

American National Standard for

Centrifugal and Vertical Pumps

for Vibration Measurements and Allowable Values

Secretariat
Hydraulic Institute
www.pumps.org

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American National Standards Institute, Inc.



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 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 constant review, and revisions are undertaken whenever it is found necessary because of new developments and progress in the art.

Units of Measurement

This standard is written using both metric and US Customary units of measurement. Metric units appear first followed by US units in brackets. Tables, charts and sample calculations are printed twice, first in metric units, then in US units.

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.

A.R. Wilfley & Sons, Inc.	Krebs Consulting Service
Afton Pumps, Inc.	KSB, Inc.
ANSIMAG Incorporated	Lawrence Pumps, Inc.
Bechtel Corporation	M.W. Kellogg Company
Black & Veatch LLP	Malcolm Pirnie, Inc.
Brown & Caldwell	Marine Machinery Association
Carver Pump Company	Marshall Eng. Prod. Co. (MEPCO)
Cascade Pump Co	Moving Water Industries (MWI)
Chas. S. Lewis & Company, Inc.	Ortev Enterprises Inc.
Chempump Division, Crane Pumps & Systems	Pacer Pumps
Cheng Fluid Systems, Inc.	Pacheco Engineering
Cuma S.A.	Patterson Pump Company
Dean Pump Division, Metpro Corp.	Pinellas County, Gen. Serv. Dept.
DeWante & Stowell	Price Pump Company
Dow Chemical	Raytheon Engineers & Constructors
Essco Pumps	Red Jacket
Exeter Energy Limited Partnership	Reddy-Buffaloes Pump, Inc.
Fairbanks Morse Pump Corp.	Scott Process Equipment Corp.
Ferris State Univ. Construction and Facilities Dept.	Settler Supply Company
Flowserve Corporation	Skidmore
Fluid Sealing Association	South Florida Water Mgmt. Dist.
Franklin Electric	Sta-Rite Industries, Inc.
Grundfos Pumps Corporation	Sterling Fluid Systems (Canada) Inc.
Illinois Department of Transportation	Stone & Webster Eng. Corp.
ITT Fluid Handling (B & G)	Summers Engineering, Inc.
ITT Fluid Technology	Systecon, Inc.
ITT Flygt Corporation	Taco, Inc.
Iwaki Walchem Corporation	The Process Group, LLC
J.P. Messina Pump and Hydr. Cons.	University of Montana
John Crane, Inc.	Val-Matic Valve & Manufacturing Corp.
	Yeomans Chicago Corporation
	Zoeller Engineered Products

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

Chairman – Jack Claxton, Patterson Pump Company

Other Members

Thomas Angle, EnviroTech
Pumpsystems
William A. Beekman, Floway Pumps
Frederic W. Buse, Ingersoll-Dresser
Pump
Michael Derr, Afton Pumps
R. Barry Erickson, ITT Industrial Pump
Group
Herman Greutink, Johnston Pumps
Gunnar Hovstadius, ITT Flygt
Al Iseppon, Sta-Rite Industries
Thomas Morton, Sulzer Bingham
Pat Moyer, ITT, Bell & Gossett
James Osborne, A.R. Wilfley & Sons
Ray Perriman, Sunstrand Fluid
Handling
Y.J. Reddy, Reddy-Buffaloes Pump
Arnold Sdano, Fairbanks Morse
Ron Sperry, Flowserve Corporation

Alternates

Aleks Roudnev, EnviroTech
Pumpsystems
Paul Behnke, Ingersoll-Dresser Pump
Allan Budris, ITT Industrial Pump
Group
John Eddy, Johnston Pumps
Stephan Abelin, ITT Flygt
Don Spencer, Sulzer Bingham
Jim Roberts, ITT, Bell & Gossett
Fred Hery, Flowserve Corporation
Roger Turley, Flowserve Corporation

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9.6.4.1 Introduction/Scope

This standard describes the vibration characteristics for industrial/commercial centrifugal and vertical pumps. Included is a description of the dynamics of vibration, vibration measurement, allowable vibration values and factors that effect vibration.

9.6.4.2 Dynamics of vibration

All centrifugal and vertical turbine pumps have rotors and structures that can vibrate in response to excitation forces. When the frequency of the excitation forces is close to the natural frequencies of the structures, resonance can occur and excessive and damaging vibration levels can be reached. These natural frequencies of vibration usually occur in one or more of the following modes:

- Rotor lateral vibration
- Rotor torsional vibration
- Structure lateral vibration

The natural frequencies of vibration can be determined by one of the following methods:

- Simple beam formulas based on those derived from common structural mechanics
- Finite elements methods using any one of a number of commercially available computer programs
- Experimental techniques using variable frequency exciters or impact devices in conjunction with vibration sensors and recording instruments

9.6.4.2.1 Lateral critical speed

The natural frequency of rotor lateral vibration is also called the *lateral critical speed*. More than one lateral mode can occur naturally, as shown in the following example of a simple shaft supported by two bearings. In Figure 9.6.4.1, the shaft is bowed at the center and

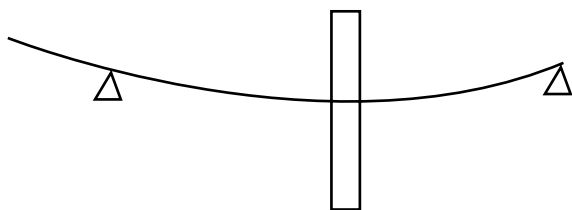


Figure 9.6.4.1 — First critical speed

vibrates back and forth in this shape. In Figure 9.6.4.2, a node or steady point occurs between the bearings and the shaft takes an “S” shape and vibrates in this manner. Other more complex shapes may also occur.

Figure 9.6.4.1 has the lowest natural frequency and is sometimes called the *first critical speed*. Figure 9.6.4.2 has a higher natural frequency than Figure 9.6.4.1 and is sometimes called the *second critical speed*.

Determination of lateral critical speed is important for pumps and associated rotating equipment because if a critical speed or resonant frequency is close to an operating speed or other exciting frequency, such as the impeller vane pass frequency, small excitation forces can be greatly amplified. The resulting stresses and deflections can cause premature equipment failure.

Knowledge of critical speed is also important for balancing considerations. Rotors having a first critical speed less than the rated rotating speed may require balancing to a more stringent balance level.

Calculation of critical speed can become very complex, depending on the effects one wants to consider in the calculation. A simple calculation of the first critical speed of a rotor is done by determining the static deflection of the center of gravity of a shaft or rotor under its own weight, when assumed to be in a horizontal position (despite its actual orientation). Knowing the static deflection “ d_{st} ” in millimeters (inches) of the center of gravity, it is possible to calculate the first natural frequency or critical speed (in CPM), as follows:

$$\text{Metric: } N_c = 0.0299 / d_{st}^5$$

$$\text{US Units: } N_c = 187.7 / d_{st}^5$$

Where:

N_c = critical speed (rpm)

d_{st} = static deflection, mm (in.)

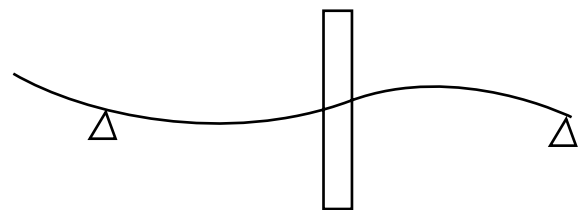


Figure 9.6.4.2 — Second critical speed