ANSI/HI 7.6-2012

American National Standard for

Controlled-Volume Metering Pumps

for Test

ANSI/HI 7.6-2012

Hydraulic Institute

6 Campus Drive
First Floor North
Parsippany, New Jersey
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American National Standard

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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 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 contents 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 parentheses. Charts, graphs, and example calculations are also shown 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 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 controlled-volume metering pumps, were contacted prior to the approval of this 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 Company
Brown & Caldwell
GIW Industries, Inc.
Kemet Inc.
Neptune Chemical Pump Co., Inc.
Wasserman, Horton - Consultant

Working group 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:

Chair – Don Weidemann, Neptune Chemical Pump Co., Inc.

Committee Members	Company
James Carling	Milton Roy Americas
Gary Cornell	Blacoh Fluid Controls, Inc.
Aaron Hinchliffe	Iwaki America Incorporated
Peter Timpanelli	LEWA, Inc.

Alternates	Company
Peter Brule	Iwaki America Incorporated
James Casey	Milton Roy Americas
Joel Higbee	Milton Roy Americas
Dennis Ruis	Iwaki America Incorporated
Carlos Uribe	Grundfos North America

7.6 Test

7.6.1 Scope

This standard is for the testing of positive displacement reciprocating controlled-volume metering pumps (see ANSI/HI 7.1-7.5 *Controlled-Volume Metering Pumps for Nomenclature, Definitions, Application, and Operation*).

These standards apply to test of the pump only, unless stated otherwise.

Variations in test procedures may exist without violating the intent of this standard. Exceptions may be taken if agreed on by the parties involved without sacrificing the validity of the applicable parts of the standard.

7.6.1.1 Objective

This standard provides uniform procedures for hydrodynamic controlled-volume pump performance testing and for recording of the test results of metering pumps.

Vibration and acoustical testing methods are not included in this standard. Refer to ANSI/HI 9.1–9.5 *Pumps – General Guidelines for Types, Definitions, Application, Sound Measurement and Decontamination*, Section 9.4 Measurement of airborne sound, for acoustical testing procedures.

7.6.2 Types of tests

This standard contains procedures for the following types of performance tests to demonstrate one of the following:

1) Functional testing of production units.

2) Mechanical integrity at speed and pressure specified.

3) Rate of flow and mechanical integrity at speed and pressure specified.

4) Verification of performance to the manufacturer's specifications.

Other optional tests may be specified (not included in this standard):

a) Steady state accuracy as described in Section 7.2.2 of ANSI/HI 7.1-7.5.

b) Linearity as described in Section 7.2.10 of ANSI/HI 7.1-7.5.

c) Repeatability as described in Section 7.2.27 of ANSI/HI 7.1-7.5.

d) Net positive suction head required as described in Section 7.2.12 of ANSI/HI 7.1-7.5.

7.6.2.1 Test conditions

The manufacturer's standard production test for quality assurance and to establish conformance with the manufacturer's commercial mechanical or performance criteria. Tests shall be performed using clean water essentially free of entrained gasses at ambient temperature and at the ambient temperature of the test facility.

7.6.3 Terminology

The following terms and symbols are used to designate test parameters used in connection with pump tests.

7.6.3.1 Symbols

Table 7.6.3.1 — Symbols

Symbol	Term	Metric unit	Abbreviation	US Customary Unit	Abbreviation	Conversion factor[a]
A	Area of piston/plunger	square centimeter	cm^2	square inch	in^2	6.45
β (beta)	Meter or orifice ratio	dimensionless	—	dimensionless	—	1
C	Coefficient for acceleration head	dimensionless	—	dimensionless	—	1
d	Diameter	millimeter	mm	inch	in	25.4
D	Displacement	cubic centimeter	cm^3	cubic inches	in^3	16.39
Δ (delta)	Difference	dimensionless	—	dimensionless	—	1
η (eta)	Efficiency	percent	%	percent	%	1
g	Gravitational acceleration	meter/second squared	m/s^2	foot/second squared	ft/s^2	0.3048
γ (gamma)	Specific weight	newton/cubic meter	N/m^3	pound/cubic foot	lb/ft^3	0.0064
h	Head	meter	m	foot	ft	0.3048
L	Stroke length	millimeter	mm	inch	in	25.4
M	Number of pistons	dimensionless	—	dimensionless	—	1
n	Speed	stroke/minute	spm	stroke/minute	spm	1
NPIPA	Net positive inlet pressure available	bar absolute	bara	pound/square inch absolute	psia	0.0689
NPIPR	Net positive inlet pressure required	bar absolute	bara	pound/square inch absolute	psia	0.0689
NPSHA	Net positive suction head available	meter absolute	m	foot	ft	0.3048
NPSHR	Net positive suction head required	meter	m	foot	ft	0.3048
ν (nu)	Viscosity, kinematic	meter squared/second	m^2/s	centistoke	cSt	10^6
π	pi = 3.1416	dimensionless	—	dimensionless	—	1
p	Pressure	bar	bar	pound/square inch	psi	0.0689
P	Power	kilowatt	kW	horsepower	hp	0.7457
Q	Rate of flow (capacity)	liter/hour	L/h	US gallon/hour	gph	3.7854
ρ (rho)	Density	kilogram/cubic meter	kg/m^3	pound mass/cubic foot	lbm/ft^3	16.02
s	Specific gravity	dimensionless	—	dimensionless	—	1
S	Slip	percent	%	percent	%	1
t	Temperature	degree Celsius	°C	degree Fahrenheit	°F	$(°F-32) \times {}^5/_9$
τ (tau)	Torque	newton-meter	N·m	pound-foot	lb-ft	1.356
μ (mu)	Viscosity, absolute	centipoise	cP	centipoise	cP	1
v	Velocity	meter/second	m/s	foot/second	ft/s	0.3048
V	Specific volume	cubic meter/kilogram	m^3/kg	cubic foot/pound	ft^3/lb	0.0624
x	Exponent	none	none	none	none	1
Z	Elevation gauge distance above or below datum	meter	m	foot	ft	0.3048

[a] Conversion factor × US customary units = metric units (except temperature).

7.6.3.2 Subscripts

Table 7.6.3.2 — Subscripts

Subscript	Term	Subscript	Term
a	Absolute	drv	Driver input
b	Barometric	p	Pump
c	Piston or plunger	s	Suction
g	Gauge	t	Theoretical
H	Total head	Δ (delta)	Differential
i	Inlet	v	Velocity
max	Maximum	V	Volume
min	Minimum	vp	Vapor pressure
mot	Motor	w	Hydraulic or water
ni	Net inlet	x	Exponent
o	Outlet	1	Test condition
oa	Overall	2	Specific condition
d	Discharge		

7.6.3.3 Rated condition point

Rated condition point applies to the rate of flow, discharge pressure, suction pressure, net positive suction head required (NPSHR), and speed of the pump. Suction pressure and NPSHR are only included in the rated condition point when requested by the purchaser and not when the pump will be used in a flooded suction application.

7.6.3.4 Volume (standard units)

The standard unit of volume shall be as follows:

a) Metric – liter.

b) US customary unit – US gallon.

c) 1 US gallon = 3.785 liters.

7.6.3.4.1 Stroke (*L*)

The traverse of one complete unidirectional motion of the piston, plunger, or diaphragm.

7.6.3.4.2 Pump displacement (*D*)

The volume swept by all pistons, plungers, or diaphragms.

(Metric) $$D = \frac{ALM}{1 \times 10^3}$$

(US customary units) $$D = ALM$$

Where:

D = pump displacement

A = area of piston/plunger

L = stroke length

M = number of pistons or plungers

7.6.3.5 Rate of flow (Q)

The quantity of liquid theoretically delivered per unit of time, assuming no losses or inefficiencies.

$$\text{(Metric units) } Q = Dn\left(\frac{60}{1000}\right)$$

$$\text{(US customary units) } Q = Dn\left(\frac{60}{231}\right)$$

n = strokes per minute

7.6.3.6 Datum

The centerline of the pump inlet from which all elevations and NPSH (net positive inlet pressure [NPIP]) are measured. The elevation pressure (p_Z) to the datum is positive when the gauge is above datum and negative when the gauge is below datum.

7.6.3.7 Pressure (p)

Pressure is the expression of the energy content of the liquid in units of force per unit area.

7.6.3.7.1 Gauge pressure (p_g)

The pressure energy of the liquid determined by a pressure gauge or other pressure-measuring device, relative to the atmosphere.

7.6.3.7.2 Elevation pressure (p_Z)

The potential energy of the liquid due to elevation.

7.6.3.7.3 Elevation head (Z)

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

7.6.3.7.4 Velocity pressure (p_v)

The kinetic energy of the liquid flow expressed in equivalent pressure. It is determined as follows:

$$\text{(Metric)} \quad p_v = \left(\frac{\left(\frac{v^2}{2g}\right)}{0.102}\right) \times s$$

(US customary units) $$p_v = \left(\frac{\left(\frac{v^2}{2g}\right)}{2.31}\right) \times s$$

7.6.3.7.5 Total discharge pressure (p_d)

The total discharge pressure is the algebraic sum of the discharge gauge pressure (p_{gd}), the velocity pressure (v_d), and the elevation pressure (Z_d) measured on the discharge side of the pump:

(Metric) $$p_d = p_{gd} + \frac{\left[\left(\frac{v_d^2}{2g}\right) + Z_d\right] \times s}{0.102}\ kPa$$

(US customary units) $$p_d = p_{gd} + \frac{\left[\left(\frac{v_d^2}{2g}\right) + Z_d\right] \times s}{2.31}\ psia$$

7.6.3.7.6 Total differential pressure (p_H)

The total differential pressure is the measure of the pressure increase imparted to the liquid by the pump and is therefore the difference between the total discharge pressure (p_d) and the total suction pressure (p_s):

$$p_H = p_d - p_s$$

7.6.3.7.7 Net positive suction head available (NPSHA)/Net positive inlet pressure available (NPIPA)

NPIPA is the total absolute suction pressure available from the system, determined at the pump suction nozzle, less the absolute vapor pressure of the liquid at pumping temperature.

NPIPA = $p_{sa} - p_{vp}$, in kPa (psi)

Where:

p_{sa} = total suction pressure + barometric pressure = $p_s + p_b$, in kPa (psi)

p_{vp} = vapor pressure of the liquid at the temperature being pumped, in kPa (psi)

or

NPIPA = $p_s + p_b - p_{vp}$, in kPa (psi)

Where:

(Metric units) $p_s = p_{gs} + p_v + \frac{Z_s}{0.102}$, in kPa

(US customary units) $p_s = p_{gs} + p_v + \frac{Z_s}{2.31}$, in psi

NPIPA is determined at the centerline of the pump suction nozzle.

NPSHA is the same concept expressed in units of meters (feet) of process fluid.

7.6.3.7.8 Net positive inlet pressure required (NPIPR)/Net positive suction head required (NPSHR)

Net positive inlet pressure required (NPIPR) is the amount of suction pressure required by the pump to obtain satisfactory volumetric efficiency and minimize cavitation. This is usually when there is no more than 3% reduction in flow rate (capacity) from the pump at any air inlet pressure and total head condition on the pump curve.

The pump manufacturer determines by test the net positive inlet pressure required by the pump at the specified operating conditions.

NPSHR is the same concept expressed in units of meters (feet) of process fluid.

7.6.3.8 Volumetric efficiency (η_V)

The ratio of the actual pump delivery per stroke to the theoretical displacement, expressed as a percent.

7.6.4 Performance test

7.6.4.1 Performance test acceptance

The acceptance tolerance applies to the rated condition point only. Follow manufacturer's criteria within ± 3% repeatability and linearity unless contractually agreed on by manufacturer and end user.

7.6.4.2 Witnessing of performance tests

The purchaser or purchaser's designated representative may witness the test when requested.

7.6.4.3 Performance test

The manufacturer's standard production test is performed for quality assurance and to establish conformance with the manufacturer's commercial mechanical or performance criteria.

7.6.4.4 Performance test instrumentation

7.6.4.4.1 Introduction

Performance test instrumentation shall be selected so that it can provide measurements with the accuracy shown in Section 7.6.4.4.2 at rated conditions. Instruments need not be calibrated specifically for each test but are to be periodically calibrated by the instrument manufacturer or other suitable party.

7.6.4.4.2 Instrument fluctuation[1] and accuracy

Acceptable fluctuations of test readings during test and accuracy of instruments are shown in the following table:

Actual Measurement		
	Acceptable fluctuation of test reading ± % of the values	Accuracy of the instrument as a ± % of the values
Rate of flow	0.1% to 5%	0.1% to 5%
Differential pressure	2.5%	2.5%
Discharge pressure	2.5%	2.5%
Suction pressure	2.5%	2.5%

7.6.4.5 Performance test setup

This section contains general guidelines for pump test setup to ensure accurate and repeatable test results (see Figure 7.6.4.5).

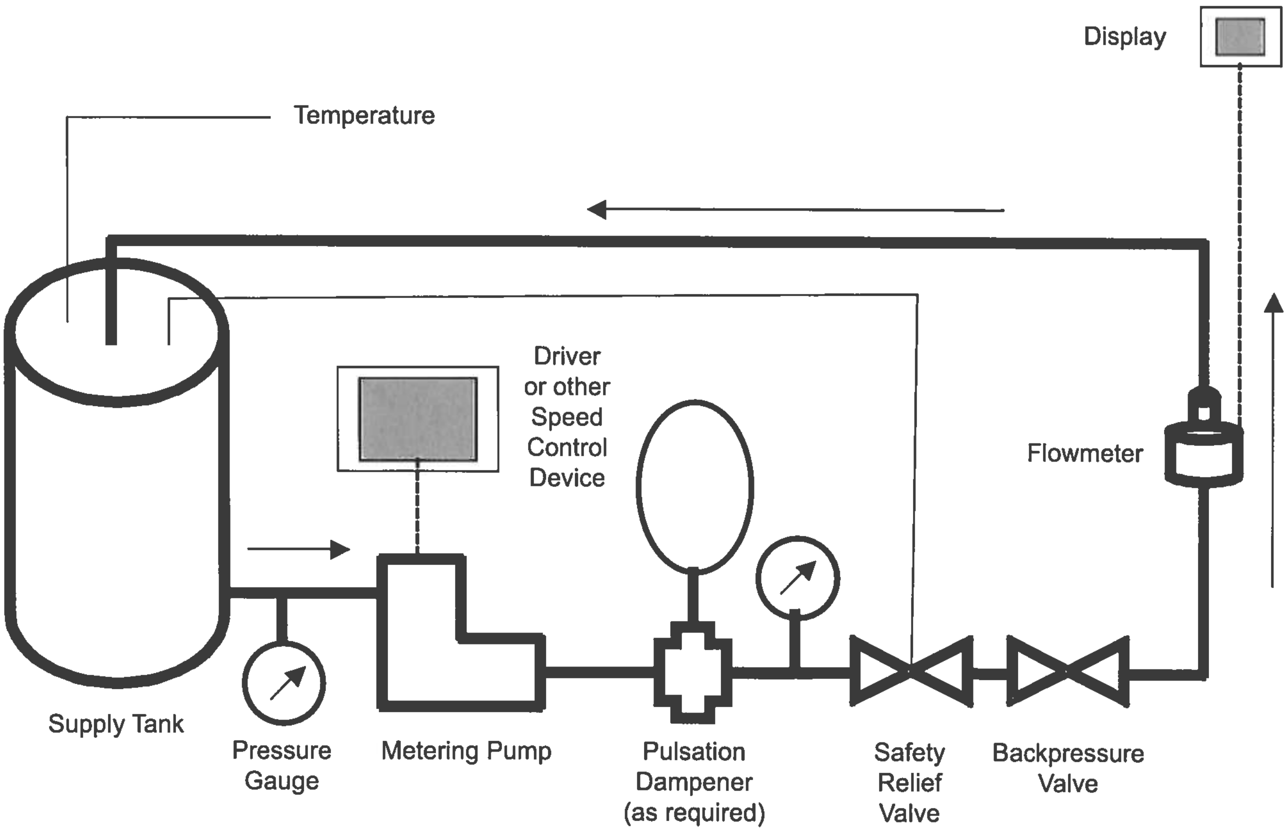

Figure 7.6.4.5 — Generalized schematic for open or closed vented tank

1 To avoid erroneous results due to inherent pulsing flows, instrumentation with sensitivity to frequency response less than the pumping stroke frequency shall be employed.

It must be understood that test setups that do not conform with respect to intake structure, piping, and measuring equipment, may not duplicate test facility results.

A test setup drawing can include an alternative for suction calibration column on the suction instead of flowmeter on the discharge. Measurement of suction pressure is recommended under all test conditions.

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

a) Factory or purchaser furnished driver. Depending on the method used to provide pump input power, driver efficiency data may be required.

b) Drive motor of proper voltage or appropriate technology to operate metering pump.

c) A suction pipe or hose from safety relief valve return, closed tank, or open sump, properly sized for the pump being tested.

d) A discharge pressure gauge suitable for measuring not more than two times the complete range of pressures being tested, located as close as possible downstream of at or near the pulsation dampener. An additional pressure gauge may be located at the suction side of the pump.

e) A discharge pipe or hose returning to the supply tank.

f) Dampening devices may be used for the discharge if required, such as pulsation dampeners, needle valves, or capillary tubes to dampen out the pressure pulsations at the gauges. Dampening devices may be used when electronic flow measurement devices are used to determine and electronically record flow rates.

g) For variable speed applications, a means for measuring input speed to the pump shall be provided and shall be suitable for measuring the complete range of speed over the turndown range. This can include AC or DC power control, or applicable driver for pump technology.

h) A means for measuring pump rate of flow in liters/hour (gallons/hour), or other acceptable units.

   1) Rate-of-flow measurement by weight

   Measurement of rate of flow by weight depends on the accuracy of the scales used and the accuracy of the measurement of time. A certification of scales shall become part of the test record, or, in the absence of certification, the scales shall be calibrated with standard weights before or after test. Time intervals for the collection period must be measured to an accuracy of one quarter of 1%.

   2) Rate-of-flow measurement by volume

   This is done by measuring the change in volume of a 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 into or out of the tank or reservoir must pass through the pump.

   In establishing reservoir volume by linear measurements, consideration must be given to the geometric regularity (flatness, parallelism, roundness, etc.) of the reservoir surfaces as well as dimensional changes due to thermal expansion or contraction, or distortion resulting from hydrostatic pressure of the liquid.

   Liquid levels shall be measured by means such as hook gauges, floats, and vertical or inclined gauge glasses.

   In some locations and under some circumstances, evaporation and loss of liquid by spray may be significant and may be greater than the effects of thermal expansion or contraction. Allowance for such loss shall be made, or the loss shall be prevented.

3) Rate-of-flow measurement by direct reading meters

   For this section, the only suitable meters are direct read devices, such as paddle meters, magnetic flowmeters, and other accepted process measurement instruments.

i) Test setups intended for NPSH testing shall be provided with a means for adjusting the NPSHA to the pump (such as a suction throttle valve with optional screen or straightening vanes), variable level sump, suction tank vacuum pump, or suction tank heater. No NPSH test is required when the manufacturer recommends flooded suction.

j) If required, a means for measuring the temperature of the test liquid.

7.6.4.6 Performance test procedure

The following data, where applicable, shall be obtained and furnished on a pump test report prior to the test run:

General:

1) Owner's name ____________________

2) Plant location ____________________

3) Elevation above sea level ____________________

4) Type of service ____________________

Pump:

1) Manufactured by ____________________

2) Manufacturer's model number ____________________

3) Manufacturer's serial number ____________________

Driver:

1) Manufactured by ____________________

2) Model number ____________________

3) Type: motor _______ air _______ other ____________________

4) Rated power ____________________

5) Rated speed ____________________

6) Characteristics (voltage, frequency, etc.) ____________________

Specifying rated conditions

The following information is necessary to specify rated conditions:

1) Liquid pumped (water, oil, etc.) and ambient temperature ______________________
2) Rate of flow ______________________
3) Total suction pressure ______________________
4) Net positive suction head required (NPSHR) ______________________
5) Total discharge pressure ______________________

Test information

Test information should be listed substantially as follows:

General:

1) Where tested ______________________
2) Date ______________________
3) Tested by ______________________
4) Test witnessed by ______________________

Rate of flow:

1) Method of measurement ______________________
2) Meter—make and serial number ______________________
3) Calibration details ______________________
4) Water temperature ______________________

Power (if required):

1) Method of measurement ______________________
2) Make and serial number of instrument ______________________
3) Calibration details ______________________

Speed:

1) Method of measurement ______________________
2) Make and serial number of instrument ______________________
3) Calibration details ______________________

(End of data sheet)

Instructions:

1) Record the pump type, size, and serial number.

2) Verify and record the liquid used and its temperature before and after testing (more often during NPSH tests or with high-power pumps).

3) Record ambient temperature and elevation relative to sea level of test.

4) Record critical installation dimensions, such as tank internal dimensions, pipe internal dimensions, and liquid levels relative to datum.

5) Record driver data, such as type, power, speed range, amperage, voltage, and efficiency; i.e., test motor nameplate to be recorded.

6) Record auxiliary equipment data, such as pressure monitors, leakage detectors, alarms, etc.

7) Make notations of calibration records and correction factors in accordance with instrumentation section.

8) Identity and qualification level(s) of test personnel.

7.6.4.7 Performance test records

Written test results shall be furnished upon request. Details and type of report are to be agreed upon by the parties involved.

7.6.4.8 Performance test calculations

See Table 7.6.3.1 for terms and units for the symbols used.

7.6.4.8.1 Plotting performance test results

Linearity of rate of flow versus percentage of flow can be plotted as ordinates on the same sheet, as shown in Figure 7.6.4.8.1.

Y = Flow rate

X = Percent of flow, adjustable by strokes per minute or stroke length

m = Scaling factor

B = Offset from zero (if any)

7.6.4.9 Report of performance test

Written test results shall be furnished upon request. Details and type of report are to be agreed upon by the parties involved.

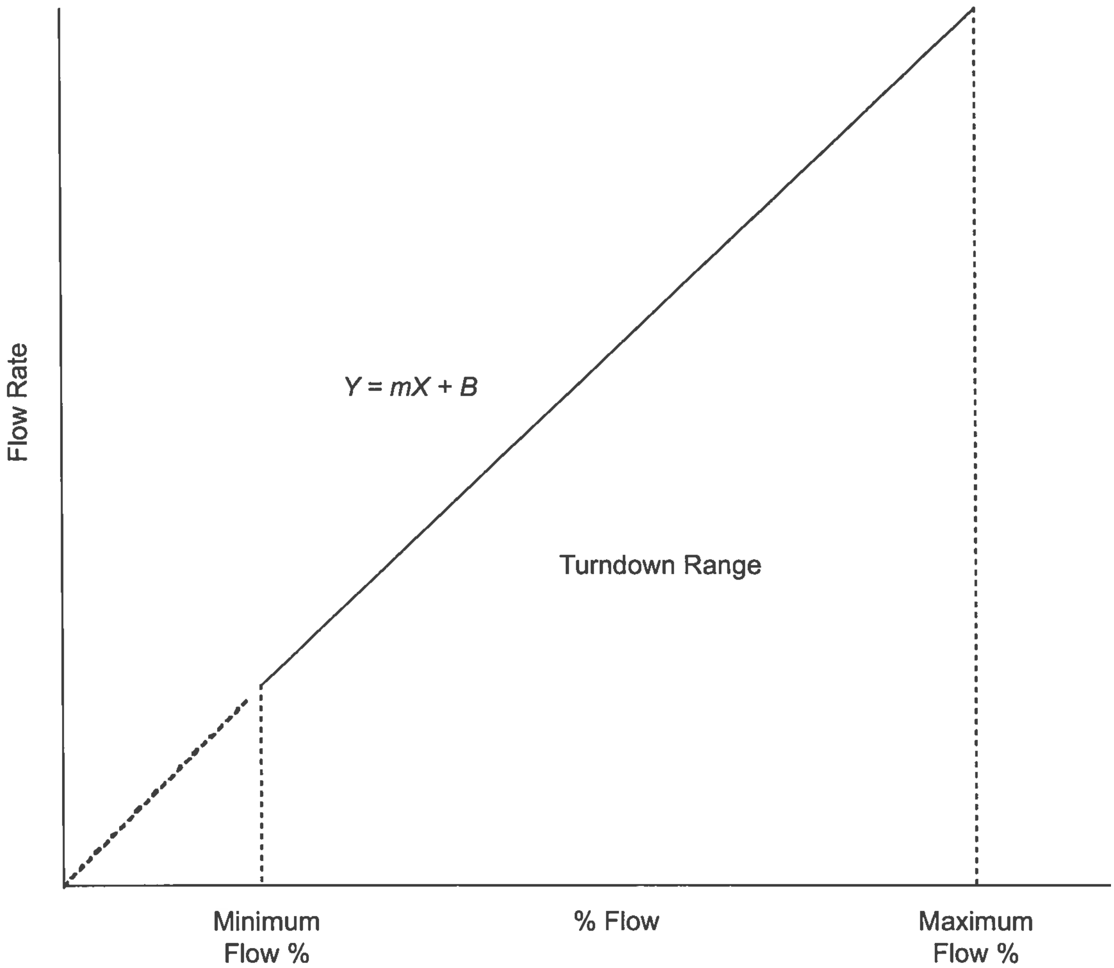

Figure 7.6.4.8.1 — Plotting test results

Appendix A

Index

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

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

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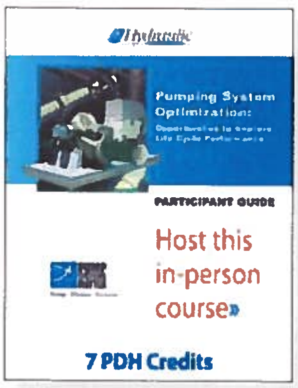

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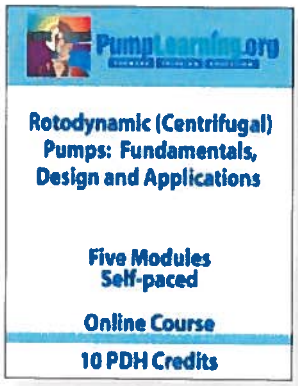

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