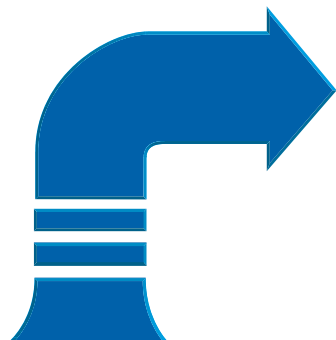


ANSI/HI 2.6-2000



American National Standard for

Vertical Pump Tests

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American National Standard for
Vertical Pump Tests

Secretariat
Hydraulic Institute
www.Pumps.org

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American National Standards Institute, Inc.

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Foreword (Not part of Standard)

Purpose and aims of the Hydraulic Institute

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

- a) To develop and publish standards for pumps;
- b) To collect and disseminate information of value to its members and to the public;
- c) To appear for its members before governmental departments and agencies and other bodies in regard to matters affecting the industry;
- d) To increase the amount and to improve the quality of pump service to the public;
- e) To support educational and research activities;
- f) To promote the business interests of its members but not to engage in business of the kind ordinarily carried on for profit or to perform particular services for its members or individual persons as distinguished from activities to improve the business conditions and lawful interests of all of its members.

Purpose of Standards

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

Definition of a Standard of the Hydraulic Institute

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

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

Comments from users

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

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

Revisions

The Standards of the Hydraulic Institute are subject to review, and revisions are undertaken whenever it is found necessary because of new developments and progress in the art.

Scope

This Standard is for vertical diffuser type centrifugal pumps. It includes detailed procedures on the setup and conduct of hydrostatic and performance tests of such pumps.

Several methodologies to test centrifugal and vertical pump equipment are available to pump manufacturers, users and other interested parties. The United States has two sets of pump test Standards which represent two approaches to conducting and evaluating pump performance. One, promulgated by the American Society of Mechanical Engineers (ASME) and designated PTC 8.2, Centrifugal Pumps, provides for two levels of tests and is based on a detailed procedure that produces results of a low level of uncertainty. The other, promulgated by the Hydraulic Institute (HI), designated HI 1.6, Centrifugal Pump Tests, and HI 2.6, Vertical Pump Tests, also provides for two levels of test in which the test procedures are less restrictive. The ASME Code relies on the parties to the test to agree beforehand on the Scope and Conduct of the test and does not specify how the test results shall be used to compare with guarantee. The ASME is especially suited to highly detailed pump testing, whereas HI Standards detail test scope, conduct and acceptance criteria, and are thus suited to commercial test practices. ASME Codes do not permit the use of acceptability tolerances in reporting results, while the HI Standards do. It is recommended that the specifier of the test standard become familiar with both the ASME Code and the HI Standards before selecting the one best-suited for the equipment to be tested, since there are a number of other differences between the two which may affect accuracy or cost of the tests.

Both the ASME and HI Standards can be used for testing in either field or factory installations. The detailed requirements of the ASME test Code are intended to reduce the effect of various installation arrangements on performance results and are applied more to field testing. The HI Standard specifies test piping and more controllable conditions, which is more suitable to factory testing. The HI Standards do not address field testing. Surveys have shown that both ASME and HI Standards have been applied successfully to applications from small chemical pumps (1 hp) to large utility pumps (over 5000 hp).

Units of Measurement

Metric units of measurement are used; corresponding US units appear in brackets. Charts, graphs and sample calculations are also shown in both metric and US units.

Since values given in metric units are not exact equivalents to values given in US units, it is important that the selected units of measure to be applied be stated in reference to this standard. If no such statement is provided, metric units shall govern.

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

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

Black & Veatch LLP	Lawrence Pumps, Inc.
Brown & Caldwell	Malcolm Pirnie, Inc.
Camp Dresser & McKee, Inc.	Marine Machinery Association
Cascade Pump Company	Moving Water Industries (MWI)
Chas. S. Lewis & Company, Inc.	Pacer Pumps
Cheng Fluid Systems, Inc.	Patterson Pump Company
EnviroTech Pumpsystems	Pinellas County, Gen. Serv. Dept.
Exeter Energy Limited Partnership	The Process Group, LLC
Fairbanks Morse Pump Corp.	Raytheon Engineers & Constructors
Ferris State Univ. Const. and Facilities Dept.	Reddy-Buffaloes Pump, Inc.
Floway Pumps	Settler Supply Company
Flowserve Corporation	South Florida Water Mgmt. Dist.
Fluid Sealing Association	Sta-Rite Industries, Inc.
Illinois Department of Transportation	Stone & Webster Eng. Corp.
Ingersoll-Dresser Pump Company	Sulzer Pumps (USA) Inc.
ITT Industrial Pump Group	Summers Engineering, Inc.
J.P. Messina Pump and Hydr. Cons.	Systecon, Inc.
John Crane, Inc.	Val-Matic Valve & Manufacturing Corp.
Krebs Consulting Service	Zoeller Engineered Products

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2.6 Test

2.6.1 Scope

This standard is limited to the testing of vertical diffuser type centrifugal pumps with clear water. The tests conducted under these standards shall be made and reported by qualified personnel.

This standard applies to tests of the pump only, unless stated otherwise.

The type of test(s) performed, and the auxiliary equipment to be used, should be agreed upon by the purchaser and manufacturer prior to the test.

It is not the intent of this standard 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 if agreed upon by the parties involved without sacrificing the validity of the applicable parts of this standard.*

2.6.1.1 Objective

This standard is intended to provide uniform procedures for hydrostatic, hydraulic, and mechanical performance testing of vertical pumps and recording of the test results. This standard is intended to define test procedures which may be invoked by contractual agreement between a purchaser and manufacturer. It is not intended to define a manufacturer's standard practice.

2.6.2 Types of tests

This standard describes the following tests:

- a) Performance test to demonstrate hydraulic and mechanical integrity;

Optional tests as follows when specified:

- b) Hydrostatic test of pressure-containing components;
- c) Net positive suction head required test (NPSHR test);
- d) Mechanical test.

For airborne sound testing see HI 9.1–9.6-2000, *Pumps – General Guidelines*.

2.6.2.1 Test conditions

Unless otherwise specified, the rate of flow, head, efficiency, NPSHR and priming time are based on shop tests using water corrected to 20°C (68°F). If the facility cannot test at rated speed because of limitations in power, electrical frequency, or available speed changers, the pump may be tested at between 50% and 200% of rated speed.

2.6.3 Terminology

The following terms are used to designate test parameters or are used in connection with pump testings.

2.6.3.1 Symbols

See Table 2.11.

2.6.3.2 Subscripts

See Table 2.12.

2.6.3.3 Specified condition point

Specified condition point is synonymous with rated condition point.

2.6.3.4 Rated condition point

Rated condition point applies to the rate of flow, head, speed, NPSH and power of the pump as specified by the purchase order.

2.6.3.5 Normal condition point

Normal condition point applies to the rate of flow, head, speed, NPSH and power at which the pump will normally operate. It may be the same as the rated condition point.

2.6.3.6 Best efficiency point (BEP)

The rate of flow and head at which the pump efficiency (η_p) is a maximum.

2.6.3.7 Shut off (SO)

The condition of zero flow where no liquid is flowing through the pump.

2.6.3.8 Volume

The unit of volume shall be one of the following:

Table 2.11 — Symbols

Symbol	Term	Metric unit	Abbreviation	US Customary Unit	Abbreviation	Conversion factor ^a
A	Area	square millimeter	mm ²	square inches	in ²	645.2
β (beta)	Meter or orifice ratio	dimensionless	—	dimensionless	—	1
D	Diameter	millimeter	mm	inches	in	25.4
Δ (delta)	Difference	dimensionless	—	dimensionless	—	1
η (eta)	Efficiency	percent	%	percent	%	1
g	Gravitational acceleration	meter/second squared	m/s ²	feet/second squared	ft/sec ²	0.3048
γ (gamma)	Specific weight			pounds/cubic foot	lb/ft ³	
h	Head	meter	m	feet	ft	0.3048
H	Total head	meter	m	feet	ft	0.3048
n	Speed	revolutions/minute	rpm	revolutions/minute	rpm	1
NPSHA	Net positive suction head available	meter	m	feet	ft	0.3048
NPSHR	Net positive suction head required	meter	m	feet	ft	0.3048
Ns	Specific speed $N_s = nQ^{1/2}/H^{3/4}$	dimensionless	—	dimensionless	—	1.162
ν (nu)	Kinematic viscosity	millimeter squared/sec	mm ² /s	seconds Saybolt Universal	SSU	0.22
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	cubic meter/hour	m ³ /h	cubic feet/second	ft ³ /sec	101.94
Q	Rate of flow	cubic meter/hour	m ³ /h	US gallons/minute	gpm	0.2271
ρ (rho)	Density	kilogram/cubic meter	kg/m ³	pound mass/cubic foot	lbm/ft ³	16.02
s	Specific gravity	dimensionless	—	dimensionless	—	1
t	Temperature	degrees Celsius	°C	degrees Fahrenheit	°F	(°F-32) × ⁵ / ₉
τ (tau)	Torque	Newton – meter	N·m	pound-feet	lb-ft	1.356
v	Velocity	meter/second	m/s	feet/second	ft/sec	0.3048
x	Exponent	none	none	none	none	1
Z	Elevation gauge distance above or below datum	meter	m	feet	ft	0.3048

^a Conversion factor × US units = metric units.

- Metric: cubic meter;
- US units: US gallon;
- US units: cubic foot.

The specific weight of water at a temperature of 20°C (68°F) shall be taken as 9.79 kN/m³ (62.3 lb. per cu. ft.). For other temperatures, proper specific weight corrections shall be made using values from the ASME steam tables.

2.6.3.9 Rate of flow (capacity) (Q)

The rate of flow of a pump is the total volume throughput per unit of time at suction conditions. It assumes no entrained gases at the stated operating conditions.

2.6.3.10 Speed (n)

The number of revolutions of the shaft in a given unit of time. Speed is expressed as revolutions per minute.

2.6.3.11 Datum

The reference line or eye of the first stage impeller from which all elevations are measured (see Figure 2.63).

Optional tests can be performed with the pump mounted in a suction can. Irrespective of pump mounting, the pump's datum is maintained at the eye of the first stage impeller (see Figure 2.64).

The elevation head (Z) to the datum is positive when the gauge is above datum and negative when the gauge is below datum.

2.6.3.12 Head (h)

Head is the expression of the energy content of the liquid referred to a datum. It is expressed in units of energy per unit weight of liquid. The measuring unit for head is meter (feet) of liquid.

2.6.3.12.1 Gauge head (h_g)

The pressure energy of the liquid determined by a pressure gauge or other pressure measuring device:

Table 2.12 — Subscripts

Subscript	Term	Subscript	Term
1	Test condition or model	min	Minimum
2	Specific condition or prototype	mot	Motor
a	Absolute	ot	Operating temperature
atm	Atmospheric	OA	Overall unit
b	Barometric	p	Pump
ba	Bowl assembly	s	Suction
d	Discharge	t	Test temperature
dvr	Driver input	t	Theoretical
g	Gauge	v	Velocity
im	Intermediate mechanism	vp	Vapor pressure
max	Maximum	w	Water

$$\text{(Metric)} \quad h_g = \frac{p_g}{9.8 \, s}$$

$$\text{(US units)} \quad h_g = \frac{(2.31)(62.3)p_g}{\gamma} = \frac{2.31(p_g)}{s}$$

2.6.3.12.2 Velocity head (h_v)

The kinetic energy of the liquid at a given section. Velocity head is expressed by the following equation:

$$h_v = \frac{v^2}{2g}$$

2.6.3.12.3 Elevation head (Z)

The potential energy of the liquid due to this elevation relative to a datum level measured to the center of the pressure gauge or liquid surface.

2.6.3.12.4 Total suction head (h_s) – open suction test

For open suction (wet pit) tests, the first stage impeller of the bowl assembly is submerged in a pit (see Figure 2.65).

The total suction head (h_s) at datum (see Figure 2.63) is the submergence in meters (feet) of water (Z_w). The average velocity head of the flow in the pit is small enough to be neglected and gauge head is zero.

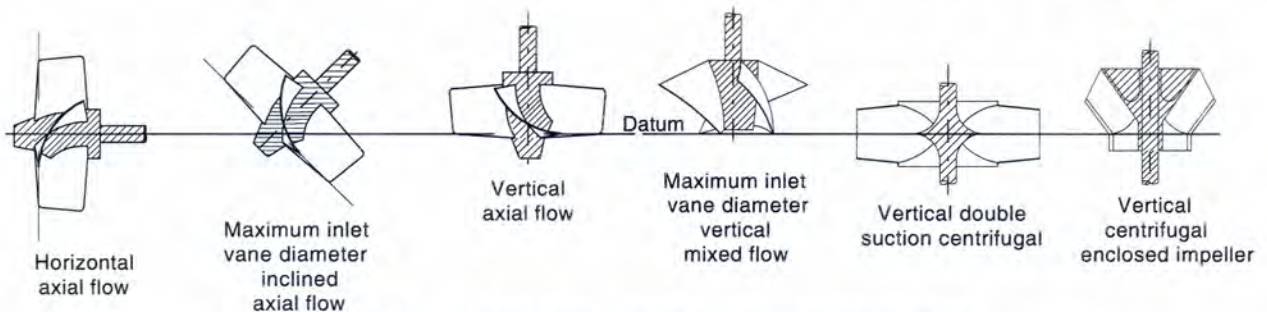


Figure 2.63 — Datum elevations for various pump designs

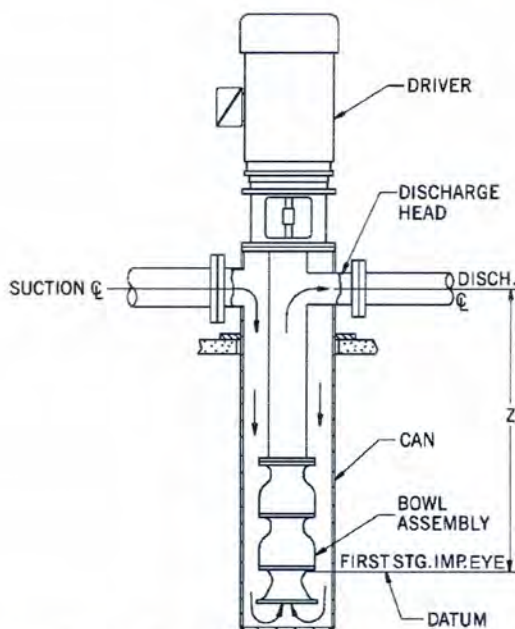


Figure 2.64 — First stage impeller datum closed suction – can pump

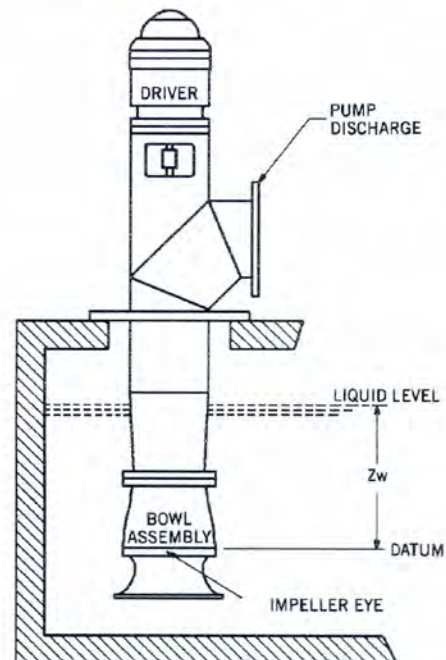


Figure 2.65 — Total suction head – open suction

2.6.3.12.7.1 Open suction tests

For open suction tests, the total head (H) is the sum of the pressure head (h_{gd}) measured on the discharge pipe downstream from the discharge head, plus the velocity head (h_{vd}) at point of gauge attachment, plus the vertical distance (Z_d) from datum to the pressure gauge centerline, minus the submergence (Z_w) (see Figure 2.67).

$$H = h_d - h_s = (h_{gd} + h_{vd} + Z_d) - Z_w$$

Hydraulic losses between the bowl assembly and the discharge nozzle are charged to the pump.

2.6.3.12.7.2 Bowl assembly total head (H_{ba}) (established on open suction test)

This is the developed head at the discharge of the bowl assembly and is a multiple of the head per stage as typically shown on the pump manufacturer's rating curves.

The bowl assembly total head (H_{ba}) is the gauge head (h_{gd}) measured at a gauge connection located on the column pipe downstream from the bowl assembly, plus the velocity head (h_{vd}) at point of gauge connection, plus the elevation head (Z_d) from datum to the pressure gauge centerline, minus the submergence Z_w , which is the vertical distance from datum to the liquid level.

$$H_{ba} = h_{gd} + h_{vd} + Z_d - Z_w$$

Friction losses in suction pipe and strainer, if used in the test setup, must be added to the measured head. The friction loss in the column between the bowl assembly outlet and the gauge connection must also be added if significant.

2.6.3.12.7.3 Closed suction tests

For closed suction tests (can pumps), and with the total discharge head (h_d) and the total suction head (h_s) referenced to datum (Figure 2.68), the total head is:

$$H = h_d - h_s$$

$$= (h_{gd} + h_{vd} + Z_d) - (h_{gs} + h_{vs} + Z_s)$$

When the suction gauge head (h_{gs}) is negative (below atmospheric) and the gauge connecting line free of liquid, then Z_s becomes the elevation distance from the pump suction centerline to datum.

All hydraulic losses between the pump suction and discharge nozzles are charged to the pump.

2.6.3.12.8 Atmospheric head (h_{atm})

Local atmospheric pressure expressed in meters (feet).

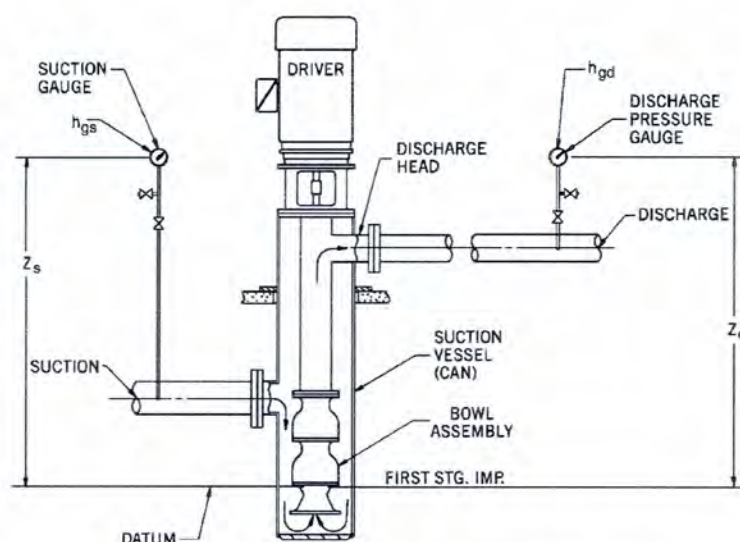


Figure 2.68 — Total head – closed suction

2.6.3.12.7.1 Open suction tests

For open suction tests, the total head (H) is the sum of the pressure head (h_{gd}) measured on the discharge pipe downstream from the discharge head, plus the velocity head (h_{vd}) at point of gauge attachment, plus the vertical distance (Z_d) from datum to the pressure gauge centerline, minus the submergence (Z_w) (see Figure 2.67).

$$H = h_d - h_s = (h_{gd} + h_{vd} + Z_d) - Z_w$$

Hydraulic losses between the bowl assembly and the discharge nozzle are charged to the pump.

2.6.3.12.7.2 Bowl assembly total head (H_{ba}) (established on open suction test)

This is the developed head at the discharge of the bowl assembly and is a multiple of the head per stage as typically shown on the pump manufacturer's rating curves.

The bowl assembly total head (H_{ba}) is the gauge head (h_{gd}) measured at a gauge connection located on the column pipe downstream from the bowl assembly, plus the velocity head (h_{vd}) at point of gauge connection, plus the elevation head (Z_d) from datum to the pressure gauge centerline, minus the submergence Z_w , which is the vertical distance from datum to the liquid level.

$$H_{ba} = h_{gd} + h_{vd} + Z_d - Z_w$$

Friction losses in suction pipe and strainer, if used in the test setup, must be added to the measured head. The friction loss in the column between the bowl assembly outlet and the gauge connection must also be added if significant.

2.6.3.12.7.3 Closed suction tests

For closed suction tests (can pumps), and with the total discharge head (h_d) and the total suction head (h_s) referenced to datum (Figure 2.68), the total head is:

$$H = h_d - h_s$$

$$= (h_{gd} + h_{vd} + Z_d) - (h_{gs} + h_{vs} + Z_s)$$

When the suction gauge head (h_{gs}) is negative (below atmospheric) and the gauge connecting line free of liquid, then Z_s becomes the elevation distance from the pump suction centerline to datum.

All hydraulic losses between the pump suction and discharge nozzles are charged to the pump.

2.6.3.12.8 Atmospheric head (h_{atm})

Local atmospheric pressure expressed in meters (feet).

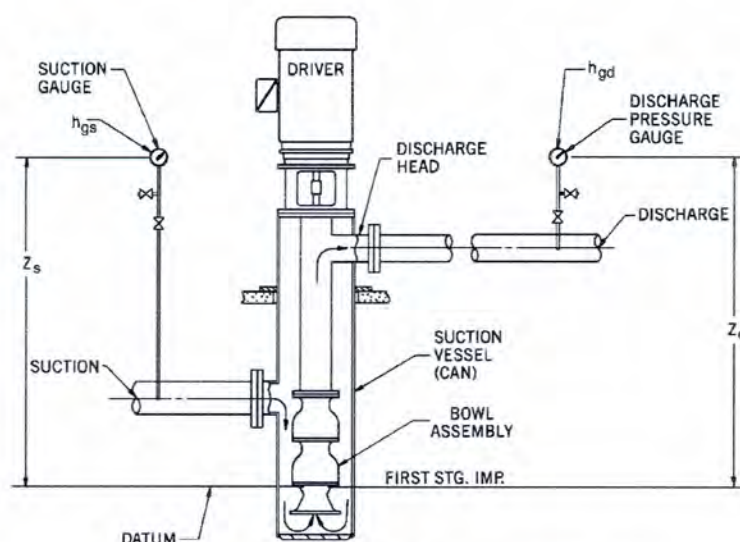


Figure 2.68 — Total head – closed suction