cubic meter	m ³	gallon	gal	264.2	0.003785
		liter	L	quart	qt	1.057	0.9464

Table 9.0.3 — Preferred measurement units and conversion factors (continued)

Quantity ^a	Typical applications	Metric unit	Abbr.	US customary unit	Abbr.	Conversion factors - multiply by	
						Metric to US unit	US unit to metric
time	time interval	hour	h	hour	h	1 ^b	1 ^b
		minute	min	minute	min	1 ^b	1 ^b
		second	s	second	s	1 ^b	1 ^b
volume per unit time	flow rate of fluids	cubic meter per hour	m ³ /h	gallon per minute	gpm	4.403	0.2271
		liter per minute	L/min	gallon per minute	gpm	0.2642	3.785
velocity, linear	fluid velocity	meter per second	m/s	foot per second	ft/s	3.281	0.3048 ^b
acceleration	gravity	meter per second – squared	m/s ²	foot per second – squared	ft/s ²	3.281	0.3048 ^b
2. Periodic and related phenomena							
frequency	system vibration, sound, alternating current	hertz	Hz	hertz	Hz	1 ^b	1 ^b
speed of rotation	speed of rotation	revolution per minute	rpm	revolution per minute	rpm	1 ^b	1 ^b
3. Mechanics							
mass	equipment mass	kilogram	kg	pound (decimalized)	lb or #	2.205	0.4536
		gram	g	ounce	oz	0.03527	28.35
unbalance	impeller, rotor	gram-millimeter	g•mm	ounce-inch	oz•in	0.001389	720.1
density (mass density)	density of solids and fluids	kilogram per cubic meter	kg/m ³	pound-mass per cubic foot	lbm/ft ³	0.06243	16.02
specific weight (force)	solids and fluids	kilonewton per cubic meter	kN/m ³	pound-force per cubic foot	lbf/ft ³	6.366	0.1571
moment of inertia (dynamic)	rotor inertia	kilogram meter-squared	kg•m ²	pound foot-squared	lb•ft ²	23.73	0.04214
force	applied load	newton	N	pound-force	lbf	0.2248	4.448
fluid energy	head of fluid	meter	m	foot	ft	3.281	0.3048 ^a
moment of force, torque and bending moment	bolt tightening, shaft torque, beam stress and deflection calculations	newton-meter	N•m	pound-force foot	lbf•ft	0.7376	1.356
		newton-meter	N•m	pound-force inch	lbf•in	8.851	0.1130
pressure	fluid pressure or vacuum	kilopascal (kN/m ²)	kPa	pound-force per square inch	psi	0.1450	6.895
		kilopascal	kPa	inch of mercury (60 °F)	inHg	0.2961	3.377
		kilopascal	kPa	inch of water (60 °F)	inH ₂ O	4.019	0.2488
	sound pressure level	pascal (SPL) (P _{ref} = 2 x 10 ⁻⁵ Pa)	Pa	decibel SPL	dB SPL	SPL = 20 log (P/P _{ref})	P = P _{ref} x 10 ^(SPL/20)

Table 9.0.3 — Preferred measurement units and conversion factors (*continued*)

Quantity ^a	Typical applications	Metric unit	Abbr.	US customary unit	Abbr.	Conversion factors - multiply by	
						Metric to US unit	US unit to metric
stress	unit force	megapascal	MPa ^e	pound-force per square inch	psi	145.0	0.006895
specific speed	rotodynamic pump $\frac{N(Q)^{0.5}}{h^{0.75}}$	$\frac{\text{rpm}(\text{m}^3/\text{s})^{0.5}}{\text{m}^{0.75}}$	n_s	$\frac{\text{rpm}(\text{gpm})^{0.5}}{\text{ft}^{0.75}}$	N_s	51.64	0.0194
suction specific speed	rotodynamic pump $\frac{N(Q)^{0.5}}{\text{NPSH}^{0.75}}$	$\frac{\text{rpm}(\text{m}^3/\text{s})^{0.5}}{\text{m}^{0.75}}$	S	$\frac{\text{rpm}(\text{gpm})^{0.5}}{\text{ft}^{0.75}}$	S	51.64	0.0194
viscosity, dynamic	liquid characteristic	pascal-second	Pa•s	pound-force second per square foot	lbf•s/ft ²	0.02089	47.88
viscosity, kinematic ^f	liquid characteristic	square centimeter per second	cm ² /s	square foot per second	ft ² /s	0.001076	929.0
energy, work (see also heat & electricity)	force times distance	joule (N•m) ^g	J	foot-pound-force	ft•lbf	0.7376	1.356
power (see also heat & electricity)	mechanical power	kilowatt (kJ/s) ^g	kW	horsepower	hp	1.341	0.7457
4. Heat							
temperature	temperature	degree Celsius ^h	°C	degree Fahrenheit	°F	(°C×9/5)+32 ^b	(°F–32)×5/9 ^b
	absolute temperature	degree Kelvin	K	degree Rankine	°R	9/5 ^b	5/9 ^b
heat (energy)	heat input	kilojoule	kJ	British thermal unit	Btu ⁱ	0.9478	1.055
heat flow rate (power)	heat rejection rate, air-conditioning power	watt [(J/s)] ^g	W	British thermal unit per minute	Btu/min	0.05687	17.58
5. Electricity							
electric current	electricity flow	ampere	A	ampere	A	1 ^b	1 ^b
electromotive force	battery potential	volt	V	volt	V	1 ^b	1 ^b
electric resistance	resistors, conductors	ohm	Ω	ohm	ohm	1 ^b	1 ^b
electric conductance	conductors	siemens per meter	S/m	mho per meter	mho/m	1 ^b	1 ^b
electric energy	electric consumption	kilowatt-hour ^j	kW•h	kilowatt-hour	kW•h	1 ^b	1 ^b
electric power	motors	kilowatt	kW	kilowatt	kW	1 ^b	1 ^b

^a As used in ISO-31 and ISO-1000, “quantity” means “measurable property.”

^b Exact.

- ^c Symbols in brackets [] are explanatory only.
- ^d The US Department of Commerce, National Bureau of Standards, has established the capital letter “L” as the preferred unit symbol for liter for the United States.
- ^e Except in very weak materials (for which kPa may be more convenient), or for modulus of elasticity (for which GPa will usually be more convenient).
- ^f Conversion to and from Saybolt Universal Seconds or centistokes can be done from a table and Appendix A of ANSI/HI 9.6.7-2010 in ANSI/HI 9.6.7 or by using the conversion Tool in the HI Engineering Data Library <https://edl.pumps.org/>.
- ^g By using J instead of N•m, the distinction from N•m for moment of force is made apparent.
- ^h Conversion requires a formula, wherein the Fahrenheit temperature is indicated by °F and the Celsius temperature by °C.
- ⁱ All factors in this table are based on Btu-international Table.
- ^j The SI unit for electric energy is watt•second (W•s), which is equal to joule (J). (1 kW•h = 3.6 MJ.)

9.1 Materials

9.1.1 Introduction

Factors that must be considered in the selection of materials for wetted pump components include: user experience, life cycle costs, regulatory agency requirements (e.g., limits on lead content in bronzes in contact with drinking water), required pump life, duty cycle (operating hours per period), corrosive and/or erosive properties of the fluid, hazardous nature or toxicity of the fluid, the potential for cavitation, and the potential for contamination of the fluid. Corrosive and/or erosive properties of fluids may vary with temperature, concentration of chemicals or solids, the properties of the solids, velocity, and the extent of entrained gasses.

Reference the standards listed below for general guidelines on pump construction materials. However, materials listed by these standards are not to be considered required materials for the liquids listed because the standards do not take into account the operating environment and specific pumping liquid. HI presents this material list only as a guide for the user’s consideration.

Clear Water: ANSI/AWWA E103

This standard outlines material selection of horizontal and vertical line-shaft pump components for use with potable water or water that will be treated to become potable. The standard offers a table of pump components and a guideline for suitable material for construction of the components.

Chemical process: ASME B73.1

This standard provides a list of recommended materials for construction of centrifugal pumps for use with chemical processes.

Petroleum handling: API 610

This standard outlines material selection for centrifugal pumps and associated components for use with petroleum and various other hydrocarbons. Specific material class requirements are given for various fluids being pumped based on temperature.

Petroleum handling: API 674

This standard covers the minimum requirements for reciprocating positive displacement pumps for use in petroleum, chemical, and gas industry services. Both direct-acting and power-frame types are included.

Petroleum handling: API 675

This standard covers controlled volume positive displacement pumps for use in the petroleum, chemical, and gas industries. Both packed-plunger and diaphragm types are included.

Petroleum handling: API 676

This standard covers the minimum requirements for rotary positive displacement process pumps and pump units for use in the petroleum, petrochemical, and gas industry services.

National Association of Corrosion Engineers

Refer to the National Association of Corrosion Engineers (NACE) for additional material selection guidelines based on corrosiveness. NACE provides corrosion details for thousands of chemicals and their effects on various metals. It is helpful to use Corrosion Data Survey: Metals Section to determine the average corrosion penetration rate per year based on the chemical and its effect on the prospective metal pump component.

9.1.2 Data on liquids**9.1.2.1 General characteristics**

The guidelines set forth here assume that the pumped fluid is of a commercial quality and a degree of purity commonly available. However, it must be recognized that the presence of a foreign substance, even in small percentages, may, and frequently does, have a profound effect on the corrosiveness and erosiveness of the solution and, hence, on the choice of materials. Various liquid conditions and characteristics are listed in the referenced standards.

9.1.2.2 Effects of temperature and concentration

In some cases, the satisfactory use of a material is restricted to a definite temperature and/or concentration range. Where this is known to occur, the limitations are noted in the referenced standards.

9.1.2.3 Handling high or low temperature liquids

Careful selection of materials and attention to construction details are usually required when handling liquids at temperatures below 0 °C (32 °F) or above 120 °C (250 °F). For material selections, applicable codes and practices of the industry in which the pump is to be used should be consulted.

9.1.2.4 Specific gravity

These data are given in the referenced standards where accurate information is available. Unless otherwise specified, they apply at room temperature.

9.1.2.5 Chemical symbols

The chemical symbols have been included, where available, both as a matter for information and as a means of identification in the event the liquid name is not fully descriptive.

9.1.3 Factors affecting material selection

The materials listed for the various liquids are those that have been specified by the pump users for the principal parts of the pump, such as casing, cylinders, pumping chambers, impellers, rotating elements, or other wetted parts. Where applicable, the American Society for Testing and Materials (ASTM) designations are used. Refer to the ASTM standards or other materials handbooks for the chemical and physical properties of materials.

If reliable performance data are unavailable, then test specimens of like materials suitably exposed to the pumping media may assist in the selection of those most resistant to corrosive attacks. When possible, a plant test using actual flow and temperature condition is preferable to a laboratory test. However, the practical limitations of such tests must be recognized. The difficulty of subjecting a single test specimen to the many variables that may exist in a system is considerable, such as velocity impingement, abrasion, aeration, and galvanic action, any of which may

have an important effect on the result. Nevertheless, helpful information may be obtained through such tests, despite their limitations.

9.1.3.1 Optimize life cost

Operational costs, replacement costs, longevity of service, and repair costs will determine the selection of materials. Standard pump part materials, for example, cast-iron housings and bronze impellers, are the least expensive materials and most readily available items for replacement. Depending on the service, increased corrosion resistance dictates upgrading of materials to levels at which the cost of the equipment is still acceptable to the user in terms of life cycle cost.

9.1.3.2 General design of pumps

The general design of pumps selected for a given service may be any of those shown in the other sections of the HI Standards, and each design has its own standard materials of construction. It is important to be well-guided on the proper design for the service intended, and the materials must be selected accordingly.

9.1.3.3 Properties – chemical and physical

The chemical and physical properties of the material selected must be considered. It is not uncommon to use materials that are not quite up to the corrosion resistance and/or wear resistance required for long-term service. If this is the case, then the user must be prepared to replace or repair components at more frequent intervals. On the other hand, when designing the equipment, physical properties such as the tensile strength and yield strength of the material must be such that failure of the material is not a risk when operating.

The chemical and physical properties of the materials listed by the referenced standard are substantially in agreement with the current ASTM Standards, and the inspection of testing requirements set forth in the ASTM Standards are, in general, applicable. For certain materials, and where direct human exposure to the pressurized component is not a risk, slight leakage through a porous spot when under hydrostatic test, in an otherwise structurally sound casting, may be sealed by impregnation with a sealing medium that, after processing, is not degraded by the liquid to be handled.

NOTE: Impregnation may not be acceptable for certain applications, e.g., hydrocarbons, but may be suitable for services such as seawater.

For certain materials, casting defects may be corrected by welding without impairing the strength or quality of the piece, provided suitable techniques are used. This assumes that any welding or elimination of major defects is done prior to final heat treatment. The latter is particularly important in the case of the more highly alloyed steels intended for use with the more corrosive liquids.

When the liquid to be handled is an electrolyte, combinations of dissimilar metals that may promote galvanic reactions should, where practical, be avoided. The rate of corrosion, where metals widely separated in the galvanic series are used, will depend on such factors as the nature of the electrolyte, temperature, velocity, and, particularly, the relative cathode-anode surface area (see Figure 9.1.3.5.1).

9.1.3.4 Temperature of liquid pumped

High or low temperatures will affect the corrosion resistance and/or the physical properties of many materials. Therefore, it is important that the temperature of the liquid pumped be considered.

Handling liquids at temperatures below 0 °C (32 °F) or above 120 °C (250 °F) usually requires the careful selection of materials and corresponding attention to construction details. For material selections acceptable in the temperature range involved, the applicable codes and practices of the industry in which the pump is to be used should be consulted.

Selection of materials for pumps operating at low temperature should be made only after each component and its function has been considered. Many materials change from ductile to brittle behavior with a decrease in temperature. Although a considerable amount of research has been completed, and many varieties of tests have been developed to evaluate the toughness of metals and the conditions under which this transition takes place, these tests have not yet been able to predict all the variables significant to the problems of embrittlement.

The following generalities may serve as a starting point in the selection of suitable ferritic stainless steel for low-temperature service.

A heat-treated, fine-grain, low-carbon alloy steel with low phosphorus, with nickel and molybdenum, and of moderate hardness, usually offers better notch toughness at low temperatures than do other ferritic steels.

Consideration should also be given to the austenitic stainless steels and to bronzes for possible use in low-temperature pumping applications. Austenitic stainless steels, fully annealed, show improving toughness with decreasing temperature and exhibit no transition point. Most bronzes and all aluminum alloys are not embrittled at low temperatures and may also serve for this type of service, if otherwise suitable for the application.

Other considerations, such as cost, corrosion resistance, availability, erosion resistance, hardness, toughness, and fatigue strength must be carefully considered before the final selection of materials for high- or low-temperature service is made.

9.1.3.5 Galvanic corrosion

Galvanic corrosion may be defined as the accelerated electrochemical corrosion produced when one metal is in electrical contact with another more noble metal, both being immersed in the same corroding medium (called the electrolyte). Corrosion of this type usually results in an accelerated degradation for one member of the couple (anodic) and protection (cathodic) for the other. The protected member, the one that does not corrode, is called the more noble metal. Note that as galvanic corrosion is generally understood, it consists of the total corrosion, which comprises the normal corrosion that would occur on a metal exposed alone, plus the additional amount that is due to contact with the more noble material.

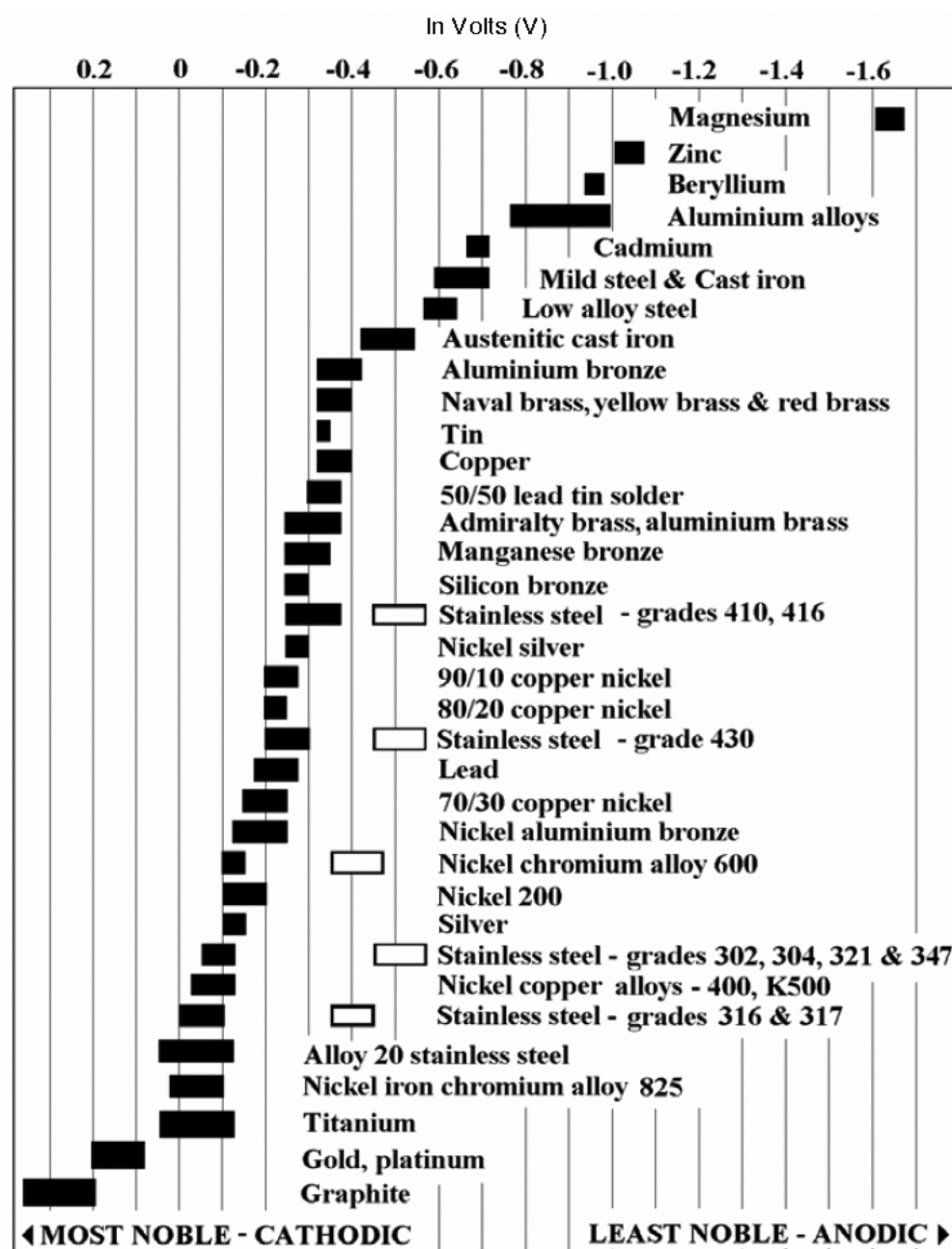
9.1.3.5.1 Galvanic series

With a knowledge of the galvanic corrosion behavior of metals and alloys, it is possible to arrange them in a series that indicates their general tendencies to form galvanic cells and then to predict the probable direction of the galvanic effects. The relative positions of the metals will vary to some extent depending on the electrolyte. Such a series for seawater is illustrated in Figure 9.1.3.5.1.

This series should not be confused with the familiar electromotive series, which is found in many textbooks and is of value in physical chemistry and thermodynamic studies.

Note that some of the metals in the list below are grouped together. These group members have no strong tendency to produce galvanic corrosion on each other. From a practical standpoint, they are relatively safe to use in contact with each other, but the coupling of two metals from different groups and distant from each other in the list will result in galvanic, or accelerated, corrosion of the one higher in the list. The farther apart the metals stand, the greater the galvanic action will be. This may be determined by measurement of the electrical potential difference between them, and this is often done; but it is not practical to tabulate these differences, because the voltage values for combinations of the metals will vary with every different corrosive condition. What actually determines galvanic effect is the quantity of current generated rather than the potential difference.

The relative position of a metal within a group sometimes changes with external conditions, but only rarely do changes occur from group to group. Note that certain metals, such as chromium stainless steel, 400 series (passive), and 18-8 chromium-nickel stainless steel, type 304 (passive), may frequently change positions within the galvanic series. The fluctuation is due to corrosive media and stability of the metal's oxide film. The most important



NOTE: White boxes indicate active behavior of active-passive alloys.

Figure 9.1.3.5.1 — Galvanic series of metals and alloys beginning with the corroded end (anodic, or least noble)