



American National Standard for

Rotary Pumps

for Nomenclature, Definitions, Application and Operation



American National Standard for

Rotary Pumps

for Nomenclature, Definitions,
Application and Operation

Sponsor
Hydraulic Institute
www.Pumps.org

Approved August 30, 2021
American National Standards Institute, Inc.

American National Standard

Approval of an American National Standard requires verification by American National Standards Institute (ANSI) that the requirements for due process, consensus, and other criteria for approval have been met by the standards developer.

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.

The use of American National Standards is completely voluntary; their existence does not in any respect preclude anyone, whether he/she has approved the standards or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standards.

The American National Standards Institute does not develop standards and will in no circumstances give an interpretation of any American National Standard. Moreover, no person shall have the right or authority to issue an interpretation of an American National Standard in the name of ANSI. Requests for interpretations should be addressed to the secretariat or sponsor whose name appears on the title page of this standard.

CAUTION NOTICE: This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken periodically to reaffirm, revise, or withdraw this standard. Purchasers of American National Standards may receive current information on all standards by calling or writing the ANSI.

Published By

Hydraulic Institute
300 Interpace Parkway
Building A, Third Floor
Parsippany, NJ 07054-4406
www.Pumps.org

Copyright © 2021 Hydraulic Institute
All rights reserved.

No part of this publication may be reproduced in any form,
in an electronic retrieval system or otherwise, without prior
written permission of the publisher.

Printed in the United States of America

ISBN 978-1-954671-02-7

Contents

	Page
Foreword	vii
3 Rotary pumps	1
3.0 Introduction	1
3.0.1 Purpose	1
3.0.2 Scope	1
3.0.3 Capability chart	1
3.1 Types and nomenclature	6
3.1.1 Sliding vane (rigid)	7
3.1.2 Axial piston pumps	7
3.1.3 Flexible member	8
3.1.4 Lobe	9
3.1.5 Gear	10
3.1.6 Circumferential piston	12
3.1.7 Screw	12
3.2 Definitions	16
3.2.1 Fluids and liquids	17
3.2.2 Pumping chamber	17
3.2.3 Inlet or suction port	17
3.2.4 Outlet or discharge port	17
3.2.5 Body	17
3.2.6 End plate	17
3.2.7 Stator (Liner)	17
3.2.8 Rotor	18
3.2.9 Bearing	18
3.2.10 Timing gear	18
3.2.11 Rotating assembly	18
3.2.12 Relief valve	18
3.2.13 Stuffing box	19
3.2.14 Gland	19
3.2.15 Packing	19
3.2.16 Lantern ring	19
3.2.17 Seal chamber	19
3.2.18 Mechanical seal	19
3.2.19 Radial seal	19
3.2.20 Direction of rotation	19
3.2.21 Jacketed pump	19
3.2.22 Rate of flow (Q)	20

3.2.23	Displacement (D)	20
3.2.24	Speed (n)	20
3.2.25	Pump volumetric efficiency (η_v)	20
3.2.26	Slip (S)	20
3.2.27	Pressure (p)	20
3.2.28	Pump pressures	22
3.2.29	Net positive inlet pressure available ($NPIPA$)	24
3.2.30	Cavitation	24
3.2.31	Net positive inlet pressure required ($NPIPR$)	24
3.2.32	Power (P)	25
3.2.33	Pump input power (P_p)	25
3.2.34	Pump output power (P_w)	25
3.2.35	Pump torque	25
3.2.36	Pump efficiency (η_p)	26
3.2.37	Multiphase	26
3.2.38	Letter (dimensional) designations	26
3.3	Design and application	36
3.3.1	Temperature (t)	37
3.3.2	Liquid identification and properties	37
3.3.3	Fluid type	37
3.3.4	Entrained or dissolved gases in liquids	38
3.3.5	Viscosity	38
3.3.6	Viscous response types	42
3.3.7	Effect of viscosity on pump and system performance	44
3.3.8	Specific gravity (s)	44
3.3.9	Vapor pressure	45
3.3.10	Effect of vapor pressure on pump performance	45
3.3.11	Other fluid properties	45
3.3.12	Drive specifications	45
3.3.13	Efficiency and energy conservation	45
3.3.14	Duty cycle	46
3.3.15	Other user requirements	46
3.3.16	Slurry applications	46
3.3.17	Rotary pump noise and vibration levels	51
3.3.18	Rotary multiphase pumps in oil and gas application	53
3.3.19	Data sheet	54
3.4	Installation, operation, and maintenance	54
3.4.1	Shipment inspection	54
3.4.2	Storage	58
3.4.3	Installation	58

3.4.4	Operation	68
3.4.5	Maintenance	70
3.4.6	Malfunctions: cause and remedy	71
3.5	Reference and source material	74
3.5.1	ASTM	74
3.5.2	Hydraulic Institute	74
3.5.3	3-A Sanitary Standards	75
3.5.4	API	75
3.5.5	Igor J. Karassik, et al	75
3.5.6	Cameron Hydraulic Data	75
Appendix A	Index	76
Figures		
3.0.3b	— Rotary pump consolidated range chart (metric units)	4
3.0.3c	— Rotary pump consolidated range chart (US customary units)	5
3.1	— Types of rotary pumps	6
3.1.1	— Sliding vane pump	7
3.1.2	— Axial piston pump	7
3.1.3.1	— Flexible vane pump	8
3.1.3.2	— Flexible tube pump (peristaltic)	9
3.1.4a	— Single-lobe pump	9
3.1.4b	— Three-lobe pump	10
3.1.5.1	— External gear pump	10
3.1.5.2a	— Internal gear pump (with crescent)	11
3.1.5.2b	— Internal gear pump (without crescent)	11
3.1.6	— Circumferential piston pump	12
3.1.7.1	— Single-screw pump (progressing cavity)	12
3.1.7.2.1	— Two-screw pump (timed)	13
3.1.7.2.2a	— Three-screw single end pump (untimed)	14
3.1.7.2.2b	— Three-screw double end pump (untimed)	14
3.2.38a	— Internal gear pump (foot mounting)	27
3.2.38b	— Internal gear pump (flange mounting)	27
3.2.38c	— Internal gear pump (frame mounting)	28
3.2.38d	— Internal gear pump (close coupled)	28
3.2.38e	— External gear pump (flanged ports)	29
3.2.38f	— External gear pump (threaded ports)	29
3.2.38g	— External gear pump on base plate	30
3.2.38h	— Timed screw pump on baseplate	31
3.2.38i	— Untimed screw pump	32
3.2.38j	— Lobe pump	33

3.2.38k — Vane pump	34
3.2.38l — Stuffing box or seal chamber	35
3.3 — Flow vs. Pressure for PD pumps	37
3.3.4a — Effect of entrained gas only on liquid rate of flow of rotary pumps (metric units)	39
3.3.4b — Effect of entrained gas only on liquid rate of flow of rotary pumps (US customary units)	39
3.3.4d — Effect of dissolved gas only in saturated solution on liquid rate of flow of rotary pumps (US customary units)	40
3.3.4c — Effect of dissolved gas only in saturated solution on liquid rate of flow of rotary pumps (metric units)	40
3.3.13 — Specified conditions: constant speed, constant pressure	47
3.3.16.1.4 — Materials hardness	48
3.3.16.1.6 — Typical slurry system conversion curve	49
3.3.16.2 — Differential pressure versus pump input power	49
3.3.19 — Suggested rotary pump application data sheet	55
3.4.3.3 — Typical foundation bolts	60
3.4.3.6 — Leveling and grouting	61
3.4.3.8 — Types of misalignment	62
3.4.3.10 — V-belt sheave and synchronous sprocket alignment	64
3.4.3.11 — Pipe-to-pump alignment	65
Tables	
3.0.3a — Capability table – Metric	2
3.0.3b — Capability table – US customary units	3
3.2a — Symbols and terminology	16
3.2b — Subscripts	17
3.3.5.4.1 — Viscosity of common fluids	41
3.4.6 — Malfunctions: Cause and remedy	71

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.

Leistritz Advanced Technologies Corp.	HRSD - Hampton Roads Sanitation District
Petrofac	WC Livoti Consulting
Hydraulic, Measurement, & Inspection Consulting	LVVWD- Las Vegas Valley Water District
Company Unknown	Irving Oil
Patterson Pump Company	Kemet Inc.
Moving Water Industries (MWI)	Brown and Caldwell
Summit Pump, Inc.	

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 – Scott Wild, Leistritz Advanced Technologies Corp.
Vice-chair – Kelly Barnes, Boerger LLC

Committee members

Edison Brito
Mark Lawson
Michael Mueller
Alternate members
Randy Bennett
Bryce Wells
Bernhard Wessendorf

Company

PSG, a Dover Company
CIRCOR Pumping Technologies
Flowserve Corporation
Company
Leistritz Advanced Technologies Corp.
Flowserve Corporation
Boerger LLC

3 Rotary pumps

3.0 Introduction

3.0.1 Purpose

This standard sets out requirements, recommendations, and statements to define, select, apply, operate, and maintain rotary pumps. Requirements convey criteria to be fulfilled if compliance with the document is to be claimed and from which no deviation is permitted. Recommendations convey that, among several possibilities, one is particularly suitable, without excluding or prohibiting others.

3.0.2 Scope

This standard applies to industrial/commercial rotary positive displacement pumps. It includes types and nomenclature; definitions; design and application; and installation, operation, and maintenance. It does not include standards on magnetic drives for sealless pumps (see ANSI/HI 4.1-4.6 *Sealless, Magnetically Driven Rotary Pumps for Nomenclature, Definitions, Application, Operation, and Test*) nor rotary pumps primarily used for fluid power applications. For information on rotary pump tests, see ANSI/HI 3.6 *Rotary Pump Tests*.

A comprehensive overview of features and attributes of rotary pumps is presented in Sections 3.1.1 through 3.1.7.2.2, which contain descriptive material covering the basic technologies highlighted in Figure 3.1. These include a description of each configuration, typical applications, and general operating ranges for commercially available designs for viscosity, flow, and pressure. Operating ranges stated represent only a single hydraulic parameter and do not indicate that all maximum conditions can be met simultaneously. Suppliers should be contacted for such details.

3.0.3 Capability chart

The capability tables (see Tables 3.0.3a and b) and consolidated range charts (see Figures 3.0.3b and c) with individual technology descriptions provide an overview of operating ranges and application characteristics for the industrial rotary pumps covered in this document. These ranges are not absolute because custom designs at alternate speeds, clearances, or with special materials may be available based on a thorough understanding of the application between the user and the manufacturer. The maximum parameter listed is only an indication of the range for that parameter and typically not all maximum values can be obtained simultaneously. Relative capabilities (i.e., abrasive handling, shear sensitivity, and pulsation) are highly dependent on application conditions and the pump technology to which the comparison is made. Shear sensitivity relates to the effect the pump has on the liquid. The abrasive handling capabilities ratings allow material enhancements. Consultation with the supplier is recommended to confirm specific application recommendations and to investigate special designs, which are often available to provide unique solutions.

Table 3.0.3a — Capability table – Metric

Pump type	Flow <i>m³/h</i>	Pressure <i>bar</i>	Viscosity <i>cSt</i> (×1000)	Solids <i>cm</i>	Temps. °C	Dry, Self- priming	Wet, Self- priming	Dry running	Reversible	Abrasive handling	Shear sensitive	Pulseless	Power <i>kW</i>
Sliding vane	570	20	220	0.08	200	Y	Y	Y	Y	Fair	Fair	Fair	0.75-190
Piston, axial	70	250	0.44	Clear	60	N	Y	Y	Y (special)	Poor	Poor	Poor	0.75-450
Flexible vane	25	4	22	Clear	90	Y	Y	N	N	Fair	Good	Good	0.15-4
Peristaltic	80	16	44	3.3	80	Y	Y	Y	Y	Excellent	Excellent	Poor	0.1-30
Lobe	1000	28	440	6.35	177	N	Y	Y	Y	Good	Excellent	Fair	0.75-160
Gear, external internal	180	21	4000	0.08	275	Y	Y	Y	Y	Fair	Poor	Good	0.37-110
	340	21	440	0.08	275	Y	Y	Y	Y	Fair	Poor	Good	0.37-110
Circumferential piston	140	31	1000	3.2	275	Y	Y	Y	Y	Good	Excellent	Poor	0.75-150
Progressing cavity	850	70	440	9	205	Y	Y	N	Y	Excellent	Excellent	Excellent	0.1-150
Timed screw	5000	104	990	0.08	371	N	Y	Y	Y	Good	Good	Excellent	3.7-1500
Untimed screw	1200	310	220	Clear	275	N	Y	N	Y (special)	Good	Good	Excellent	0.75-750

Table 3.0.3b — Capability table – US customary units

Pump type	Flow <i>gpm</i>	Pressure <i>psi</i>	Viscosity <i>SSU</i> (million)	Solids <i>in.</i>	Temps. °F	Dry, Self- priming	Wet, Self- priming	Dry running	Reversible	Abrasive handling	Shear sensitive	Pulseless	HP range
Sliding vane	2500	290	1.0	1/32	400	Y	Y	Y	Y	Fair	Fair	Fair	1-250
Piston, axial	300	3600	0.002	Clear	140	N	Y	Y	Y (special)	Poor	Poor	Poor	1-600
Flexible vane	110	60	0.1	Clear	195	Y	Y	N	N	Fair	Good	Good	0.2-5
Peristaltic	350	230	0.2	1.3	175	Y	Y	Y	Y	Excellent	Excellent	Poor	0.05-40
Lobe	4400	260	2.0	2.5	350	N	Y	Y	Y	Good	Excellent	Fair	1-210
Gear, external internal	800	300	18.5	1/32	525	Y	Y	Y	Y	Fair	Poor	Good	1-150
	1500	300	2.0	1/32	525	Y	Y	Y	Y	Fair	Poor	Good	1-150
Circumferential piston	600	450	4.5	1.25	525	Y	Y	Y	Y	Good	Excellent	Poor	1-200
Progressing cavity	3750	1040	2.0	3.5	400	Y	Y	N	Y	Excellent	Excellent	Excellent	0.1-200
Timed screw	22,000	1500	4.5	1/32	700	N	Y	Y	Y	Good	Good	Excellent	5-2000
Untimed screw	5300	4500	1.0	Clear	500	N	Y	N	Y (special)	Good	Good	Excellent	1-1000

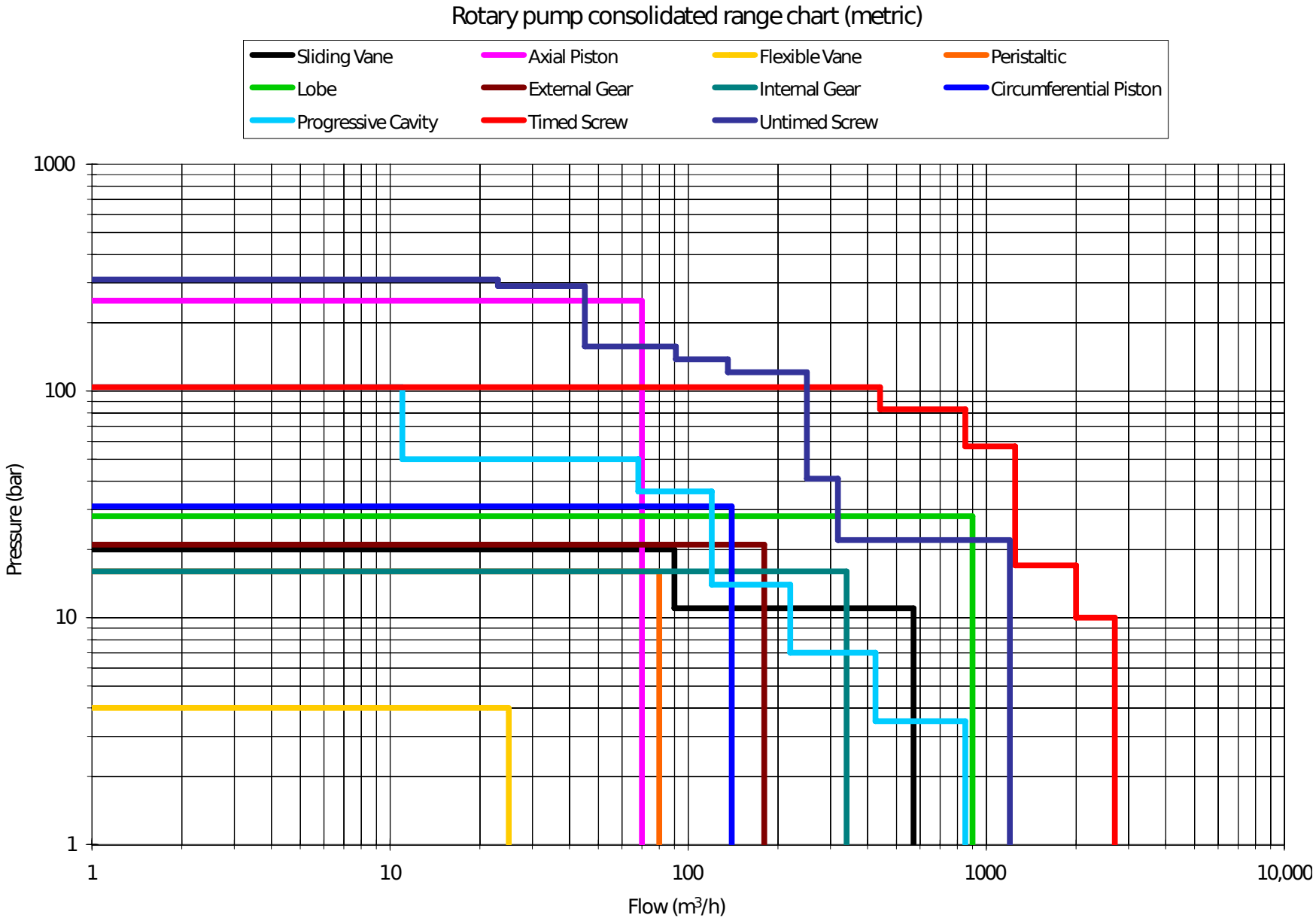


Figure 3.0.3b — Rotary pump consolidated range chart (metric units)

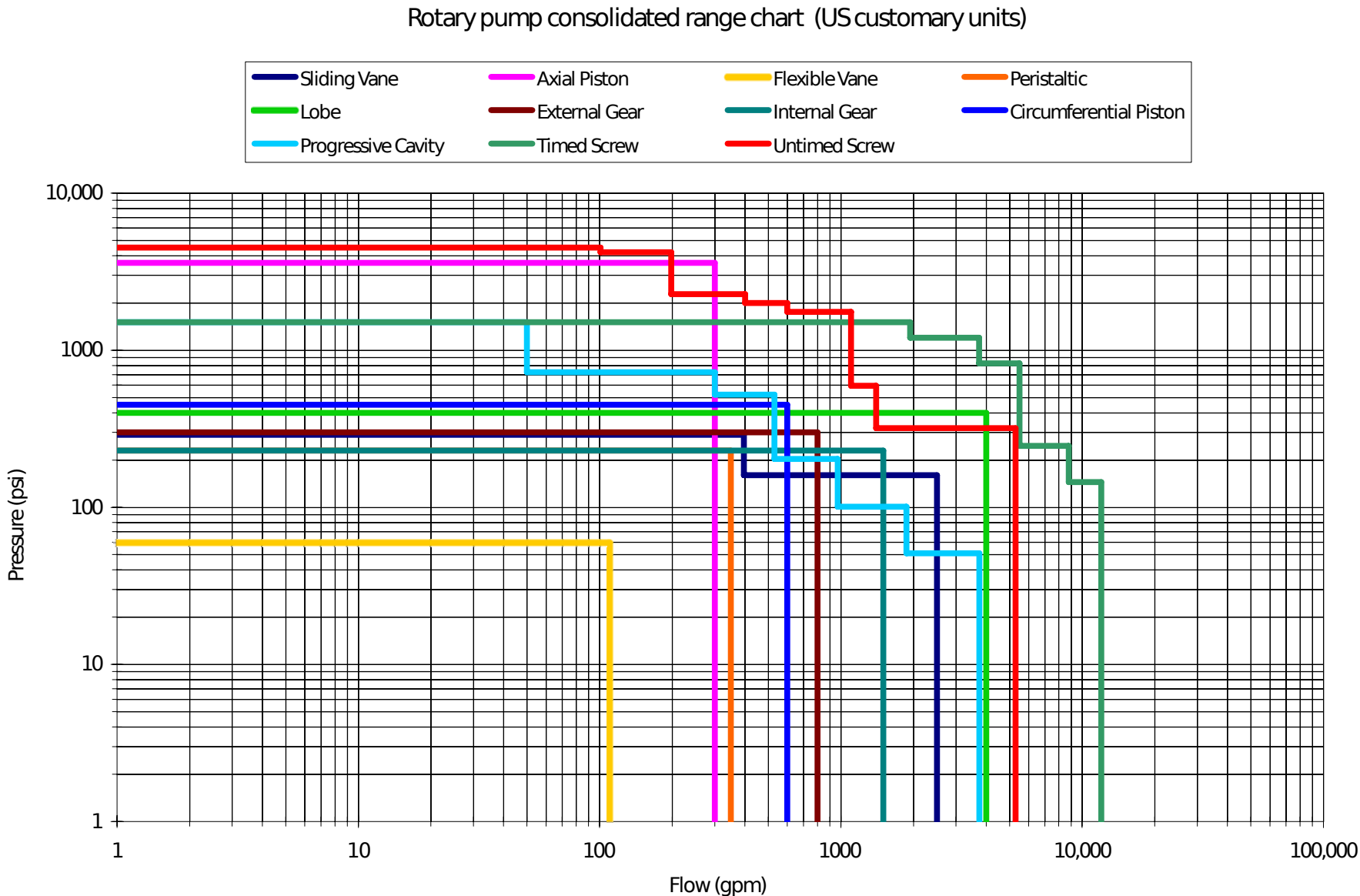


Figure 3.0.3c — Rotary pump consolidated range chart (US customary units)

3.1 Types and nomenclature

A rotary pump is a positive displacement pump consisting of a chamber containing gears, cams, screws, vanes, plungers, or similar elements actuated by relative rotation of the drive shaft to casing, and which has no separate inlet and outlet valves. These pumps are characterized by their close running clearances.

There are seven common basic types of rotary pumps identified by the type of pumping element. Relationships between these types of pumps are illustrated in Figure 3.1.

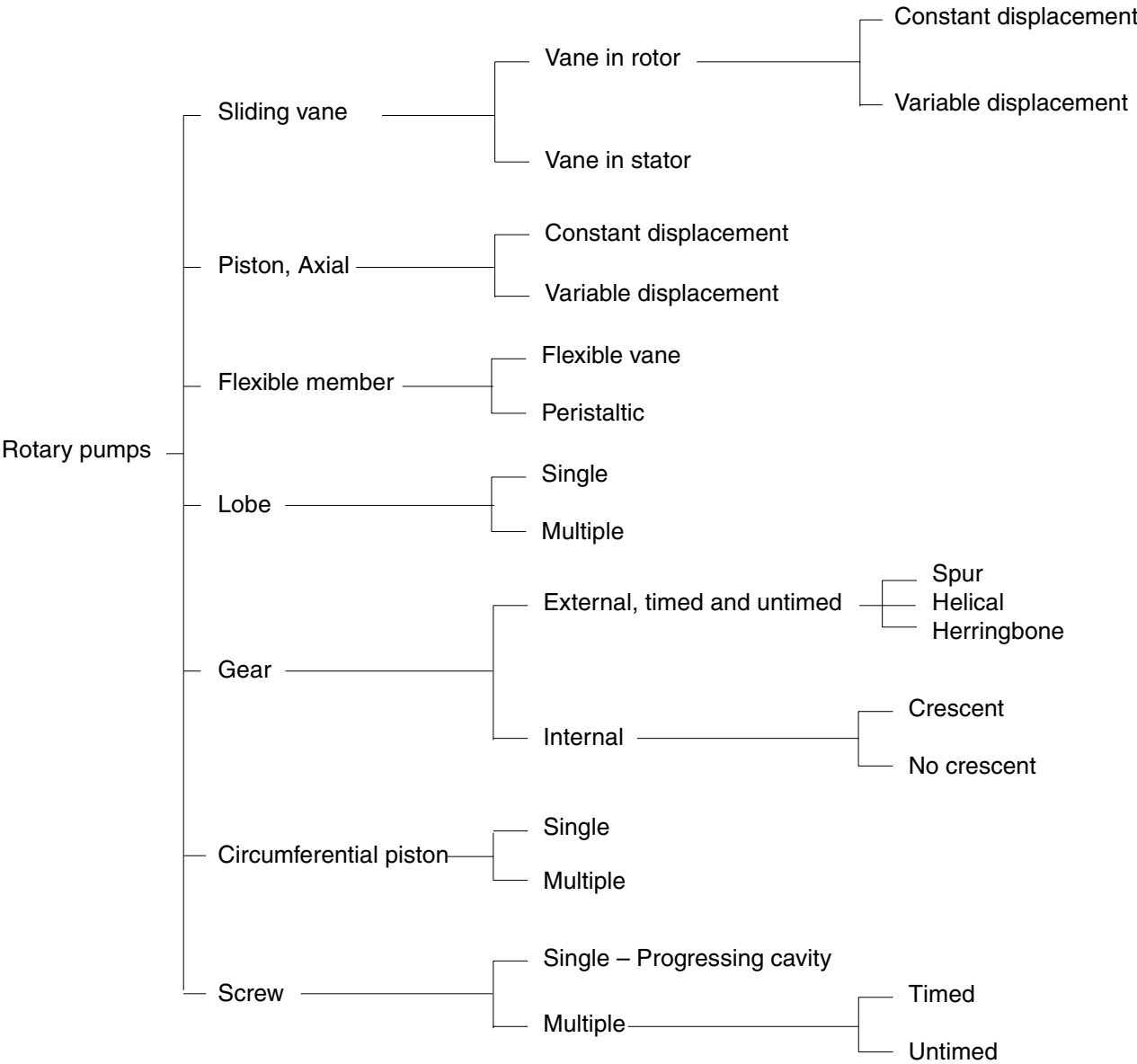


Figure 3.1 — Types of rotary pumps

3.1.1 Sliding vane (rigid)

In this rotary pump technology, a rotor moves the vane or vanes, thereby drawing fluid into, and forcing fluid out from, the pumping chamber formed in cooperation with the pump casing. These pumps are made with vanes in the rotor and with radial hydraulic forces balanced or unbalanced on the rotor. Figure 3.1.1 illustrates a vane-in-rotor, constant-displacement unbalanced pump. Vane-in-rotor pumps also may be made with variable displacement pumping elements. Design considers that vanes may be either in the rotor or stator; however, vane-in-rotor is the most common arrangement, widely used by vane pump manufacturers.

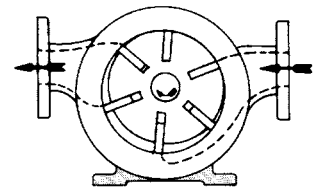


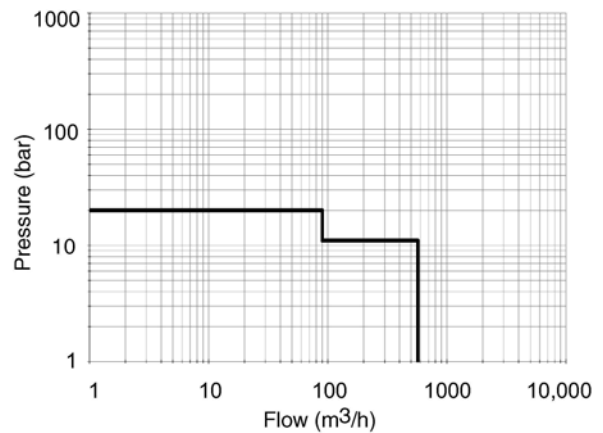
Figure 3.1.1 — Sliding vane pump

A common design has several vanes that are free to move into and out of slots in the pump rotor, which is inside an eccentrically shaped casing that acts as a cam. In this design, when the driver turns the rotor, centrifugal forces, internal pusher rods, and/or pressurized fluids cause the vanes to move outward in their slots and bear against the inner bore of the pump, forming pumping chambers. As the rotor revolves, fluid flows into the area between the vanes (pumping chambers) when they pass the suction port. The fluid is transported around the pump casing until the discharge port is reached. At that point the fluid is squeezed out into the discharge piping.

In variable capacity designs, displacement of the pump is changed by mechanical movement of the cam ring relative to the rotor. Appropriately configured designs do not need relief valves but simply move the cam to compensate for overpressure until the flow is reduced to zero.

Engineered vane materials make these pumps well-suited for low-viscosity, nonlubricating liquids. Such liquids include solvents, fuel oils, gasoline, refrigerants, and liquefied gas. They handle fluid viscosities ranging from 0.5 to 220,000 centistokes (cSt) (1,000,000 Seconds Saybolt Universal [SSU]), which are used in a wide range of industries from aviation and automotive to textile. In proper configurations they can be used for fluid temperatures from -40 °C (-40 °F) to 204 °C (400 °F) and pressures to 20 bar (290 pounds per square inch [psi]).

Sliding vane pump range chart



At volumes below 23 cubic meters per hour (m^3/h) (100 gallons per minute [gpm]), direct-coupled operation up to 1800 RPM is possible using a four-pole motor. In general, for larger flows up to $570 \text{ m}^3/\text{h}$ (2500 gpm), design rotating speeds are typically below 600 revolutions per minute (rpm). Because of their versatility they are available in a wide range of materials, such as stainless steel, nodular iron, cast iron, bronze, and aluminum.

3.1.2 Axial piston pumps

In this pump type, fluid is drawn in and forced out by multiple pistons that reciprocate within cylinders. The reciprocating motion is created by a cam plate that is inclined at an angle with the pump centerline and does not rotate. One end of each piston is held in contact with the cam plate as the cylinder block and piston assembly rotates with the driveshaft. This causes the pistons to reciprocate within the cylinders. The length of the piston stroke is proportional to the angle that the cam plate makes with the pump centerline. Valving is accomplished by rotation of the pistons and cylinders over the inlet and outlet ports.

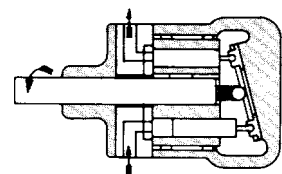
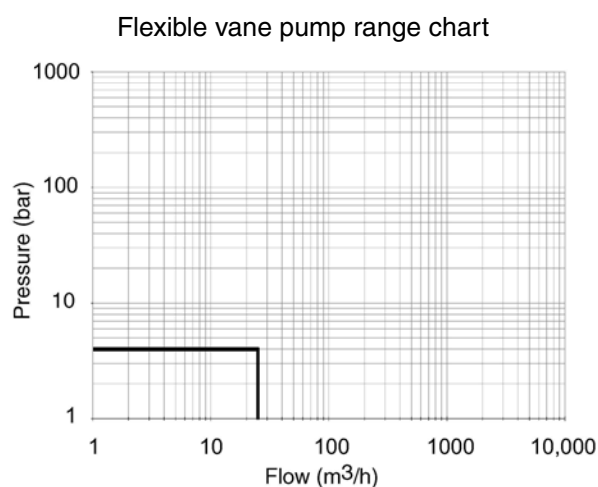
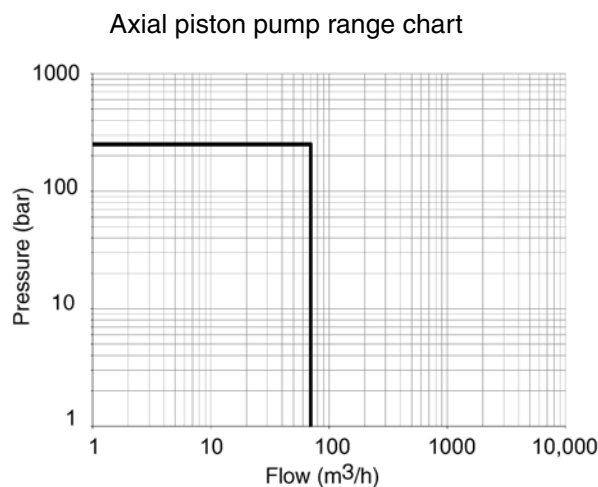


Figure 3.1.2 — Axial piston pump

In fixed displacement axial piston pumps, the angle of the cam plate with respect to the pump centerline is fixed. In variable displacement axial piston pumps the angle of the cam plate with respect to the pump centerline can be varied.

Axial piston pumps have relatively low flow rates, 70 m³/h (300 gpm), but can operate at pressures to 250 bar (3600 psi). Typical applications include the spraying of clean fluids or high-pressure pumping of lubricants. This type of pump will typically operate at synchronous motor speeds. Figure 3.1.2 illustrates a fixed displacement axial piston pump.



3.1.3 Flexible member

3.1.3.1 Flexible vane

Another member of the rotary family is the flexible vane pump (sometimes categorized as a flexible impeller pump). These designs have a typical range up to 25 m³/h (110 gpm) and a maximum pressure capability of 4.1 bar (60 psi). They perform a wide variety of transfer duty applications for low-viscosity fluids up to 22,000 cSt (100,000 SSU). Temperature capabilities typically extend to 90 °C (195 °F) fluids.

The pump uses an elastomer rotating member with enlarged vane tips that form a pumping chamber in conjunction with a casing when the rotor is placed with the shaft centered in the substantially circular casing that incorporates an eccentric section. Discharge forcing action is accomplished as the vane bends in the eccentric section, effectively squeezing liquid from the discharge chamber. This design is shown in Figure 3.1.3.1.

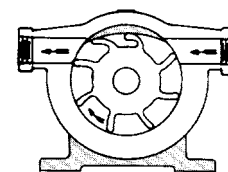


Figure 3.1.3.1 — Flexible vane pump

Because of the variety of applications, stationary components are available in various materials, including stainless steel, bronze, steel, cast iron, and nonmetallic. Flexible members are correspondingly available in a broad range including neoprene, nitrile, EPDM, and Viton®.* Some designs have hygienic certifications, and magnetic drive models are available. This allows a very broad range of industries to be served, from food, beverage, and pharmaceuticals; to chemical and paints; to recreational marine. Flexible vane pumps are typically direct-coupled to the drivers and operate at synchronous motor speeds.

* Viton® is a registered trademark of DuPont Performance Elastomers.

3.1.3.2 Peristaltic

In this type, the fluid pumping and sealing action depends on the elasticity of the flexible member. The flexible member may be a tube or a liner. This type of pump is illustrated in Figure 3.1.3.2. The most common type of flexible member pump is the peristaltic pump that has a flexible tube compressed between one or more moving rollers or shoes and a fixed track. The track is curved and the rollers or shoes rotate about an axis coincident with the center of the radius of curvature of the track. The roller or shoe compresses the tubing and pushes the fluid in front of the roller or shoe towards the discharge end of the tubing. The tubing behind the roller expands to full shape and fills with more fluid. The most common peristaltic pumps have two or three rollers or shoes, which maintains closure of the tubing between the suction and discharge ends at all times.

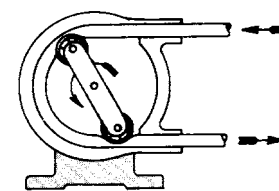
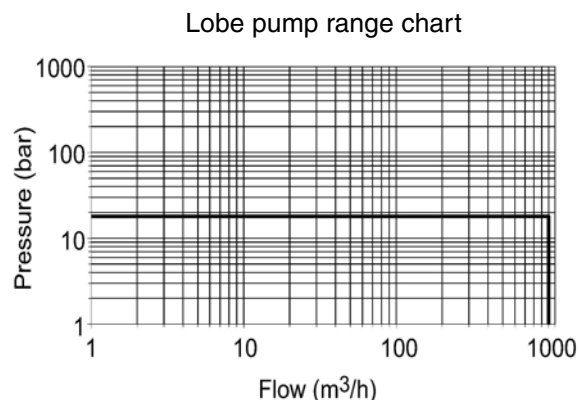
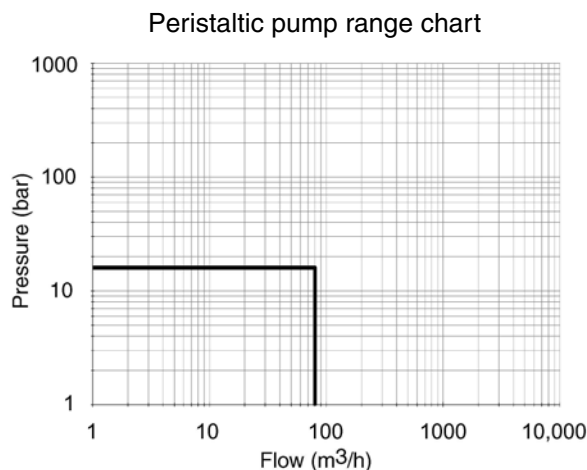


Figure 3.1.3.2 — Flexible tube pump (peristaltic)

The primary advantage of peristaltic pumps is that the fluid contacts only the tubing. Peristaltic pumps are self-priming, do not require seals and valves, and are reversible. They are used in pharmaceutical, chemical, food, and beverage production, and several industrial applications. Small peristaltic pumps are used in various medical applications, and the industrial models can be used for pumping slurries, abrasive fluids, fluids with solids in suspension, and low- to medium-viscosity fluids. Peristaltic pumps are available with flow rates up to 80 m³/h (350 gpm) and differential pressures to 16 bar (230 psi). The smaller models typically operate at speeds below 200 rpm and the larger models are limited to speeds below 100 rpm.

Because only the tubing contacts the fluid, it is available in a variety of materials to ensure compatibility with the fluid being pumped. The life of the tubing depends on the fluid pumped, differential pressure, pump speed, and tubing material.



3.1.4 Lobe

In this design, the pump has two shafts and the fluid is carried between counter rotating lobe surfaces and the pumping chamber from the inlet to the outlet. The rotor surfaces work together with the pump housing and each other to provide continuous sealing. The rotors must be timed by separate means, which include a timing gear or belt as part of the pump. Each rotor has one or more lobes. Figures 3.1.4a and 3.1.4b illustrate a single- and three-lobe pump, respectively. Two-lobe and four-lobe pumps are also common.

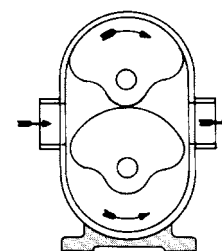


Figure 3.1.4a — Single-lobe pump

Lobe pumps are available in several configurations for a variety of applications and industries. The rotors may be rubber coated; metal with replaceable tips (rubber or metal); hard plastic, or all metal (steel or stainless steel); and come in a variety of shapes and configurations for a wide variety of applications. They can pump a variety of fluids, including most low- to medium-viscosity fluids such as slurries, solids in suspension, and shear-sensitive fluids. If wetted by injecting fluid into the pumping chamber prior to starting, they can self-prime, operate dry for brief periods of time, and handle relatively large solids. They are frequently used to handle food products because of their ability to handle solids without damaging the product and their ability to be readily cleaned.

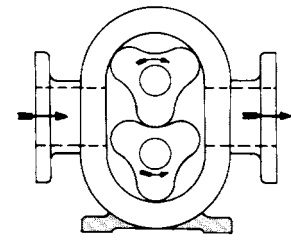


Figure 3.1.4b — Three-lobe pump

Lobe pumps are available in flow rates up to 1000 m³/h (4400 gpm) and can pump fluids with viscosities of 440,000 cSt (2,000,000 SSU). Lobe pumps can operate at temperatures up to 177 °C (350 °F) and differential pressures up to 18 bar (260 psi). Lobe pumps typically operate up to speeds of 600 rpm.

3.1.5 Gear

3.1.5.1 External gear

The external gear pump is a positive displacement pump composed of a casing with two meshing gears with external teeth. One gear is driven by the shaft coupled to a driver. This gear drives the other gear. The rotation of the gears is such that the liquid comes into the inlet port and flows into and around the outer periphery of the two rotating gears. As the liquid comes around the periphery it is discharged to the outlet port (Figure 3.1.5.1). As the viscosity increases, the pump speed is lowered to allow the liquid to fill the space between the rotating teeth. Viscosity range is 2 to 4,000,000 cSt (40 to 18,540,000 SSU).

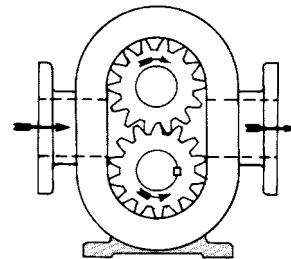
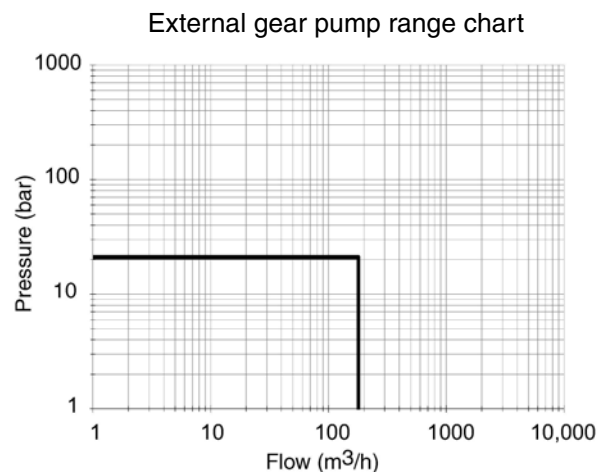


Figure 3.1.5.1 — External gear pump

Most external gear pumps use spur, helical, or herringbone gears. The helical and herringbone gears will deliver more flow and higher pressure. They are quieter than the spur gears but may require more net inlet pressure than a spur gear.

The most common uses for these pumps are to supply fuel oil for burners, gasoline transfer, kerosene, fuel oil, and diesel oil. They are used for hydraulic devices such as elevators and damper controls. They also pump coolants, paints, bleaches, solvents, syrups, glues, lard, greases, asphalt, petroleum, and lube oils and are used in general industrial applications. External gear pumps can handle small suspended solids in abrasive applications but will gradually wear and lose performance. Materials of construction are dictated by the application and are available in cast iron, ductile iron, bronze, cast steel, stainless steel, and higher alloys. Because of their broad application scope, numerous optional designs are available.

Typical performance range is 1 to 180 m³/h (5 to 800 gpm) and 3.5 to 21 bar (50 to 300 psi), however, there are certain designs that are capable of pressures up to 207 bar (3000 psi). Small external gear pumps frequently operate at four-pole motor speeds (1800 rpm) and have operated at two-pole speeds (3600 rpm). Larger pumps will operate at reduced speeds.



3.1.5.2 Internal gear

The internal gear pump is a rotary flow, positive-displacement pump design, which is well-suited for a wide range of applications due to its relatively low speed and inlet pressure requirements. These designs have only two moving parts and have proven reliable, simple to operate, and easy to maintain.

Internal gear pumps have one gear with internally cut gear teeth that mesh with the other gear that has externally cut gear teeth. Pumps of this type are made with (Figure 3.1.5.2a) or without (Figure 3.1.5.2b) a crescent-shaped partition. Based on pump design, either the internally cut or externally cut gear can be the driving gear, and the design can be operated in either direction. Designs are available to provide the same direction of flow regardless of the direction of shaft rotation.

As the gears come out of mesh on the inlet side, liquid is drawn into the pump. The gears have a fairly long time to come out of mesh, allowing for favorable filling. The mechanical contacts between the gears form a part of the moving fluid seal between the inlet and outlet ports. The liquid is forced out the discharge port by the meshing of the gears.

Internal gear pumps are commercially available in product families with flows from 1 to 340 m³/h (5 to 1500 gpm) and discharge pressures to 21 bar (300 psi) for applications covering a viscosity range of 2 to 400,000 cSt (32 to 2,000,000 SSU). Internal gear pumps are made to close tolerances and typically contain at least one bushing in the fluid. They can be damaged when pumping large solids. They can handle small suspended solids in abrasive applications but will gradually wear and lose performance. The application dictates design details and materials of construction and include cast iron, ductile iron, bronze, cast steel, and stainless steel.

Small internal gear pumps frequently operate at four-pole motor speeds (1800 rpm) and have operated at two-pole speeds (3600 rpm). Larger pumps will operate at reduced speeds.

Pinion-drive internal gear pumps are a distinctive subclass with unique operating characteristics. They are typically direct-drive arrangements operating at two-, four-, and six-pole speeds for flows below 45 m³/h (200 gpm) on clear to very light abrasion, low-viscosity, hydrocarbon-based fluids. They are available in single or multistage module designs capable of pressures to 265 bar (4000 psi).

Internal gear pumps are applied in petrochemical, marine, terminal unloading, asphalt, chemical, and general industrial applications for transfer, lubrication, processing, and low-pressure hydraulics handling a wide range of fuel oils, lube oils, and viscous chemicals (both corrosive and noncorrosive).

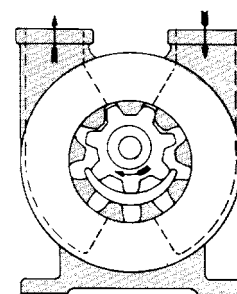


**Figure 3.1.5.2a —
Internal gear pump
(with crescent)**

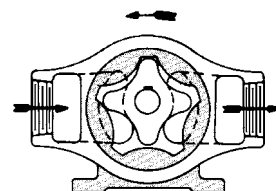
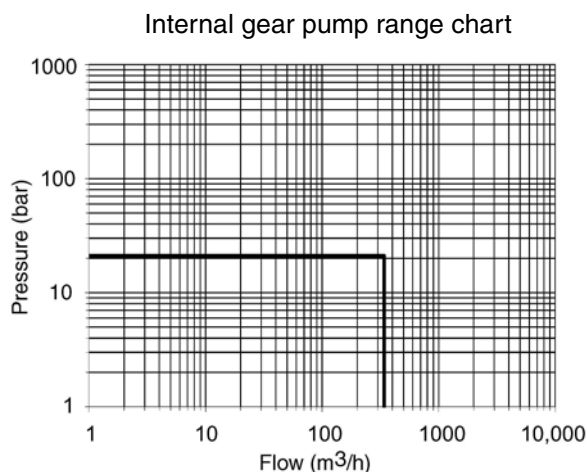


**Figure 3.1.5.2b —
Internal gear pump
(without crescent)**



3.1.6 Circumferential piston

The circumferential piston pump is a rotary flow positive displacement pump design, which is well-suited for a wide range of applications due to its relatively low speed and inlet pressure requirements and large cavities. These designs have only two moving parts within the fluid chamber and have proven reliable. There is no sealing contact between the piston (rotor) surfaces, which distinguishes this design from gear and screw pumps. External timing gears synchronize the circumferential pistons. As the circumferential piston rotates on the inlet side, the expanding volume draws the liquid into the pump. The liquid is forced out the discharge port by the collapsing cavity on the discharge side.

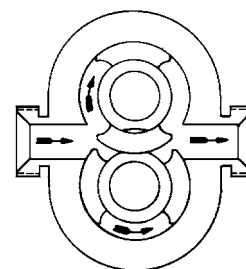


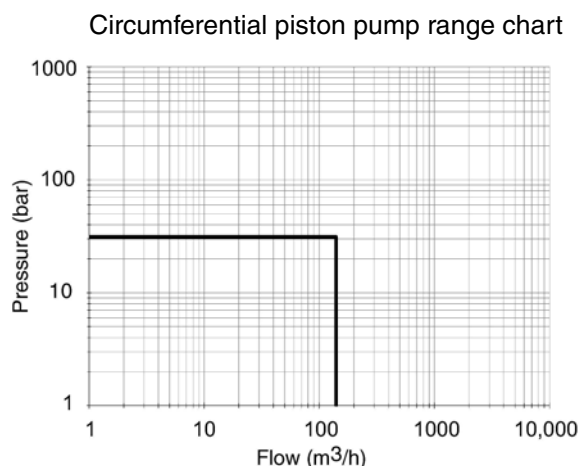
**Figure 3.1.6 —
Circumferential
piston pump**

Circumferential piston pumps are commercially available in product families with flows to 140 m³/h (600 gpm) and discharge pressures to 31 bar (450 psi) for applications covering a viscosity range of 50 to 1,000,000 cSt (200 to 4,500,000 SSU). Circumferential piston pumps are made to close tolerances. They can pump almost any liquid that can be moved and can handle rather large solids and shear-sensitive fluids. They are suitable to run dry for extended periods. Shaft supports often are external from the fluid chamber allowing for higher pressure capabilities. The application dictates materials of construction and include cast iron, ductile iron, cast steel, stainless steel, and many exotic materials.

With smaller circumferential piston pumps, speeds of 1800 rpm are possible. Larger circumferential pumps typically operate at lower speeds.

Circumferential piston pumps are used in petrochemical, paper, marine, wastewater, food processing, tank and terminal unloading, asphalt, chemical, and general industrial applications for transfer and processing handling a wide range of liquids and viscous chemicals (both corrosive and noncorrosive). They are particularly suited for high viscosities, shear-sensitive fluids, and applications that may run dry for a period.

Figure 3.1.6 illustrates a circumferential piston pump.



3.1.7 Screw

In this pump type, fluid is carried in spaces formed by the screw(s) and the screw housing and is displaced axially from suction to discharge as they mesh.

3.1.7.1 Single screw (progressing cavity)

Single-screw pumps (commonly called *progressing cavity pumps*) illustrated in Figure 3.1.7.1, have a rotor with external threads and a stator with internal threads. In the simplest form of progressing cavity pump a single-threaded inner member (rotor) rotates inside a double-threaded outer member (stator). The geometry of the rotor and stator are such that cavities are created between the rotor and stator. In each revolution of the rotor two cavities are formed that progress from one end of the rotor and stator pair to the other end. The geometry of the rotor and stator also causes the rotor to rotate eccentric to the axis of rotation. In most progressing cavity pumps the stator is made of an elastomeric material and the rotor is made of a rigid material. There is a compressive fit between the elastomeric stator and the rotor. Progressing cavity pumps are also available with rigid stators that fit on the rotor with a clearance.

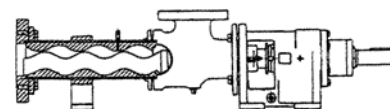


**Figure 3.1.7.1 —
Single-screw pump
(progressing cavity)**

Progressing cavity pumps can pump a wide variety of fluids, from less than 1 cSt viscosity to over 430,000 cSt (2,000,000 SSU) viscosity. They can handle fluids containing abrasives and solid particles up to 9 cm (3.5 in) in diameter, and can handle multiphase fluids with up to 99% gas. They are capable of self-priming and can suction lift fluids up to 8.5 m (28 ft). They can pump practically any fluid that is compatible with the materials of construction. Progressing cavity pumps are available with flow rates up to 850 m³/h (3750 gpm). Standard industrial models are available with differential pressure capabilities up to 70 bar (1040 psi).

Although some of the smaller progressing cavity pump models operate at speeds up to 1800 rpm, most industrial pump models operate at speeds from 150 to 600 rpm. The low operating speeds and rotor and stator design enable progressing cavity pumps to handle delicate and shear-sensitive fluids without damaging the fluid.

3.1.7.2 Multiple-screw pumps

3.1.7.2.1 Timed screw pump

Within this family there are a broad range of mechanical configurations, from standard designs to highly customized special units. Unique designs deal with elements as fundamental as screw forms, casing configuration, and timing gear types. Common among the family, however, are two rotating screws positioned by bearing locations and with synchronizing oil-lubricated timing gear elements on both rotors.

Figure 3.1.7.2.1 illustrates a timed screw pump. Fluid enters at the center inlet, splits axially into two end suction sections, and, as the rotating screws intermesh, chambers are formed trapping and conveying fluid axially to the center discharge of the pump.

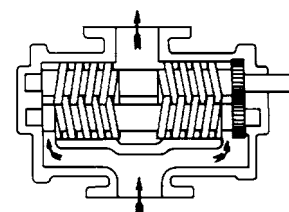


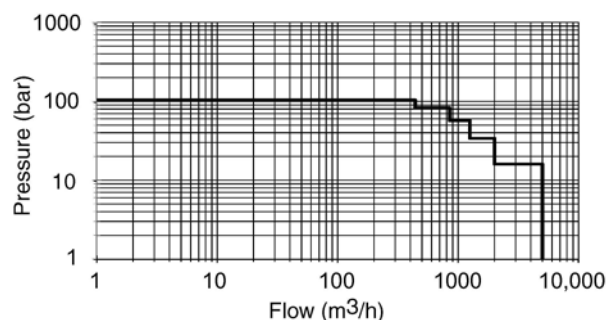
**Figure 3.1.7.2.1 —
Two-screw pump
(timed)**

Products of this design handle a wide range of viscosity from less than 2 to 1,000,000 cSt (33 to 4,500,000 SSU). They also have excellent multiphase capabilities and handle typical contaminants such as found in oil production/pipeline applications. They can be manufactured in a broad range of materials, including those for corrosive applications, making them suitable for chemical industry services. Because of the axial movement of the fluid through the pump and the compact diameter of the rotors, timed screw pumps typically operate at speeds (two-, four-, and six-pole) up to 3600 RPM.

Pressure capabilities to 104 bar (1500 psi) are available for fuel injection and crude oil pipeline services. Flow ranges to 5000 m³/h (22,000 gpm) are available for marine cargo handling, terminals, and transfer pump applications.

Products of this design pump with a minimum of fluid shear also making them suitable for handling non-Newtonian fluids. Temperature capabilities to 371 °C (700 °F) qualify them for selected refinery process applications. They have extremely low net positive inlet pressure required (NPIPR) capabilities for high vapor pressure fluid and multiphase applications.

Timed screw pump range chart



3.1.7.2.2 Untimed screw pump

The untimed rotary screw pump is an axial-flow, multirotor, positive displacement design used in a wide range of applications to pump clean to mildly abrasive viscous liquids. The design may use two, three, four, or five screws. The most common configuration is the three-screw pump, which consists of a power rotor (drive screw) and two symmetrically opposed idler rotors (driven screws) that mesh within a close-fitting housing forming a succession of cavities to continuously convey fluid to the pump discharge.

Untimed screw pumps are available with a single-ended flow path, as shown in Figure 3.1.7.2.2a, or a double-ended flow path, as illustrated in Figure 3.1.7.2.2b. Timing occurs through rotor geometry. In a properly applied three-screw pump, there is no rotor contact because screws are supported radially in their bores and are hydraulically balanced or free to float on a hydrodynamic film created by the pumped liquid. In other untimed screw pump configurations, the screws may be supported in product-lubricated bushings.

Units are commercially available in product families with flows to 1200 m³/h (5300 gpm) and discharge pressures to 310 bar (4500 psi). Applications cover a wide viscosity range from 2 to 220,000 cSt (33 to 1,000,000 SSU) and temperatures from -40 °C (-40 °F) to 274 °C (525 °F). Because of the axial movement of the fluid and the compact diameter of the rotors, untimed screw pumps typically operate at motor speeds (two-, four-, and six-pole). Screw pumps operate with a minimum of noise, vibration, and fluid pulsation. Other characteristics important in many applications are their good suction capability and low shear rate.

The application and product family dictate materials of construction with options available in aluminum, cast iron, ductile iron, carbon steel, alloy steel, bronze, and corrosion-resistant materials. Hardened components may be offered for mildly abrasive applications in which internal wear is a function of the amount and nature of particulate present in the pumped liquid, materials of construction, and operating conditions.

Screw pumps are used in oil field, pipeline, refinery, marine, power generation, chemical, hydraulic systems, and general industrial applications for transfer, lubrication, injection, and hydraulics. The pumps can handle a wide range of fluids, such as fuel oils, lube oils and greases, asphalts, noncorrosive viscous chemicals, and high-pressure coolants.

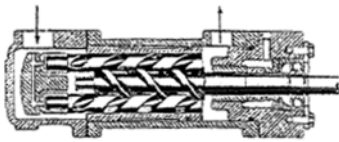


**Figure 3.1.7.2.2a —
Three-screw single end
pump (untimed)**

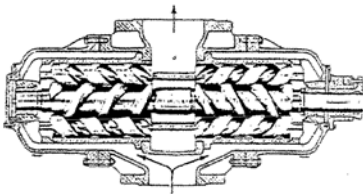
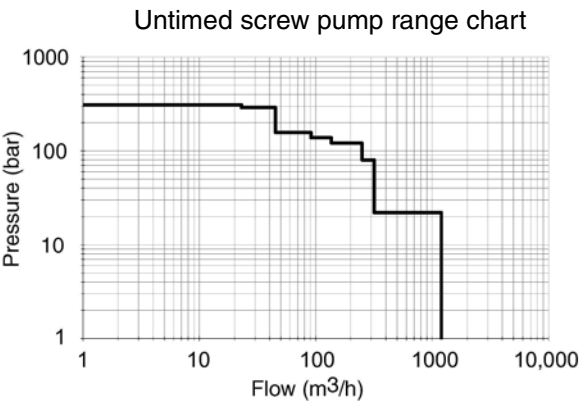


**Figure 3.1.7.2.2b —
Three-screw double end
pump (untimed)**



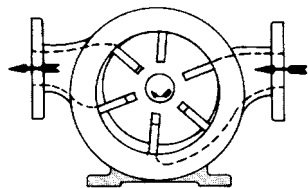


Figure 3.1.1 — Sliding vane pump

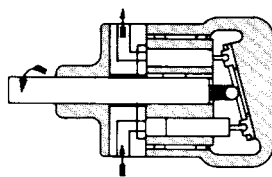


Figure 3.1.2 — Axial piston pump

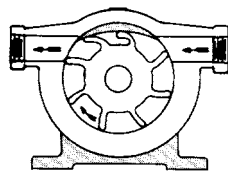


Figure 3.1.3.1 — Flexible vane pump

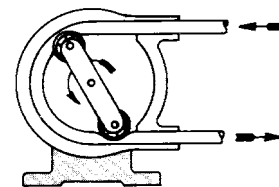


Figure 3.1.3.2 — Flexible tube pump (peristaltic)

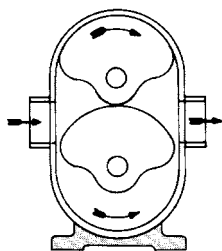


Figure 3.1.4a — Single-lobe pump

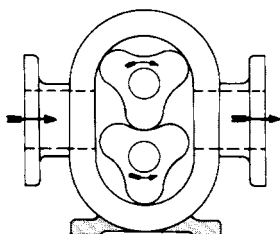


Figure 3.1.4b — Three-lobe pump

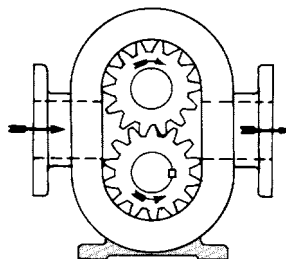


Figure 3.1.5.1 — External gear pump

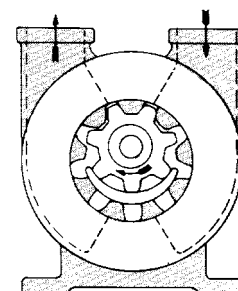


Figure 3.1.5.2a — Internal gear pump (with crescent)

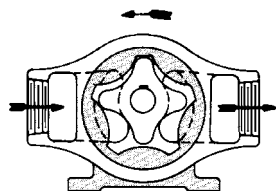


Figure 3.1.5.2b — Internal gear pump (without crescent)

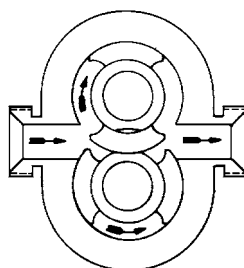


Figure 3.1.6 — Circumferential piston pump

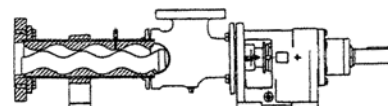


Figure 3.1.7.1 — Single-screw pump (progressing cavity)

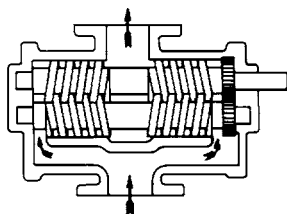


Figure 3.1.7.2.1 — Two-screw pump (timed)

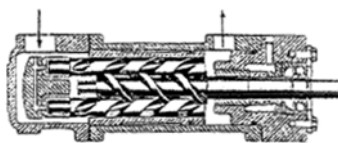


Figure 3.1.7.2.2a — Three-screw single end pump (untimed)

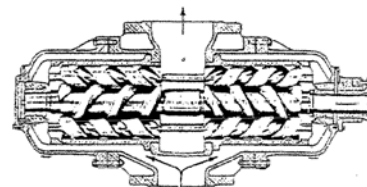


Figure 3.1.7.2.2b — Three-screw double end pump (untimed)

3.2 Definitions

The nomenclature and definitions in these standards identify the various pump components and provide terminology that will be mutually understandable to the purchaser, manufacturer, and anyone writing specifications for pumps and pumping equipment.

Throughout this standard, standard terms and units, applicable to the quantities discussed, are defined in the following paragraphs. Summaries of the terms, subscripts, symbols, and units used throughout this standard are shown in Tables 3.2a and 3.2b.

Table 3.2a — Symbols and terminology

Symbol	Term	Metric Unit	Abbr.	US Customary Unit	Abbr.	Conversion Factor [*]
A	Area	square millimeter	mm ²	square inches	in ²	645.2
D	Displacement	cubic centimeters/revolution	cc/rev	cubic inches/revolution	in ³ /rev	16.39
d	Diameter	millimeter	mm	inches	in	25.4
Δ (delta)	Difference	dimensionless	--	dimensionless	--	1
η (eta)	Efficiency	percent	%	percent	%	1
F	Force	newton	N	pound-force	lbf	4.448
g	Gravitational acceleration	meters/second squared	m/s ²	feet/second squared	ft/s ²	0.3048
γ (gamma)	Specific weight	kilonewtons/cubic meter	kN/m ³	pounds/cubic foot	lb/ft ³	6.37
h	Head	meter	m	feet	ft	0.3048
n	Speed	revolutions/minute	rpm	revolutions/minute	rpm	1
NPIPA	Net positive inlet pressure avail.	kilopascal, absolute	kPa (abs)	pounds/square inch, absolute	psia	6.895
NPIPR	Net positive inlet pressure required	kilopascal, absolute	kPa (abs)	pounds/square inch, absolute	psia	6.895
ν (nu)	Kinematic viscosity	millimeter squared/second	mm ² /s	Seconds Saybolt Universal	SSU	0.216 @ 100° F and > 325 SSU [†]
ν (nu)	Kinematic viscosity	centistokes	cSt	Seconds Saybolt Universal	SSU	0.216 @ 100° F and > 325 SSU [†]
Π	pi = 3.1416	dimensionless	--	dimensionless	--	1
p	Pressure	kilopascal	kPa	pounds/square inch	psi	6.895
P	Power	kilowatt	kW	horsepower	hp	0.7457
Q	Rate of flow (capacity)	cubic meter/hour	m ³ /h	US gallons/minute	gpm	0.2271
s	Specific gravity	dimensionless	--	dimensionless	--	1
t	Temperature	degrees Celsius	°C	degrees Fahrenheit	°F	(°F-32) × $\frac{5}{9}$
τ (tau)	Torque	newton-meter	N•m	pound-feet	lb-ft	1.356
v	Velocity	meters/second	m/s	feet/second	ft/s	0.3048
x	Exponent	none	none	none	none	1
Z	Elevation gauge distance above or below datum	meter	m	foot	ft	0.3048

^{*} Except for temperature, metric units / conversion factor = US customary units.

[†] Refer to ASTM D2161 for viscosity lower than 70 cSt.

Table 3.2b — Subscripts

Subscript	Term	Subscript	Term
a or abs	Absolute	mot	Motor
b	Barometric	OA	Overall unit
d	Outlet (discharge)	p	Pump
g	Gauge	s	Inlet (suction)
im	Intermediate mechanism	t	Theoretical
m	Metering	v	Velocity, volumetric
max	Maximum	vp	Vapor pressure
min	Minimum	w	Water

3.2.1 Fluids and liquids

In these standards, the term *fluid* covers liquids, gases, vapors, and mixtures thereof. The word *liquid* describes only true liquids that are free of vapors and solids. The word *fluid* is more general and describes liquids that may contain, or be mixed with, matter in other than the liquid phase.

3.2.2 Pumping chamber

The pumping chamber or cavity is the space formed by the body and end plate(s), into which fluid is drawn and from which fluid is discharged by the action of the rotor(s).

3.2.3 Inlet or suction port

One or more openings in the pump through which the pumped fluid may enter the pump body.

3.2.4 Outlet or discharge port

One or more openings in the pump through which the pumped fluid may leave the pump body.

3.2.5 Body

The body is an external part that surrounds the periphery of the pumping chamber and that also may form one end plate. It is sometimes called a *casing* or a *housing*.

3.2.6 End plate

An end plate is a part that closes an end of the body to form the pumping chamber. One or more are used, depending on the construction of the pump. It is sometimes called a *head* or *cover*.

3.2.7 Stator (Liner)

The stationary parts of the pump that surround the pumping chamber.

3.2.8 Rotor

A rotor is a part that rotates in the pumping chamber. One or more are used per pump. It is sometimes referred to by a specific name, such as *gear*, *screw*, *lobe*, etc.

3.2.9 Bearing

A bearing is a part that supports or positions the shafts on which a rotor is mounted. A bearing may be internal (wetted by the liquid being pumped) or external and may be either a rolling element bearing (ball or roller) or fluid film type (sleeve and journal).

3.2.10 Timing gear

A timing gear is a part used to transmit torque from one rotor shaft to another and to maintain the proper angular relationship to prevent contact between the meshed rotating elements. It may be outside the pumping chamber and is sometimes called a *pilot gear*.

3.2.11 Rotating assembly

The rotating assembly generally consists of all rotating parts essential to the pumping action but also may include other parts specified by the manufacturer.

3.2.12 Relief valve

A relief valve is a mechanism designed to control or to limit pressure by the opening of an auxiliary passage at a predetermined absolute pressure or differential pressure.

A relief valve may be either integral with the body or end plate or attachable. It may be adjustable through a predetermined range of pressures or have a fixed setting. It may be designed to recirculate the liquid internally from the pump outlet to the pump inlet or externally through an auxiliary port.

Sections 3.2.12.1 through 3.2.12.4 define terms commonly used in specifying relief valve performance.

3.2.12.1 Cracking pressure

Cracking pressure is called *set pressure*, *start-to-discharge pressure*, or *popping pressure*—the pressure at which the relief valve starts to open. This pressure cannot be determined readily in a valve that recirculates the liquid within the pump.

3.2.12.2 Full-flow relief pressure

Full-flow relief pressure is the pressure at which the full output of the pump flows through the valve and the auxiliary passage.

3.2.12.3 Reseating pressure

Reseating pressure is the pressure at which the relief valve closes completely. This pressure is usually below the cracking pressure and is difficult to measure accurately when the liquid is recirculated within the pump.

3.2.12.4 Percent overpressure

Percent overpressure is called *percent accumulation* or *percent regulation*—the difference between full-flow relief pressure and cracking pressure, expressed as a percent of cracking pressure.