American National Standard for

Rotodynamic Pumps

Guideline for NPSH Margin

ANSI/HI 9.6.1-2012

Hydraulic INSTITUTE

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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 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 contents of a Hydraulic 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

US customary units of measurement are predominantly used. Due to the reference to ANSI/ASME B73 standards for pump dimensions, conversion to metric units was inappropriate. Consistent units must be used in all calculations required by this standard.

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

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

4B Engineering & Consulting, LLC
A.W. Chesterton Company
Bechtel
Black & Veatch (B & V)
Budris Consulting
Colfax Fluid Handling
DuPont Company
ekwestrel corp
GIW Industries, Inc.
Gorman-Rupp Company
Healy Engineering, Inc.
Hydraulic, Measurement, & Inspection Consulting
ITT - Industrial Process
J.A.S. Solutions Ltd.
LVVWD - Las Vegas Valley Water District
Mechanical Solutions, Inc.
MWH Americas, Inc.
Patterson Pump Company
Pentair
Pump Design, Development & Diagnostics, LLC
Sulzer Pumps (US) Inc.
Summit Pump, Inc.
Weir Floway, Inc.
Weir Minerals North America
Weir Specialty Pumps

Committee list

Although this standard was processed and approved for submittal to ANSI by the Canvass Method, a working committee met many times to facilitate its development. At the time it was developed, the committee had the following members:

Chair – Arnie Sdano, Pentair Water
Vice-Chair – Charles Cappellino, ITT - Industrial Process

Committee Members	Company
Stefan Abelin	Xylem Inc - Water & Wastewater
Graeme Addie	GIW Industries, Inc.
John Anspach	John Anspach Consulting
Jack Claxton	Patterson Pump Company
Michael Cropper	Sulzer Pumps (US) Inc.
Randal Ferman	ekwestrel corp
Thomas Hendrey	Whitley Burchett & Associates
Allen Hobratschk	National Pump Company
Al Iseppon	Pentair Water
Garr Jones	Brown and Caldwell
Dimitar Kalchev	Peerless Pump Company
Yuri Khazanov	InCheck Technologies Inc
Rodney Mrkvicka	Smith & Loveless, Inc.
Michael Mueller	Flowserve Corporation
James Roberts	Xylem Inc - Residential & Commercial Water
Mark Rosebraugh	Grundfos North America
Aleksander Roudnev	Weir Minerals North America
Paul Ruzicka	Xylem Inc. - Applied Water Systems
Ernest Sturtz	CDM Smith Inc.
Fred Walker	Weir Floway, Inc.

Alternate Members	Company
Michael Coussens	Peerless Pump Company
Gary Leander	Weir Minerals North America

Other Contributors	Company
Ed Allis	Formerly of Peerless Pump Company
Tom Angle	Formerly of Weir Specialty Pumps
Bill Beekman	Formerly of Weir Floway, Inc.

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9.6.1 Pump NPSH margin

This guideline addresses rotodynamic general purpose pumps with absorbed power levels up to 4 megawatts (MW) (5300 horsepower [hp]) and impeller inlet tip speeds less than 40 meters per second (m/s) (130 feet per second [ft/s]). It describes the benefits to pump longevity when the net positive suction head (NPSH) available is greater than the NPSH required by a suitable margin, and suggests margins for specific applications.

An NPSH margin may be required for several reasons related to pump performance and service life, to cover the uncertainties of what the NPSH available (NPSHA) will be over the range of operation, and to provide for adequate pump reliability and performance.

NPSH is the liquid's energy, above the vapor pressure, at the inlet of the pump.

Net positive suction head (NPSH) is the absolute inlet total head above the head equivalent to the vapor pressure referred to the NPSH datum plane.

This NPSH is referred to the *NPSH datum plane*, whereas inlet total head is referred to the *reference plane*.

NPSH: The absolute inlet total head, less the vapor pressure head of the pumpage, referred to a datum which is typically the inlet of the first-stage impeller.

NPSH datum plane: The horizontal plane through the center of the circle described by the external points of the entrance edges of the impeller blades; in the first stage in the case of multistage pumps. In the case of double inlet pumps with vertical or inclined axis, it is the plane through the higher center. The manufacturer should indicate the position of this plane with respect to precise reference points on the pump.

NPSHR: A minimum NPSH given by the manufacturer/supplier for a pump achieving a specified performance at the specified rate of flow, speed, and pumped liquid (occurrence of visible cavitation, increase of noise and vibration due to cavitation, beginning of head or efficiency drop, head or efficiency drop of a given amount, limitation of cavitation erosion).

The full published pump head will not, however, be achieved when the NPSHA equals the NPSH3 of the pump. The first-stage head will be 3% less than the fully developed value. The 3% head drop referred to throughout this guideline refers to the head drop in a single-stage pump. For a multistage pump it refers to the head drop in the first stage only, not the total head of the pump.

It is therefore important to note that the NPSHR curves historically provided by pump manufacturers may not show sufficient NPSH values to provide zero head loss or to eliminate cavitation. The manufacturer's curve, if produced using NPSHR values equal to NPSH3, gives the NPSH required such that cavitation will occur to the point where 3% of the first-stage pump head is lost through cavitation.

The 3% value was implemented as early as 1932 when it first appeared in published Hydraulic Institute Standards. The choice of 3% measured head drop is based on the fact that this is the smallest head drop practically measurable. The 3% measured head drop value continues to be the industry accepted norm for characterizing pump suction performance.

Furthermore, the general consensus at the time of implementation was that pumps operating under conditions of 3% head drop would achieve generally acceptable service lives. This was probably true at the time when pumps for a given application were typically larger and slower than pumps for the same application today. Today's higher speed, higher energy density pumps might not achieve acceptable service life under suction conditions without an adequate NPSH margin.

The purpose of this guideline is to establish margins over NPSH3 that will lead to acceptable pump performance and service life.

9.6.1.1 Introduction

Noise, vibration, and possibly the reliability of a rotodynamic pump and mechanical shaft seal may be affected if an appropriate NPSH margin is not provided by the system above the published NPSH3 for the pump.

The NPSHA is the total suction head available, over the vapor pressure of the liquid pumped corrected to the centerline of the impeller (or impeller inlet vane tip datum if vertically mounted), and measured at the inlet to the pump.

$$NPSHA = h_{atm} + h_s - h_{vp}$$

Where:

h_{atm} = atmospheric pressure head, in m (ft)
h_s = total suction head = $h_{gs} + h_{vs} + z_s$, in m (ft)
h_{gs} = suction gauge head, in m (ft)
h_{vs} = suction velocity head, in m (ft)
z_s = elevation from the suction gauge centerline to datum (see Figure 9.6.1.1a), in m (ft)
h_{vp} = liquid vapor pressure head (taken at the highest sustained operating temperature), in m (ft)

The NPSH margin is the NPSHA minus the NPSH3.

$$NPSH\ margin = NPSHA - NPSH3$$

NPSH margin ratio is the NPSHA divided by the NPSH3.

$$NPSH\ margin\ ratio = \frac{NPSHA}{NPSH3}$$

See ANSI/HI 14.6 *Rotodynamic Pumps – Hydraulic Performance Acceptance Tests* and ANSI/HI 11.6 *Submersible Pump Tests* for further details on determination of NPSHA and NPSH3.

The conceptual definition of NPSHR by a pump under certain conditions is the value of NPSHA at which a selected phenomenon induced by cavitation starts to appear. Several criteria are used to qualify the different phenomena associated with cavitation, which lead to several definitions of NPSHR. Additional information can be found in *NPSH for Rotodynamic Pumps: Reference Guide,* published by Europump.

One of the most noticeable effects of cavitation is the degradation of the pump performance due to the presence of the vapor phase induced by cavitation. Migration and coalescence of the vapor bubbles affect the flow within the impeller and cause the head developed by the pump to deteriorate.

By Hydraulic Institute definition, the required NPSH of a pump is the NPSH available that will cause the total head (first-stage head of multistage pumps) to be reduced by 3%, due to flow blockage from cavitation vapor in between the impeller vanes. The required NPSH qualified by this criterion will be referred to as *NPSH3*. The full published pump head will not, however, be achieved (by definition) when the NPSHA equals the NPSH3 of the pump (see Figure 9.6.1.1b). The value of 3% head drop for NPSH3 is based on accepted industry practice for defining a condition of head breakdown due to cavitation.

Margin above NPSH3 is necessary in order for the pump to develop its full-published performance as shown on Figure 9.6.1.1c.

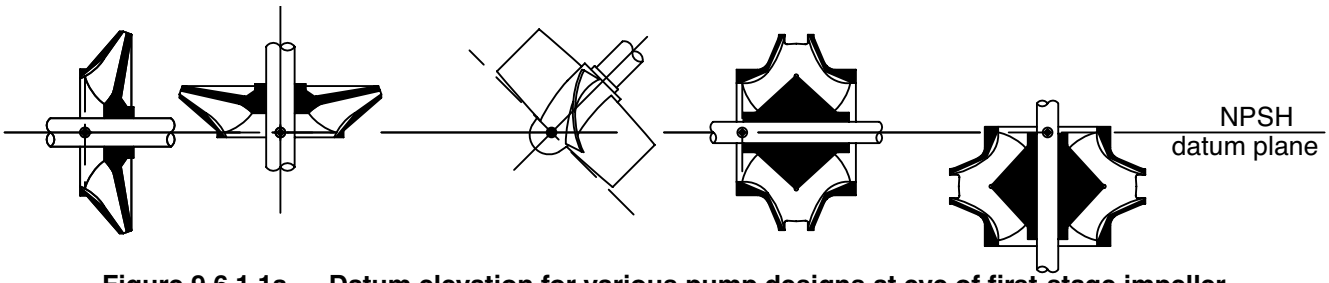

Figure 9.6.1.1a — Datum elevation for various pump designs at eye of first-stage impeller