ANSI/HI 3.6-2010

Approved American National Standard

ANSI

American National Standard for

Rotary Pump Tests

ANSI/HI 3.6-2010

Hydraulic Institute

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

This page intentionally blank.

ANSI/HI 3.6-2010

American National Standard for

Rotary Pump Tests

Sponsor

Hydraulic Institute

www.Pumps.org

Approved June 24, 2010

American National Standards Institute, Inc.

American National Standard

Approval of an American National Standard requires verification by 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 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 the American National Standards Institute. 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CAUTION NOTICE: This American National Standard may be revised or withdrawn at any time.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 American National Standards Institute.

Published By

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

www.Pumps.org

Printed in the United States of America

ISBN 978-1-880952-81-8

Recycled paper

Contents

This page intentionally blank.

Foreword (Not part of Standard)

Scope

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

a) To develop and publish standards for pumps;

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

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

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

e) To support educational and research activities;

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

Purpose of Standards

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

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

Definition of a Standard of the Hydraulic Institute

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

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

Comments from users

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

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

Revisions

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

Units of measurement

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

Consensus

Consensus for this standard was achieved by use of the canvass method. The following organizations, recognized as having an interest in the Rotary Pump Standard, 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.

A.W. Chesterton
Baldor Electric Company
Bechtel Power Corp.
Black & Veatch Corp.
Colfax Corporation
DuPont
Flowserve Corporation
FSA
GIW Industries
Healy Engineering, Inc.
J.A.S. Solutions Ltd.
Kemet, Inc.
Las Vegas Valley Water District
LyondellBasell
Malcolm Pirnie
McFarland - Tritan LLC
Moyno, Inc.
National Pump Company
Patterson Pump Company
Sulzer Pumps US Inc.
Taco, Inc.
Union Sanitary District
Weir Floway, Inc.
Weir Minerals North America

Committee Members

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:

Chairmen – John W. Owen, IMO Pump
Alan G. Wild, Consultant - Moyno, Inc.

Committee Members	**Company**
Randolph K. Bennett	Leistritz Corporation
Todd E. Brown	Moyno, Inc.
James B. Casey	Milton Roy Americas
Trygve Dahl	Intelliquip, LLC
David G. McKinstry	IMO Pump
Michael L. Mueller	Flowserve Pump Division
Manor M. Parikh	Siemens Water Technologies
John E. Purcell	Roper Pump Company
James K. Simonelli	Roper Pump Company
Fred F. Walker	Weir Floway, Inc.

Other contributors

Name	**Company**
Fred Buse	Consultant
Michael Mulcahy	Tuthill Pump Group
Kathy Parry	formerly of Tuthill Pump Group
Dan Ross	formerly of Tuthill Pump Group

3.6 Rotary pump tests

This standard recognizes various performance test levels designed to permit a reasonable selection of tests, tolerances, and accuracy requirements appropriate for the application and the customer's needs.

Tests of rotary pumps that conform to the requirements of this standard shall be designated as tests conducted in accordance with the Hydraulic Institute Test Standards. Types of performance tests are defined in Section 3.6.2.

These standards apply to rotary pump tests only, unless stated otherwise. Recorded data and the final report may include information on drives and auxiliary equipment, and must be identified as such.

The type of test performed and the auxiliary equipment to be used (purchaser's driver, gearbox, etc.) should be agreed on in writing by all interested parties before the test.

It is the intent of this standard to offer testing procedures to be used by all testing facilities. It is not the intent to limit or restrict tests to only those described herein. Variations in test procedures may exist without violating the intent of this standard. Exceptions may be taken to the provisions of this standard if properly agreed on by the parties involved without sacrificing the validity of the applicable parts of the standard.

Because pumps are used to handle different liquids or liquid/solid mixtures, it is necessary to limit this standard to the testing of pumps with readily available test liquids. For other than normal test liquids, some methods and procedures not outlined herein may be required.

The objective of the standard is to establish a uniform demonstration of a pump's ability to perform satisfactorily both mechanically and hydraulically. The quantitative values observed and recorded will depend on the type of test specified. The quantitative indices are the same for a particular type of test no matter what type of pump is specified.

3.6.1 Scope

This standard recognizes four types of performance tests for rotary pumps and provides procedures for conducting and reporting test data. The test levels have been designed to permit selection of tolerances and accuracy appropriate for the application and the customer's needs. It does not include vibration or acoustical testing.

3.6.2 Type of performance test

The test types below apply to tests on liquids.

I	II	III	IV
Internal quality-assurance test	Rpm Pressure Power	Rpm Pressure Rate of Flow	Rpm Pressure Rate of Flow Power

Type III and IV have two levels of acceptance for the quantitative values. The level of test is to be Level A unless otherwise specified by the user. Refer to Sections 3.6.5.4 and 3.6.5.5.

Optional tests: Hydrostatic test and net positive inlet pressure required test are separate tests and are described in Sections 3.6.6 and 3.6.7.

3.6.3 Net positive inlet pressure required (NPIPR)

NPIPR is the pressure required, above liquid vapor pressure (bubble point), to fill each pumping chamber or cavity while open to the inlet chamber. It is measured at the pump inlet and is expressed in bara (psia).

NPIPR for a rotary pump is difficult to establish with precision because of compounding external influences of fluid properties and dissolved and entrained gas, all of which affect measured NPIPR. The level of dissolved gas is a function of the fluid and its temperature. The level of dissolved gas is also a function of system design operation. Many liquids handled by rotary pumps have an unpredictable or very low vapor pressure (bubble point). Most of these liquids also have entrained and dissolved gas (frequently air). The practical effect of dissolved and entrained gas is to increase the NPIPR in order to suppress the symptoms of cavitation. While true cavitation occurs if the liquid pressure falls below its vapor pressure during filling of the pump cavities, most of the cavitation symptoms will be exhibited before reaching liquid vapor pressure. This is largely due to the entrained and dissolved gas expanding when subjected to reduced pressure.

Normal NPIPR tests are conducted in a test environment that minimizes entrained gas. NPIPR can be established at the first indication of any of the following:

a) A 5% reduction in rate of flow at constant differential pressure and speed.

b) A 5% reduction in power consumption at constant differential pressure and speed.

c) The inability to maintain a stable differential pressure.

d) The onset of loud or erratic noise when these criteria are previously agreed on by all parties.

Reports of NPIPR tests shall state the criteria used to establish NPIPR.

3.6.4 Terminology

The following terms, symbols, units, abbreviations, and definitions are used to designate test parameters or are used in connection with pump testing. For symbols and terminology, and subscripts, refer to Tables 3.6.4a and 3.6.4b, respectively.

3.6.4.1 Rated condition point

Rated condition point applies to the operating conditions, rate of flow, pressure, viscosity, speed, and power, and is to be confirmed by performance testing.

3.6.4.2 Displacement (*D*)

The displacement of a rotary pump is the volume displaced per revolution of the rotor(s). It may be calculated from the physical dimensions of the pumping elements, or it may be determined empirically as the volume of fluid pumped per revolution at zero differential pressure. In pumps incorporating one or more rotors operating at different speeds, it is the volume displaced per revolution of the driving rotor. The standard unit of displacement is cubic centimeter (cubic inch) per revolution. A variable displacement pump shall be rated at its maximum displacement.

3.6.4.3 Rate of flow (*Q*)

The rate of flow of a rotary pump is the volumetric quantity of fluid actually delivered per unit of time, including both the liquid and any dissolved or entrained gases, at stated operating conditions.

In the absence of any vapor entering or forming within the pump, rate of flow is equal to the volume displaced per unit of time, less slip.

3.6.4.4 Speed (*n*)

The speed of a rotary pump is the number of revolutions per minute of the rotor(s). In pumps incorporating two or more rotating elements operating at different speeds, it is the speed of the driving rotor.

3.6.4.5 Slip (*S*)

Slip is the quantity of fluid that leaks through internal clearances of a pump per unit of time. It is dependent on the internal clearances, the differential pressure, the characteristics of the fluid handled, and, in some rare cases, on the speed.

Slip is determined from the following equation:

(Metric units) $$S = \left(\frac{Dn}{16.7 \times 10^3}\right) - Q$$

(US customary units) $$S = \left(\frac{Dn}{231}\right) - Q$$

3.6.4.6 Pump volumetric efficiency (η_v)

The pump volumetric efficiency is ratio of the actual pump rate of flow to the volume displaced per unit of time. The formula for computing volumetric efficiency in percent is:

(Metric units) $$\eta_v = \frac{16.7 \times 10^3 Q}{Dn} \times 100$$

(US customary units) $$\eta_v = \frac{231\,Q}{Dn} \times 100$$

3.6.4.7 Pressure (*p*)

Pressure is the compressive stress in a liquid at a given point. It has the units of force per unit area. Pressure measurements relative to atmosphere will be positive or negative.

3.6.4.8 Absolute pressure (p_a)

The absolute pressure (p_a) is the algebraic sum of gauge pressure (p_g) and barometric pressure (p_b) and may be defined as pressure above zero pressure absolute.

Table 3.6.4a — Symbols and terminology

Symbol	Term	Metric Unit	Abbr.	US Customary Unit	Abbr.	Conversion Factor[a]
A	Area	square millimeters	mm^2	square inches	in^2	645.2
D	Displacement	cubic centimeters/revolution	cm^3/rev	cubic inches/revolution	in^3/rev	16.39
d	Diameter	millimeters	mm	inches	in	25.4
Δ (delta)	Difference	dimensionless	—	dimensionless	—	1
η (eta)	Efficiency	percent	%	percent	%	1
F	Force	newtons	N	pounds-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	0.157
h	Head	meters	m	feet	ft	0.3048
n	Speed	revolutions/minute	rpm	revolutions/minute	rpm	1

Table 3.6.4a — Symbols and terminology (*continued*)

Symbol	Term	Metric Unit	Abbr.	US Customary Unit	Abbr.	Conversion Factor[a]
NPIPA	Net positive inlet pressure avail.	bar absolute	bara	pounds/square inch absolute	psia	0.06895
NPIPR	Net positive inlet pressure required	bar absolute	bara	pounds/square inch absolute	psia	0.06895
ν (nu)	Kinematic viscosity	millimeters squared/second (centistoke)	mm^2/s	Saybolt Seconds Universal[b]	SSU	0.216 @ 100 °F and > 70 cSt (325 SSU)[c]
π	pi = 3.1416	dimensionless	—	dimensionless	—	1
p	Pressure	bar	bar	pounds/square inch	psi	0.06895
P	Power	kilowatts	kW	horsepower	hp	0.7457
Q	Rate of flow (capacity)	cubic meters/hour	m^3/h	US gallons/minute	gpm	0.2271
s	Specific gravity	dimensionless	—	dimensionless	—	1
S	Slip	cubic meters/hour	m^3/h	US gallons/minute	gpm	0.2271
t	Temperature	degrees Celsius	°C	degrees Fahrenheit	°F	$(°F-32) \times \frac{5}{9}$
τ (tau)	Torque	newton-meters	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 of gauge (distance above or below datum)	meters	m	feet	ft	0.3048

[a] Conversion factor × US customary units = metric units.

[b] mm^2/s = cSt. SSU is the common US customary unit and conversion factor instructions are given.

[c] Refer to ASTM 2161 for < 70 cSt (< 325 SSU).

Table 3.6.4b — Subscripts

Subscript	Term	Subscript	Term
a	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

3.6.4.9 Gauge pressure (p_g)

The pressure energy of the liquid determined by a pressure gauge or other pressure-measuring device relative to atmospheric pressure at the test site. The barometric pressure (p_b) shall be zero gauge pressure.

3.6.4.10 Datum

The pump's datum is the reference plane or centerline of the pump inlet from which the elevations of gauges and NPIP are measured. The datum serves as the reference of pressure measurements taken during test.

3.6.4.11 Elevation pressure (p_Z)

The potential energy of the liquid due to the elevation of the gauge or liquid surface above the datum, expressed as equivalent pressure. It is positive when the gauge is above the datum and negative when the gauge is below the datum.

(Metric units) $p_z = \pm 9.8 \times 10^{-2} sZ$

(US customary units) $p_z = \pm 0.433 sZ$

3.6.4.12 Elevation head (Z)

The vertical distance from the centerline of the pressure gauge or liquid surface to the datum.

3.6.4.13 Velocity pressure (p_v)

The velocity pressure is the kinetic energy of the liquid flow expressed in equivalent pressure. It is defined by the expression:

(Metric units) $p_v = \dfrac{9.8 \times 10^{-2} s v^2}{2g}$

(US customary units) $p_v = \dfrac{0.433 s v^2}{2g}$

Where:

s = specific gravity of the fluid pumped

$v^2/2g$ = velocity head, in meters (feet)

$0.433s$ = the conversion factor for feet of water to psi of liquid pumped.

$9.8 \times 10^{-2}s$ = the conversion factor for meters of water to bar of liquid pumped.

In the following expression, the mean velocity (v) is calculated for flow in the pipe where the gauge is connected:

(Metric units) $v = \dfrac{278\,Q}{A} = \dfrac{354\,Q}{d^2}$

(US customary units) $v = \dfrac{0.321\,Q}{A} = \dfrac{0.4085\,Q}{d^2}$

Where:

d = inside diameter of the pipe

A = inside cross-sectional area of the pipe

3.6.4.14 Outlet (discharge) pressure (p_d)

The discharge pressure at the pump outlet is the algebraic sum of the measured gauge pressure (p_g), the velocity pressure (p_v) at the point of gauge attachment, and the elevation pressure (p_z) from the discharge gauge centerline to the pump datum.

$$p_d = p_{gd} + p_v + p_z$$

(Metric units) $p_d = p_{gd} + 9.8 \times 10^{-2} s\left[Z_d + \frac{v_d^2}{2g}\right]$

(US customary units) $p_d = p_{gd} + 0.433 s\left[Z_d + \frac{v_d^2}{2g}\right]$

For tests, p_d is equal to gauge pressure at the pump outlet, which is p_{gd}, providing the gauge is within ± 0.75 m (2.5 ft) elevation of the inlet gauge and pipe velocity is less than 4.5 m/s (15 ft/s).

The measuring section should be located in the outlet pipe immediately after the pump outlet connection.

3.6.4.15 Maximum allowable working pressure

The maximum allowable working pressure is established by the manufacturer and is the maximum allowable difference between the absolute pressure of the liquid at the outlet port and the absolute ambient pressure at maximum expected operating temperature.

3.6.4.16 Inlet (suction) pressure (p_s)

The inlet pressure is the algebraic sum of the gauge pressure, the velocity pressure, and the elevation pressure as measured at the pump inlet:

(Metric units) $p_s = p_{gs} + 9.8 \times 10^{-2} s\left[Z_s + \frac{v_s^2}{2g}\right]$

(US customary units) $p_s = p_{gs} + 0.433 s\left[Z_s + \frac{v_s^2}{2g}\right]$

For the tests, p_s is equal to gauge pressure at the pump inlet, which is p_{gs}, providing the gauge is within ± 0.75 m (2.5 ft) elevation of the outlet gauge and pipe velocity is less than 4.5 m/s (15 ft/s).

The symbol p_s may be positive or negative with reference to atmospheric pressure and may, therefore, have positive or negative values. The symbol is called *inlet pressure* when positive and *inlet vacuum* when negative. The measuring section should be located in the inlet pipe immediately before the pump inlet connection.

3.6.4.17 Maximum allowable inlet working pressure

The maximum allowable inlet working pressure is established by the manufacturer and is the maximum allowable difference between the absolute pressure of the fluid at the inlet port and the absolute ambient pressure at the specified temperature. It is typically based on the pump's design limits.

3.6.4.18 Differential pressure (Δp)

The differential pressure is the algebraic difference of the outlet pressure and inlet pressure, with terms expressed in like units:

$$\Delta p = p_d - p_s$$

3.6.4.19 Maximum differential pressure (Δp_{max})

The maximum differential pressure is the maximum algebraic difference between the pressure of the fluid at the outlet port and pressure of the fluid at the inlet port with terms in like units.

3.6.4.20 Net positive inlet pressure available (NPIPA)

The net positive inlet pressure available is the difference in bar (psi) between the algebraic sum of the inlet pressure and barometric pressure at the test site minus the vapor pressure of the liquid at inlet temperature. NPIPA must always exceed NPIPR (see Section 3.6.4.21) for satisfactory pump operation. Note: net positive suction head available (NPSHA) is often used and is normally expressed in meters (feet). It is the nominal equivalent of NPIPA with appropriate unit conversions.

$$\text{NPIPA} = p_s + p_b - p_{vp}$$

3.6.4.21 Net positive inlet pressure required (NPIPR)

The net positive inlet pressure required is the minimum allowable difference in bar (psi) between the pressure of the liquid at the pump inlet and the vapor pressure of the liquid at pump inlet temperature to avoid cavitation during operation. It is determined by the manufacturer and can be verified by optional test (see Section 3.6.7).

3.6.4.22 Power (P)

Power is the work requirement per unit of time to operate the pump.

3.6.4.23 Total input power (P_{mot})

The total input power is the power required by the pump motor or prime mover under stated operating conditions of the pump. It is sometimes called *driver power* or *motor power*.

3.6.4.24 Pump input power (P_p)

The pump input power (sometimes called *brake horsepower*) is the power delivered to the pump driveshaft, under stated operating conditions of the pump. It is less than the total input power by the amount of power loss in the driver and transmission devices.

3.6.4.25 Pump output power (P_w)

The pump output power is the power imparted by the pump to the liquid discharged from the pump, under stated operating conditions of the pump. It is frequently called *liquid, water,* or *hydraulic horsepower*. It is less than the pump input power by the amount of power loss in the pump.

(Metric units) $$P_w = \frac{Q \times \Delta p}{36}$$

(US customary units) $$P_w = \frac{Q \times \Delta p}{1714}$$

3.6.4.26 Motor efficiency (η_{mot})

The motor efficiency is the ratio of the driver output power to the total input power, expressed as a percent.

3.6.4.27 Overall efficiency (η_{OA})

The overall efficiency is the ratio of the pump output power (P_w) to the total input power (P_{mot}). It is sometimes called *overall unit efficiency* or *unit efficiency*.

The formula for computing overall efficiency as a percent is:

$$\eta_{OA} = \frac{P_w}{P_{mot}} \times 100$$

3.6.4.28 Pump efficiency (η_p)

The pump efficiency is the ratio of the pump output power (P_w) to the pump input power (P_p).

The formula for computing pump efficiency as a percent is:

$$\eta_p = \frac{P_w}{P_p} \times 100$$

3.6.4.29 Specific weight (γ)

The specific weight of a liquid is the weight per unit volume.

3.6.4.30 Specific gravity (s)

The specific gravity of a liquid is a dimensionless ratio of its specific weight to the specific weight of water at 20 °C (68 °F).

3.6.5 Performance test

3.6.5.1 Acceptance

Pumps must be closely checked for satisfactory mechanical operation during performance testing. The degree and extent of such checking is independent of the test type and acceptance level.

3.6.5.2 Witnessing of tests

The purchaser or designated representative may witness the test if specified in the purchase order.

3.6.5.3 Acceptance level

Level A is the normal level of acceptance for test with this standard and will apply unless otherwise specified.

Level B will apply when specified by the purchaser.

3.6.5.4 Acceptable deviation of independent test quantities from specified values at the test parameters

	Level A (Normal)	Level B (When specified)
Outlet gauge pressure	± 1%	± 1%
Inlet gauge pressure	± 5%	± 5%
Speed	± 2%	± 2%
Viscosity	± 7.5%	± 5%

3.6.5.5 Acceptable deviation of dependent test quantities from specified values for Type III and Type IV testing

	Level A (Normal)	Level B (When specified)
Rated flow rate (metric): ($Q = m^3/h$)	$+\frac{100}{1+(4.4033Q)^{0.33}}\%$ -0	$+\frac{100}{1+(4.4033Q)^{0.4}}\%$ -0
Rated flow rate (US units): (Q = gpm)	$+\frac{100}{1+Q^{0.33}}\%$ -0	$+\frac{100}{1+Q^{0.4}}\%$ -0
Pump input power[a] (p_p)	+ 0	+ 0
Total input power[a] (p_{mot})	+ 0	+ 0

[a] When adjusted to rated pressure, speed, and viscosity.

3.6.5.6 Instrumentation

Test instrumentation should be sufficient to adequately measure relevant test conditions for the specified level of testing. Instrument accuracy requirements are defined in Section 3.6.5.6.1. Level A instruments need not be calibrated specifically for each test but are to be periodically calibrated as noted by the manufacturer. Level B instruments are to be calibrated as specified in Section 3.6.13. Description and setup of commonly used instruments can be found in Sections 3.6.8 through 3.6.12.

Gauges should be selected such that the anticipated reading is approximately mid-range with graduations no more than two times the minimum required reading so that the gauge reading between graduations can be interpreted as one half the graduation.

3.6.5.6.1 Fluctuation and accuracy (see Section 3.6.5.7.3)

		Acceptable fluctuations of mean test readings as a ± percentage		Accuracy of the mean test reading as a ± percentage	
Level		A	B	A	B
Rate of flow		4	1	2	1
Pressure or head	Outlet	5	5	4	1
	Inlet	6	5	2	1
Pump input power		2	2	1.5	1.0
Total input power		2	2	1.5	1.5
Pump speed		1	1	1	1
Temperature		1.7 °C (3 °F)	1.7 °C (3 °F)	1	1

3.6.5.7 Test setup and procedure

3.6.5.7.1 Setup

This section contains general guidelines for pump test setup, to ensure accurate and repeatable test results.

The test setup shall include provision to vary inlet and outlet pressures and to measure the following:

- Liquid temperature at the pump inlet
- Pressure at the pump inlet and outlet
- Rate of flow (Types III and IV)
- Pump speed
- Pump input power (Type IV)
- Total input power (Type IV)

Careful inspection shall be made before, during, and after the test to ensure the proper operation of the pump and measuring instruments. Instruments for measurement must not affect the pump performance.

The pump test may use, but is not limited to, the following:

a) The baseplate or foundation. This should be rigid enough to maintain the alignment between the pump, driver, and inlet and outlet piping.

b) Facility or purchaser-furnished driver. Efficiency data may be required, depending on the method used to measure pump input power.

c) Facility or purchaser-furnished speed-reduction unit, if required. Efficiency data may be required to accurately establish pump input power.

d) Dampening devices may be used for the inlet and outlet pressure-measuring instruments, such as needle valves or capillary tubes, to dampen out the pressure pulsations at the pressure-measuring instruments.

e) An inlet and outlet stabilizer (pulsation dampener) may be used.

f) A means for measuring input power to the pump shall be provided, when required by the test level, suitable for measuring the complete range of power.

g) A means for measuring pump speed shall be provided, such as a revolution counter or timer, tachometer, frequency-response device, or stroboscope.

h) A means for measuring the temperature of the test liquid shall be provided.

i) The actual dimensions of the suction and discharge openings where pressure readings are to be taken shall be determined, so that proper velocity pressure corrections can be made.

A typical test setup is shown in Figure 3.6.5.7.1. Note: Not all equipment shown is required for each test.

3.6.5.7.2 Conditions

The important factors affecting test results are:

- *Inlet conditions*: Specified inlet conditions shall be simulated as closely as the test facility's equipment permits.
- *Outlet pressure*: The outlet pressure shall be as specified. When it is not possible to obtain the specified pressure, the test data shall be extrapolated to the specified outlet pressure in accordance with the procedures unique to the product being tested.
- *Speed*: The pump speed shall be as specified. When it is not possible to obtain the specified speed, corrections to the rate of flow and input power to correspond to the specified speed shall be made (see Correction to specified speed, Section 3.6.5.9.5).
- *Liquid temperature, viscosity,* and *specific gravity*: Test shall be made using Newtonian liquids, such as clean oil or clear water, at the liquid temperature, viscosity, and specific gravity available at the test site.

The variety and characteristics of the fluids handled by rotary pumps make it impractical and, in many cases, impossible for the pump manufacturer to provide specified fluids for tests.

The quantities required to verify the rated conditions may be measured under conditions more or less different from the rated conditions. If actual test conditions vary from rated conditions, actual test data should be corrected to be the equivalent of rated conditions.

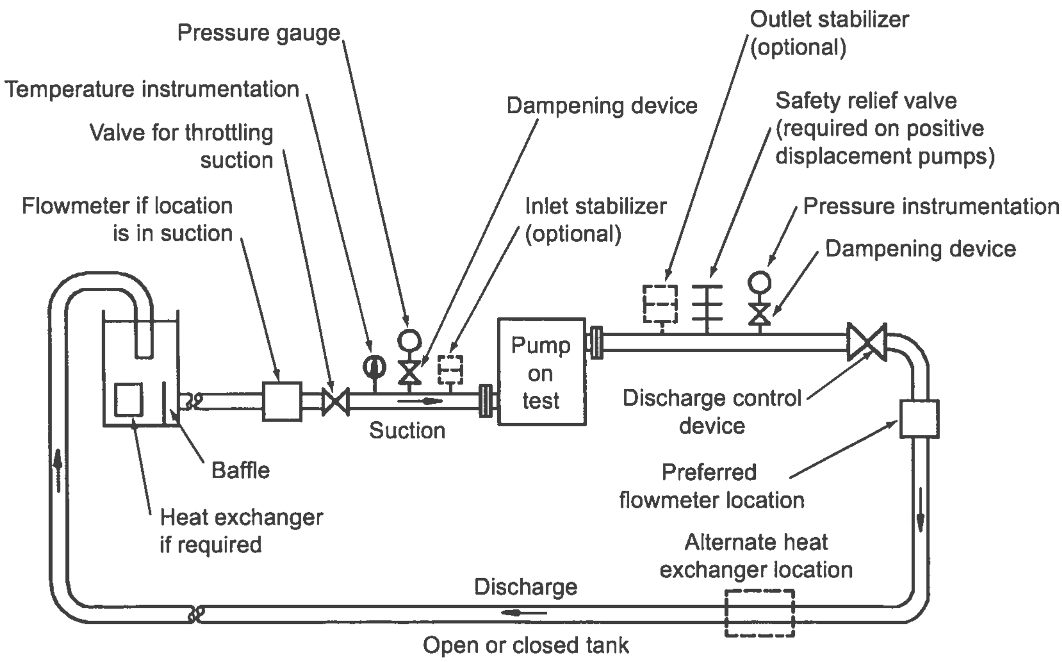


Figure 3.6.5.7.1 — Recommended test setup

3.6.5.7.3 Procedure

Data, where applicable, shall be obtained prior to the test run. See Table 3.6.5.7.3 for test tabulation sheet.

Table 3.6.5.7.3 — Test tabulation

Item	Measurement	Metric units	US units	Data points		
1	Reading number					
2	Pump speed	rpm	rpm			
3	Inlet pressure	bar	psig or in Hg			
4	Outlet pressure	bar	psig			
5	Differential pressure	bar	psi			
6	Barometric pressure	bara	psia			
7	Elevation of gauges from datum	m (+ or –)	ft (+ or –)			
8	Specific gravity					
9	Rate of flow	m^3/h	gpm			
10	Liquid description	—	—			
11	Liquid temperature at pipe inlet	°C	°F			
12	Liquid specific weight	kN/m^3	lb/ft^3			
13	Liquid (kinematic) viscosity	mm^2/s	SSU			
14	Torque	N•m	lb•ft			
15	Pump output power	kW	hp			
16	Pump input power	kW	hp			
17	Pump efficiency	%	%			

Typically, the prerun data may include:

a) Record of pump type, size, and serial number.

b) Temperature of the liquid, taken before and after testing to verify liquid viscosity, vapor pressure, and specific gravity.

c) Record of critical installation dimensions such as tank internal dimensions, pipe internal dimensions and lengths, and liquid levels (submergence) relative to datum.

d) Record of driver data, such as type, serial number, power, speed range, amperage, voltage, and efficiency.

e) Record of auxiliary equipment.

f) Instrument calibration records and correction factors.

g) Identity of test personnel.

h) The actual dimension of the areas where pressure readings are to be taken. This shall be determined so that proper velocity head corrections can be made.

Collection of Level B test data shall not commence until a satisfactory preliminary run has been made to ensure the proper operation of the pump and test equipment and the correct routine of observations has been established.

The test shall begin only when steady test conditions have been established, as determined by acceptable fluctuations per Section 3.6.5.6.1. Steady test conditions must be held throughout the duration of the test.

Test measurements shall be sufficiently accurate and consistent to fall within acceptable accuracy deviation and fluctuation ranges.

All quantities determined from a series of readings shall be the average of observations made at equal time intervals. Errors detected in results computed during the test must be immediately corrected. Errors detected in results computed after the test may be just cause for retest. Complete records of all collected data and computed results shall be furnished to all parties to the test.

A standard test shall consist of operation at one or more test points (Types I and II) or three or more test points (Types III and IV). The speed, liquid temperature, and inlet and outlet pressures shall be adjusted to the test conditions, with rate of flow (Types III and IV) and power readings recorded (Type IV).

For pumps operating at constant speed, the speed shall be maintained constant within the slip limits of the motor, and the pump shall be operated at additional values of outlet pressure, with rate of flow and power readings recorded for each.

For pumps operating at variable speeds, the outlet pressure shall be maintained constant, and the pump shall be operated at additional speed values, with rate of flow and power readings recorded for each if specified by purchaser.

3.6.5.8 Records

Complete written or computer records shall be kept of all information relevant to a test and retained on file, available to the purchaser, if specified, from the test facility, for five years.

The manufacturer's serial number, type, and size, or other means of identification of each pump and driver involved in the test shall be recorded to avoid mistakes in identity.

While these records apply to the complete unit including the driver, the standard itself applies only to test of the pump.

3.6.5.8.1 Type I test

Complete written or computer records shall be kept of all information relevant to a test and retained on file at the test facility, and be made available to the purchaser, if specified, from the test facility for a period of five years. Test data are not furnished to the purchaser.

3.6.5.8.2 Type II test

Type II test is a running test to confirm the ability of the specific pump to perform mechanically at the speed and pressure established by the contract. A certificate of compliance shall be given to purchaser.

3.6.5.8.3 Types III and IV tests

Type III and Type IV running tests are more extensive and may have data sets similar to Table 3.6.5.7.3 furnished to purchaser.

3.6.5.9 Calculations

3.6.5.9.1 Differential pressure

$$\Delta p = p_d - p_s$$

3.6.5.9.2 Input power

If input to the pump has been read in speed and torque units, then the formula for pump input power (P_p) is:

(Metric units) $P_p = \dfrac{n\tau}{9549}$

(US customary units) $P_p = \dfrac{n\tau}{5252}$

See Section 3.6.10 for more information.

3.6.5.9.3 Output power

If pump efficiency is to be plotted, pump output (hydraulic) power must be calculated. The formula for pump output power (P_w) is:

(Metric units) $P_w = \dfrac{Q \times \Delta p}{36}$

(US customary units) $P_w = \dfrac{Q \times \Delta p}{1714}$

3.6.5.9.4 Efficiency

The formula for pump efficiency (η_p) as a percent is:

$$\eta_p = \frac{P_w}{P_p} \times 100$$

3.6.5.9.5 Correction to specified speed

Where specified speed cannot be attained during a test, corrections to rate of flow and pump power input shall be made by using methods given as follows. These corrections should be limited to speeds within 50% of the specified speed.

Correction to rate of flow:

At any value of differential pressure with constant viscosity, rate of flow will vary as:

$$Q_2 = \frac{n_2}{n_1}(Q_1 + S) - S$$

Where:

Q_1 = Rate of flow at test speed

Q_2 = Rate of flow at specified speed

n_1 = Test speed, in rpm

n_2 = Specified speed, in rpm

S = Slip

The value of pump displacement used to determine slip is to be furnished by the manufacturer.

Correction to power:

$$P_2 = P_t\left(\frac{n_2}{n_1}\right) + (P_1 - P_t)\left(\frac{n_2}{n_1}\right)^x$$

Where:

P_2 = Input power at specified speed

P_1 = Input power at test speed

n_2 = Specified speed, in rpm

n_1 = Test speed, in rpm

P_t = Theoretical output power at test speed or:

(Metric units) $$P_t = \frac{\left(\frac{Dn}{16.7 \times 10^3}\right)(\Delta p)}{36}$$

(US customary units) $$P_t = \frac{\left(\frac{Dn}{231}\right)(\Delta p)}{1714}$$

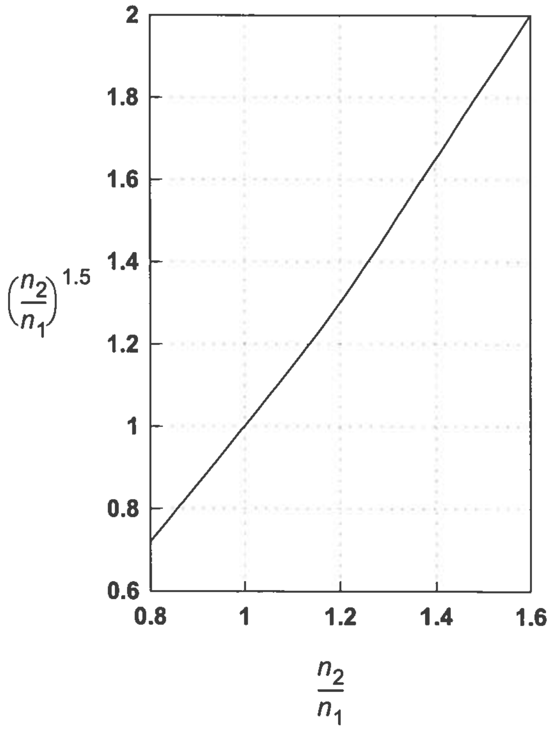


Figure 3.6.5.9.5 — Speed correction values for pump input power for $x = 1.5$

Values of $\left(\frac{n_2}{n_1}\right)^x$ are given in Figure 3.6.5.9.5 for $x = 1.5$.

The speed correction exponent x for horsepower, which is typically between 1.25 and 2.05, is design dependent. Refer to the manufacturer for recommendation of appropriate exponent based on previous tests at two or more speeds of similar design pumps.

3.6.5.10 Presentation of results

For Level B, corrections must be made to inlet and outlet pressure measurements before presenting results. After corrections, differential pressure is computed. Presented results shall depict adjusted values of rate of flow and power where adjustments are required.

Performance may be presented at constant speed, as shown in Figure 3.6.5.10a, or at constant pressure, as shown in Figure 3.6.5.10b.

3.6.5.11 Report of test for Types III and IV

3.6.5.11.1 Level A test

A performance curve meets Level A requirements and shall be furnished if specified.

3.6.5.11.2 Level B test

All parties to the test shall be furnished a copy of the following documents that constitute the Report of Test:

a) A general information data sheet that lists pertinent general information and data not recorded during the performance test. Typical data that may appear on the general information data sheet are listed in Figure 3.6.5.11.2.

b) Specifications of measuring instruments shall be given when requested.

c) A performance test data sheet with record of all data taken during the performance test along with calculated values and adjusted calculated values shall be provided when requested.

d) A performance curve indicating 1) rate of flow, efficiency, and power versus differential pressure at constant speed or 2) rate of flow, efficiency (when required), and power versus speed at constant differential pressure shall be prepared for Type IV tests.

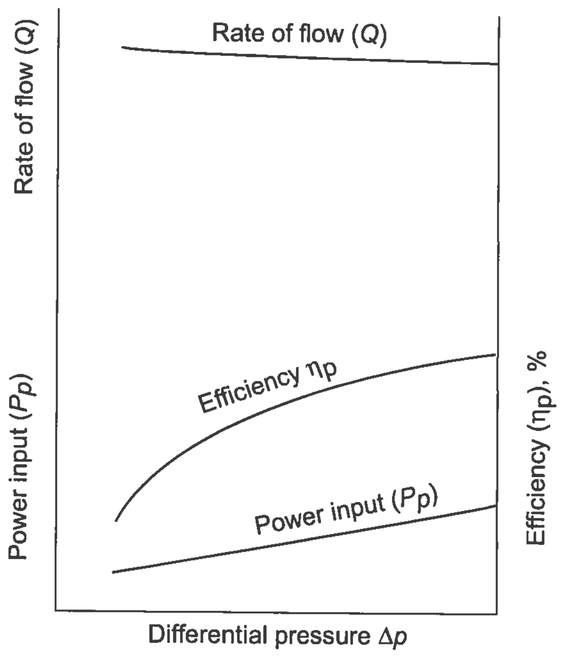


Figure 3.6.5.10a — Pump performance at constant speed

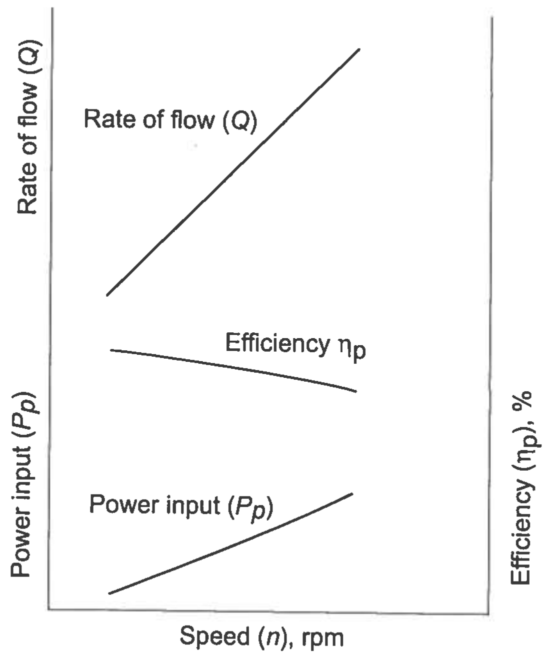


Figure 3.6.5.10b — Pump performance at constant pressure

General Data

1) Date of test ______
2) Location ______
3) Manufacturer ______
4) Purchaser ______
5) Test conducted by ______ Test witnessed by ______
6) Pump size, type, model number ______
7) Pump serial number ______
8) Driver manufacturer, size, type, hp, speed, characteristics (voltage, frequency, phase) calibration data ______
9) Driver serial number ______
10) Intermediate mechanism, manufactured by, type, serial number, speed ratio, efficiency ______

Test information

Pressure (all tests):

11) Method of measuring pressure ______
12) Pressure instrument description ______

inlet ______ make ______ calibration data ______ S/N ______
outlet ______ make ______ calibration data ______ S/N ______

Rate of flow (Type III and IV):

13) Method of measuring flow rate ______
14) Flow rate instrument description ______

flow stabilizer ______ type ______

Power (Type IV only):

15) Method of measuring power ______
16) Power instrument description ______

Temperature (all tests):

17) Method of measuring temperature ______
18) Temperature instrument description ______

Speed (all tests):

19) Method of measuring speed ______
20) Make and serial number of instrument ______
21) Calibration data ______
22) Other conditions not noted above ______

Specified conditions

23) Liquid pumped ______ specific gravity ______

temperature ______ vapor pressure ______
liquid viscosity at pumping temperature ______

24) Pump speed, rpm ______
25) Net inlet pressure ______
26) Outlet pressure ______
27) Differential pressure ______
28) Rate of flow (Types III and IV only) ______ (specify) ______
29) Pump output power (Type IV only) ______
30) Pump input power (Type IV only) ______ maximum power specified ______
31) Pump efficiency (Type IV only) ______

Figure 3.6.5.11.2 — Information data sheet

Depending on variables such as specified conditions, type of pump, etc., the manufacturer may choose to combine the general information data sheet and the performance test data sheet into a single form. Such a combined form must, however, list all data pertinent to the conduct and results of the test.

When a performance test deviates from the provision of this standard per mutual agreement of the contracting parties, the Report of Test shall include a written report on the deviations.

3.6.6 Hydrostatic test (optional)

The object of the hydrostatic test is to demonstrate that the pump will not leak or fail structurally when subjected to hydrostatic pressure. For purposes of this requirement, the containment of liquid means only prevention of its escape through the external surfaces of the pump, normally to atmosphere.

3.6.6.1 Test parameters

Components or assembled pumps: The test shall be conducted on either the liquid-containing components or the assembled pump in accordance with the manufacturer's standard procedures.

Components: The test shall be conducted on the liquid-containing components. Where appreciable pressure gradient exists across the part, care must be taken not to impose excessive pressure on areas designed for lower-pressure operation.

Assembled pump: The test shall be conducted on the entire liquid-containing area of the pump, but care must be taken not to impose excessive pressure on areas such as low-pressure sections or mechanical seal areas.

Test pressure: Normal test pressure shall be 1.5 times the maximum allowable working pressure, but no less than 3.5 bar (51 psig).

Test duration: Test pressure shall be maintained for a sufficient period of time to permit complete examination of the parts under pressure. The hydrostatic test should be considered satisfactory when no leaks or structural failures are observed for a minimum of five minutes.

Temperature correction: If the part tested is to operate at a temperature at which the strength of material is below the strength of the material at room temperature, then the hydrostatic test pressure should be multiplied by a factor obtained by dividing the allowable working stress for the material at room temperature by that at operating temperature. This pressure thus obtained will then be the minimum pressure at which hydrostatic pressure should be performed. The data sheet should list the actual hydrostatic test pressure and test temperature.

3.6.6.2 Test procedure

Items to be tested shall have all the openings adequately sealed. Provisions shall be made to vent all the air at the highest point on the item. The item shall be filled with the test liquid pressurized and the test pressure shall be maintained for the duration of the test. No leakage through the item tested shall be visible; however, leakage through stuffing-box packing shall be permitted.

3.6.6.3 Records

Complete written or computer records of all relevant information should be kept on file, available to the purchaser by the test facility for five years.

This information should include:

a) Identification of model, size, serial number, and/or component part number.

b) Test liquid.

c) Hydrostatic test pressure, temperature, and test duration.

d) Identification of the individual responsible for recording the test results.

e) Date of test.

3.6.7 Net positive inlet pressure required test (optional)

The object is to provide a basic test method to determine the NPIPR for a rotary pump when tested at the manufacturer's facility under test conditions.

Alternate test methods are available that can provide equally satisfactory results; however, no alternate test methods are described herein.

3.6.7.1 Test equipment

a) *Test circuit:* The test circuit shall be similar to Figure 3.6.5.7.1.

b) *Liquid:* A liquid such as water or a petroleum-base liquid with known characteristics may be used. Liquids used shall have predictable vapor pressure.

c) *Liquid conditions:* Liquid viscosity, specific gravity, and vapor pressure shall be as close as practical to rated values.

d) *Aeration:* Liquid aeration shall be minimized by proper system design and adequate removal of air from the system before testing. Other precautions follow:

- Submerged return lines
- Reservoir sized to allow air removal
- Control valve sized to permit achieving required pressures, positive or negative, without more than 50% throttling
- Inlet line properly located to prevent vortexing
- Reservoir baffles to isolate inlet from return line
- Pipe joints and stuffing boxes tightened to guard against air leakage into the system
- Proper adjustment of stuffing boxes

e) *Instrumentation:* Refer to Sections 3.6.5.6 and 3.6.5.6.1.

3.6.7.2 Acceptable deviation of test quantities

See Sections 3.6.5.4 and 3.6.5.5.

3.6.7.3 Test procedure

The pump shall be installed on a test stand having a suitable driver, and the alignment and direction of rotation shall be checked.

The pump shall be operated with fixed conditions as specified below until system equilibrium is achieved and fluctuations are within the limits in Section 3.6.5.6.1:

a) Differential pressure shall be held constant at rated condition or at manufacturer's recommended alternative.

b) Fluid viscosity and temperature shall be held constant.

c) Pump speed shall be held constant.

d) Initial inlet pressure shall be atmospheric, or as low as practical and yet sufficient to obtain maximum pump rate of flow.

The control valve located in the inlet line shall be closed gradually, and the control valve in the outlet line simultaneously opened, so that the inlet pressure is incrementally reduced while the differential pressure is held constant. This process shall be continued until the cavitation onset criteria has been met as indicated in Section 3.6.3.

3.6.7.4 Data presentation

The net positive inlet pressure required is expressed as a specific value at the fixed test conditions.

When required, curves may be generated by varying pump speed or fluid viscosity, thereby producing a series of values for the different conditions.

3.6.8 Rate of flow measurement

Rate of flow instruments are classified into two functional groups. One group primarily measures quantity, and the other primarily measures rate of flow.

3.6.8.1 Rate of flow measurement by weight

This is done by measuring the change in weight of a tank during a measured period of time using a liquid of known and consistent specific gravity. The tank can be located on the inlet or discharge side of the pump, and all test liquid transferred into or out of the test tank must pass through the test pump. To minimize test variation, test-tank size shall be sufficient to allow at least five minutes of pump operation at test conditions.

Refer to Section 3.6.5.6.1 for allowable fluctuation and accuracy.

3.6.8.2 Rate of flow measurement by volume

This is done by measuring the change in liquid volume in a test tank or reservoir during a measured period of time. The tank or reservoir can be located on the inlet or discharge side of the pump, and all flow in or out of the tank or reservoir must pass through the pump.

Refer to Section 3.6.5.6.1 for allowable fluctuation and accuracy.

3.6.8.3 Other methods of measurement

When the methods of quantity measurement described above are not applicable, there are other methods not included in this standard that may be used, subject to agreement by the interested parties in advance of a performance test. Some of these methods are:

a) Tagging methods:

- Salt velocity

- Dye dilution
- Thermal pulse
- Neutral density immiscible particles
- Hydrogen bubble technique

b) Head meters:

- Elbow meter
- Orifice plates
- Nozzles
- Venturi meters
- Dahl tube

c) Acoustic methods:

- Doppler velocimeter
- Turbulence noise calibration

d) Electromagnetic methods:

- Magnetic induction velocimeter
- Laser doppler velocimeter

e) Hydrodynamic oscillators:

- Swirlmeter
- Vortex shedding flowmeter
- Vortex flowmeter
- Fluidic flow measurement
- Hydrodynamic oscillator flowmeter

f) Drag force meters:

- Calibrated drag body
- Weirs
- Pitot tubes

g) Positive displacement meters provide direct reading of volume measurement.

3.6.9 Measurement of pressure

The units of pressure and the definition of differential pressure and its component parts are covered under Sections 3.6.4.9 through 3.6.4.19.

It is important that steady flow conditions exist at the point of instrument connection. For this reason, it is necessary that pressure or head measurement be taken on a section of pipe where the cross section is constant and straight. Two diameters of straight pipe of unvarying cross section following any elbow or curved member, valve, or other obstruction are necessary to ensure steady flow conditions.

Pipe friction loss between the pump discharge flange and the point of instrument connection should be added to the outlet pressure (P_d) reading to maintain pump outlet pressure test data accuracy. The friction factor used for the calculation should be based on the appropriate roughness ratios for the actual pipe section. See Section 3.6.4.14 for the definition of the outlet pressure.

The following precautions shall be taken in forming orifices for pressure-measuring instruments and for making connections:

a) The opening in the pipe shall be perpendicular to the wall of the liquid passage.

b) The wall of the liquid passage shall be smooth and of unvarying cross section for a distance of at least the larger of two pipe diameters or 300 mm (12 in) preceding the orifice. All tubercles and roughness shall be removed with a file or emery cloth.

c) The opening shall be of a diameter *d* from 3 to 6 mm (0.125 to 0.25 in) and a length equal to twice the diameter.

d) The edges of the opening shall be provided with a suitable radius tangential to the wall of the liquid passage and shall be free from burrs or irregularities. Figures 3.6.9a and 3.6.9b show two suggested arrangements of taps or orifices in conformance with the above.

e) Manometers, when used on very viscous products with wet lines interfacing directly or indirectly to the manometer, require larger inlet taps into the pipeline to avoid excessive lag time for fluid to stabilize in the measuring system.

Where more than one tap or orifice is required at a given measuring section, separate connections, properly valved, shall be made. As an alternative, separate instruments shall be provided.

Multiple orifices can be connected to an instrument, except on those metering devices such as venturi meters, etc., where proper calibrations have been made on an instrument of this form.

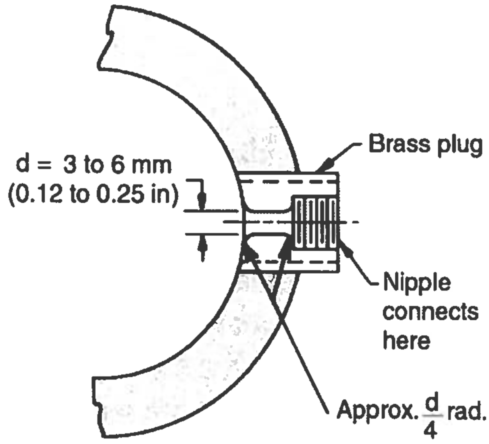


Figure 3.6.9a — Pressure tap opening with corrosion-related plug

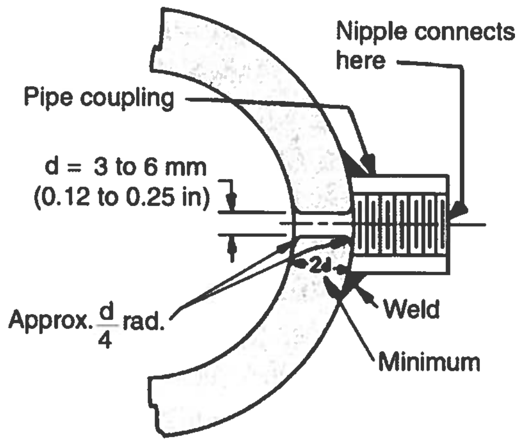


Figure 3.6.9b — Welded-on pressure tap opening

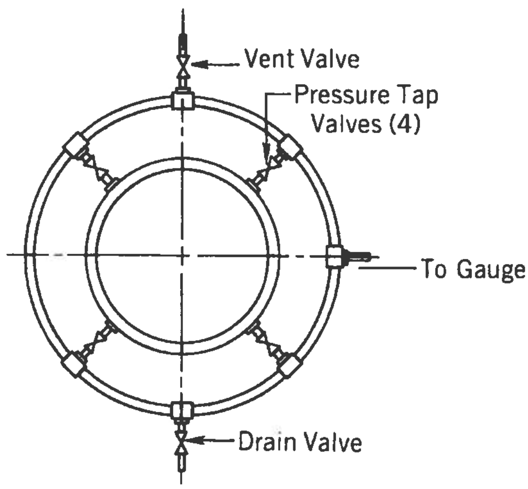


Figure 3.6.9c — Loop manifold connecting pressure taps

The multiple orifices can be connected to a manifold and then to an instrument. With four or more pressure readings, there will be no more than 1% pressure variance between readings (see Figure 3.6.9c).

All connections or leads from the orifice tap shall be tight. These leads shall be as short and direct as possible. For the dry-tube type of leads, suitable drain pots shall be provided and a loop shall be formed of sufficient height to keep the pumped liquid from entering the leads. For the wet-tube type of leads, vent cocks for flushing shall be provided at any high point or loop crest to ensure that there are no leaks.

Suitable damping devices may be used in the leads.

If the conditions specified above cannot be satisfied at the point of measurement, then it is recommended that four separate pressure taps be installed, equally spaced about the pipe, and the pressure at that section be taken as the average of the four separate values of pressure. If the separate readings show a difference of static pressure, such installation shall be corrected or an acceptable tolerance determined.

The following information presents suitable arrangements for various types of instruments, formulas for transforming instrument readings into pressure, for expressing instrument pressure as elevation over a common datum, and for correcting same for the velocity pressure existing in the suction and discharge pipes.

3.6.9.1 Measurement of pressure by means of calibrated gauges

Many types of pressure indicators may be used. See Section 3.6.5.6.1 for fluctuation and accuracy requirements.

When gauge pressure is above atmospheric pressure and the connecting line is completely filled with liquid, as in Figure 3.6.9.1, then:

(Metric units) $$p_d = p_{gd} + \left(Z_d + \frac{v_d^2}{2g}\right)(9.8 \times 10^{-2} s)$$

(US customary units) $$p_d = p_{gd} + \left(Z_d + \frac{v_d^2}{2g}\right)(0.433 s)$$

See Sections 3.6.4.12 and 3.6.4.13 for measurement of Z and v.

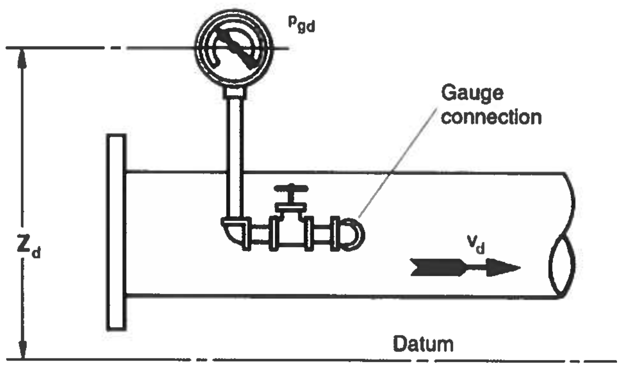


Figure 3.6.9.1 — Use of calibrated Bourdon gauge (see Section 3.6.4.10)

3.6.10 Power measurements

Measurement of power shall be concurrent with rate of flow measurement.

Methods of measurement of input power to the pump fall into two general classes:

a) Those that determine the actual power or torque delivered to the pump and are made during the test by some form of dynamometer or torque shaft.

b) Those that determine the input power to the driving element, taking into account the driver efficiency when operating under specified conditions.

When pump input power is to be determined by dynamometers, the unloaded dynamometer shall be statically calibrated prior to the test by measuring the angular deflection for a given torque and the tare reading on the dynamometer scale being taken at rated speed with the pump disconnected. After the test, the calibrations shall be rechecked to ensure that no change has taken place. In the event of an appreciable change (greater than ± 1.5%), the test shall be rerun.

The use of calibrated dynamometers or motors should be considered to give satisfactory measurement of input power to the pump.

Cradle electric and dynamometers shall not be used for testing pumps with a maximum torque below one quarter of the rated dynamometer torque.

Calibration of the dynamometer shall be conducted with the rotor torsion indicator in place. The indicator shall be observed with a series of increasing loadings and then with a series of decreasing loadings. While taking readings with increasing loadings, the loading shall at no time be decreased; similarly, during the decreasing loadings, the loading shall at no time be increased. The calculation of output shall be based on the average of the increasing and decreasing loadings as determined by the calibration. If the difference in readings between increasing and decreasing loadings exceeds 1%, then the torsion dynamometer shall be deemed unsatisfactory.

When strain-gauge type torque measuring devices are used to measure pump input power, they shall be calibrated, with their accompanying instrumentation, at regular intervals. After the test, the readout instrumentation balance shall be rechecked to ensure that no appreciable change (greater than ± 1.5%) has taken place. The test shall be rerun in the event of an appreciable change.

Calibration laboratory type electric meters and transformers shall be used to measure power input to all motors.

Calibrated electric motors are satisfactory to determine the input power to the pump shaft when the motor is directly connected to the pump shaft. The electrical input to the motor is observed, and the observations are multiplied by the motor efficiency to determine input power to the pump shaft. Where the efficiency of the motor is questionable, its efficiency shall be determined by measuring the electrical energy input and the mechanical energy output by dynamometer or by electrical methods (ANSI/IEEE-112, 113, or 115, as appropriate). The electric input power to the motor shall be measured at the motor terminals by any acceptable method, including polyphase wattmeter, single-phase wattmeter, or voltmeter-ammeter (power factor for AC).

When pump input power is to be determined by the use of a calibrated motor, measurements of input power shall be made at the terminals of the motor to exclude any line losses that may occur between the switchboard and the driver itself. Certified calibration shall be conducted on the specific motor in question and not on a similar machine. Such calibrations must indicate the true input–output value of motor efficiency and not some conventional method of determining an arbitrary efficiency.

3.6.11 Methods for rotary speed measurement

Test speeds for pumps may be in the range of a few hundred to several thousands of revolutions per minute. Because the pump test data are taken under steady state conditions, the maximum permissible short-term speed fluctuation shall be no more than 1% (Section 3.6.5.6.1). The speed-measuring methods described, therefore, are those which, at moderate speeds, give a measure of the average speed over an interval of from less than one second up to one to two minutes, depending on the type of instrumentation. The succeeding paragraphs discuss the various methods and instruments suitable for measuring the speed of rotation.

The revolution counter and timer method, as its name implies, involves counting the number of revolutions over an interval of time. A major source of error is in exact synchronization of counter and timer. When synchronization is automatic (e.g., digital tachometers), sufficient accuracy is achieved over a time interval of a few seconds. In the usual case, where a handheld counter and stopwatch are used, the timing interval should be about two minutes. During this time, the speed shall be constant and the slippage of the counter on the shaft shall be avoided. The stopwatch should be periodically checked against a standard timer. This method can be very accurate, to ± 0.25% of pump speed or better.

Tachometers provide a direct reading of speed averaged over a fixed time interval. Some types automatically repeat the reading process, while the standard handheld unit must be reset manually. The above comments regarding uniform speed and slippage pertain here also. A tachometer should be checked periodically against a counter and stopwatch. The accuracy of tachometers varies widely, from ± 0.25% to ± 3.5%, the latter limit being unacceptably high for test purposes. Test instrumentation shall be consistent with Sections 3.6.5.4 and 3.6.5.6.1.

Frequency-responsive devices have the advantage of not requiring direct contact with the motor or pump shaft and hence impose no additional load on the motor. The vibrating-reed type is of use only when the shaft is completely inaccessible.

Electronic counters may be converted to read rpm directly using a shaft-mounted gear and a noncontacting magnetic pickup. This method is accurate to the nearest rpm, as read on a digital readout. The timing interval may be set as short as 0.1 second, thus making any speed fluctuations readily discernible.

Most stroboscopes are limited in accuracy due to uncertainty in the precision of the strobe frequency. The only approach suitable for pump test purposes is to use the strobe to determine motor slip under load relative to synchronous speed, using a stopwatch to time the slippage while driving the strobe at line frequency (which is known to the accuracy given above and can be determined with even greater precision for the time and location of the test).

3.6.12 Temperature measurement

Temperature should be measured as close to the pump inlet as possible. The temperature-measuring device shall have no effect on the measurements of pressure and rate of flow.

All temperature-sensing instruments should be properly supported and installed directly into the liquid stream. When this is not practicable, wells filled with suitable intermediate conducting materials may be used.

3.6.13 Suitable interval between calibrations for performance test instruments

In the absence of manufacturer's history, the intervals shown in Table 3.6.13 are suggested.

Table 3.6.13 — Recommended instrument calibration interval[a]

Rate of flow[b]		Power (*continued*)	
Quantity meter		Torque bar	1 yr
Weighing tanks	1 yr	Calibrated motor	Not req'd[c]
Volumetric tank	10 yr	kW Transducer	3 yr
Rate meters		Watt-amp-volt, portable	1 yr
Venturi	[d]	Watt-amp-volt, permanent	1 yr
Nozzle	[d]	Strain gauges	6 mo
Orifice plate	[d]	Transmission gear to 375 kW (500 hp)	10 yr
Weir	[d]	Transmission gears above 375 kW (500 hp)	20 yr
Turbine	1 yr	**Speed**	
Magnetic flow	1 yr	Tachometers	3 yr
Rotometer	5 yr	Eddy current drag	10 yr
Propeller	1 yr	Electronic	Not req'd[c]
Ultrasonic	5 yr	Frequency-responsive devices	
Pressure[b]		Vibrating reed	10 yr
Bourdon tube (pressure gauge)	4 mo	Electronic	10 yr
Manometers	Not req'd	Photocell	10 yr
Dead weight tester	1 yr	Stroboscopes	5 yr
Transducers	4 mo	Torque meter (speed)	1 yr
Digital indicator	1 yr	**Temperature[b]**	
Power[b]		Electric	2 yr
Dynamometer w/scale	6 yr	Mercury	5 yr
Dynamometer w/load scale	6 mo		

[a] Use instrument manufacturer's recommendation if shorter than listed in table.

[b] Other methods may be suitable.

[c] Unless electrical or mechanical failure.

[d] Calibration is not required unless it is suspected there are critical dimensional changes.

Appendix A

Index

This appendix is included for informative purposes only and is not part of this standard. It is intended to help the user gain a better understanding of the factors referenced in the body of the standard.

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

Hydraulic Institute
Creating Pump Standards Since 1917

Available at eStore.Pumps.org

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

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

Variable Speed Pumping: A Guide to Successful Applications

Mechanical Seals for Pumps: Application Guidelines

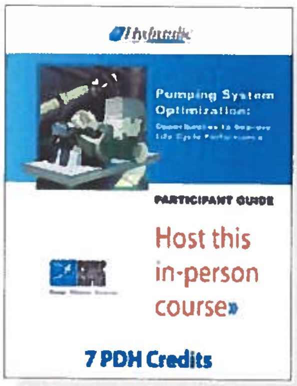
ANSI/HI Pump Standards

Individual Standards
- Hardcopy
- Downloadable

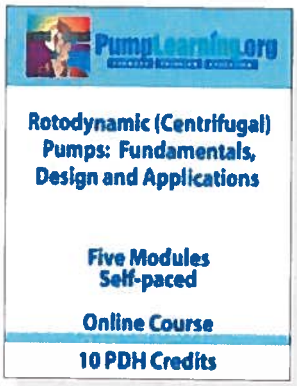
Complete Set — Hardcopy

ANSI/HI Pump Standards on CD — complete set

ANSI/HI Pump Standards by Subscription



Pumping System Optimization Course
Benefit from Major Energy Efficiency Improvements and Bottom-line Savings.



Rotodynamic (Centrifugal) Pumps: Fundamentals, Design and Applications Online Course

Positive Displacement Pumps: Fundamentals, Design and Applications Online Course

Click on the text or image to go to the eStore page for the product of your choice.

www.Pumps.org | www.PumpSystemsMatter.org | www. PumpLearning.org