ANSI/HI 9.6.2-2011

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American National Standard for

Rotodynamic Pumps

for Assessment of Applied Nozzle Loads

Hydraulic Institute

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

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Sponsor

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Approved May 19, 2011

American National Standards Institute, Inc.

American National Standard

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Contents

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
Arcadis Malcolm Pirnie, Inc.
Bechtel Power Corporation
Beekman, William, Consultant
Black & Veatch (B & V)
Brown and Caldwell
ekwestrel corp
GIW Industries, Inc.
Healy Engineering, Inc.
ITT - Industrial Process
ITT - Residential & Commercial Water
J.A.S. Solutions Ltd.
Kemet Inc.
LVVWD
Mechanical Solutions, Inc.
MWH Americas, Inc.
Pentair Water - Engineered Flow GBU
Powell Kugler, Inc.
Pump Design, Development & Diagnostics, LLC
TACO, Inc.
Weir Floway, Inc.

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 - Fred F. Walker, Weir Floway, Inc
Vice-chair - Lucian Dobrot, TACO, Inc.

Committe Members	**Company**
Charles A. Cappellino	ITT Industrial Process
Jack Claxton	Patterson Pump Company
Michael Coussens	Peerless Pump Company
Paul J. Ruzicka	ITT Residential & Commercial Water
Roger Turley	Flowserve Corporation
Alternate Members	
James R. Roberts	ITT Residential & Commercial Water
Steve P. Schmitz	ITT Residential & Commercial Water

9.6.2 Rotodynamic pumps for assessment of applied nozzle loads

9.6.2.0 Scope

This standard includes recommendations for assessment of applied nozzle loads for the following pump types. When specified by the user, pumps supplied shall conform to these requirements.

a) Horizontal end suction single stage (ANSI/ASME B73.1, B73.3, and B73.5M)

b) Vertical in-line single stage (ANSI/ASME B73.2)

c) Axial split case single and two stage

d) Vertical turbine short set pumps

Many other pump types are not included because of the different designs that are unique to each manufacturer. For pump types outside the scope of this standard, allowable nozzle loads should be established by the pump manufacturer, applied nozzle loads predicted by the purchaser, and differences, if any, negotiated and resolved by the two parties.

For assessment of applied nozzle loads for slurry pumps, see ANSI/HI 12.1-12.6 *Rotodynamic (Centrifugal) Slurry Pumps for Nomenclature, Definitions, Applications, and Operation*.

9.6.2.1 Horizontal end suction pumps

9.6.2.1.1 Scope

This section covers assessment of applied nozzle loads for the following horizontal end suction pump types:

a) Pumps designed and constructed in accordance with ASME B73.1, *Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process*, with Class 150 and 300 flanges. To be applicable, the pump casing and seal chamber or stuffing box must be constructed of a material listed in Table 9.6.2.1.7.2.2a and subjected to temperatures between –20 and 700 °F unless otherwise specified.

b) Magnetic drive pumps designed and constructed in accordance with ASME B73.3, *Specification for Sealless Horizontal End Suction Metallic Centrifugal Pumps for Chemical Process*, with Class 150 and 300 flanges. To be applicable, the pump casing must be constructed of a material listed in Table 9.6.2.1.7.2.2a and subjected to temperatures between –20 and 500 °F unless otherwise specified.

c) Pumps designed and constructed in accordance with ASME B73.5M, *Specification for Thermoplastic and Thermoset Polymer Material Horizontal End Suction Centrifugal Pumps for Chemical Process*. To be applicable, the pump must be constructed of a material with a 68 °F modulus of elasticity greater than 1.0×10^6 psi and may be subjected to temperatures between –20 and 200 °F.

9.6.2.1.2 Nomenclature and definitions

9.6.2.1.2.1 Source

The nomenclature and definitions of pump components shall be in accordance with those promulgated by the Hydraulic Institute.

9.6.2.1.2.2 Definitions (refer to Figure 9.6.2.1.2.2)

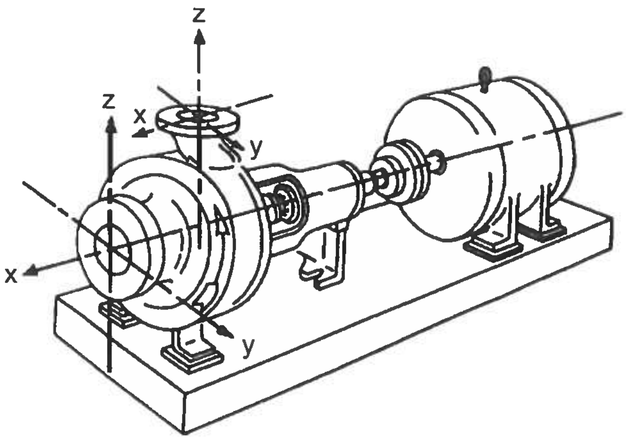


Figure 9.6.2.1.2.2 — Coordinate system for ASME B73.1, B73.3, and B73.5M horizontal end suction pumps

F_{xs} = applied force on x-axis on suction nozzle, to be assessed using equation sets 1-5

F_{ys} = applied force on y-axis on suction nozzle, to be assessed using equation sets 1-5

F_{zs} = applied force on z-axis on suction nozzle, to be assessed using equation sets 1-5

M_{xs} = applied moment about x-axis on suction nozzle, to be assessed using equation sets 1-5

M_{ys} = applied moment about y-axis on suction nozzle, to be assessed using equation sets 1-5

M_{zs} = applied moment about z-axis on suction nozzle, to be assessed using equation sets 1-5

F_{xd} = applied force on x-axis on discharge nozzle, to be assessed using equation sets 1-5

F_{yd} = applied force on y-axis on discharge nozzle, to be assessed using equation sets 1-5

F_{zd} = applied force on z-axis on discharge nozzle, to be assessed using equation sets 1-5

M_{xd} = applied moment about x-axis on discharge nozzle, to be assessed using equation sets 1-5

M_{yd} = applied moment about y-axis on discharge nozzle, to be assessed using equation sets 1-5

M_{zd} = applied moment about z-axis on discharge nozzle, to be assessed using equation sets 1-5

$F_{xs\,max}$ = maximum value of force on x-axis on suction nozzle, to be used with equation sets 1-5

$F_{ys\,max}$ = maximum value of force on y-axis on suction nozzle, to be used with equation sets 1-5

$F_{zs\,max}$ = maximum value of force on z-axis on suction nozzle, to be used with equation sets 1-5

$M_{xs\,max}$ = maximum value of moment about x-axis on suction nozzle, to be used with equation sets 1-5

$M_{ys\,max}$ = maximum value of moment about y-axis on suction nozzle, to be used with equation sets 1-5

$M_{zs\,max}$ = maximum value of moment about z-axis on suction nozzle, to be used with equation sets 1-5

$F_{xd\,max}$ = maximum value of force on x-axis on discharge nozzle, to be used with equation sets 1-5

$F_{yd\,max}$ = maximum value of force on y-axis on discharge nozzle, to be used with equation sets 1-5

$F_{zd\,max}$ = maximum value of force on z-axis on discharge nozzle, to be used with equation sets 1-5

$M_{xd\,max}$ = maximum value of moment about x-axis on discharge nozzle, to be used with equation sets 1-5

$M_{yd\,max}$ = maximum value of moment about y-axis on discharge nozzle, to be used with equation sets 1-5

$M_{zd\,max}$ = maximum value of moment about z-axis on discharge nozzle, to be used with equation sets 1-5

Group 1 is defined as ASME B73.1, B73.3, and B73.5M sizes AA and AB. Two-/four-pole, 60-cycle speed, and up to 20/10 hp, respectively.

Group 2 is defined as ASME B73.1, B73.3, and B73.5M sizes A05, A10, A20, A30, A50, A40, A60, A70, and A80. Two-/four-pole, 60-cycle speed, and up to 130/65 hp, respectively.

Group 3 is defined as ASME B73.1, B73.3, and B73.5M sizes A90, A100, A110, and A120. Four-/six-pole, 60-cycle speed, and up to 220/146 hp, respectively.

9.6.2.1.3 Criteria for loading allowances

9.6.2.1.3.1 Driver/pump coupling alignment

The radial movement of the pump shaft at the pump coupling hub due to nozzle loads shall not exceed 0.005 in. relative to initial alignment. Axial movement of the pump shaft at the pump coupling hub is not considered in this standard.

9.6.2.1.3.2 Internal pump distortion

No contact between casing and impeller is allowed.

The radial movement of the pump shaft with respect to the seal chamber due to nozzle loads shall not exceed 0.002 in. relative to initial position.

9.6.2.1.3.3 Pump hold-down bolts

Fasteners used for hold-down bolts should have yield strength of 36,000 psi or greater, i.e., greater than or equal to the yield strength of SAE J429 Grade 1 fasteners. The maximum allowable tensile stress in the pump hold-down bolts is 90% of fastener's material yield strength. The maximum allowable shear stress in the pump hold-down bolts is 25% of fastener's material yield strength.

The pump shall be bolted to the baseplate at both the casing feet and rear foot position(s) and sufficiently tightened to prevent slippage of the pump on the baseplate. Refer to API 686, Appendix E, for required torque values (use 0.5-in nominal bolt diameter torque value for Group 1 and 2 pumps, and 0.75-in nominal bolt diameter value for Group 3 pumps). It may be necessary to arrange for periodic tightening of the bolts to maintain required torque levels.

9.6.2.1.3.4 Pump mounting

The base for which the loads in Tables 9.6.2.1.4b through 9.6.2.1.4e are established must be a fully grouted metal baseplate with anchor bolts. The base as a minimum must withstand the applied nozzle loads combined with normal operating loads (e.g., driver weight and pump weight).

The base must be installed and grouted in accordance with ANSI/HI 1.4 *Rotodynamic (Centrifugal) Pumps for Manuals Describing Installation, Operation and Maintenance*.

9.6.2.1.3.5 Nozzle stress

The maximum stresses developed in the pump nozzles and flanges, constructed of a material listed in Table 9.6.2.1.7.2.2a, by the applied nozzle loads, combined with internal pressure, shall not exceed 26,250 psi tensile and 13,125 psi shear. By applying the temperature and material adjustment factors of Section 9.6.2.1.7.2.1, applied nozzle loads may be increased for stronger materials and must be decreased for weaker materials.

The allowable suction nozzle stress was based on three-dimensional stress analysis methods. The allowable discharge nozzle stress was based on the method contained in the ASME Boiler and Pressure Vessel Code, 1983 edition, Section III, NC 3653, due to its complex geometry.

9.6.2.1.3.6 Pressure/temperature

Any temperature referenced in Section 9.6.2.1 is the temperature of the pressure-containing components of the pump. In general, this temperature is the same as that of the contained liquid.

Use of a pressure rating as specified in ANSI/ASME B16.5 corresponding to a temperature other than that of the contained liquid is the responsibility of the user, subject to the requirements of the applicable code or regulation.

Low-temperature and high-temperature considerations addressed in ANSI/ASME B16.5 should be examined.

9.6.2.1.4 ANSI/ASME B73.1 pump assessment of applied nozzle loads

Loads given in Tables 9.6.2.1.4b through 9.6.2.1.4e are applicable for ASME B73.1 pumps constructed of ASTM A351/A351M - Grade CF8M (Type 316SS) operated between –20 and 100 °F and mounted on a grouted metal baseplate with anchor bolts.

For an individual force or moment, pumps must be capable of satisfactory operation when subjected to loads shown in Table 9.6.2.1.4b (adjusted if applicable) while meeting the criteria of equation set 1.

For a combination of more than one force and/or moment, pumps must be capable of satisfactory operation when subjected to the loads in Tables 9.6.2.1.4c through 9.6.2.1.4e (adjusted if applicable) while meeting the criteria of equation sets 2 – 5. When combining loads, the absolute value of any individual load must not exceed the value given in Table 9.6.2.1.4b.

Adjustment of the tabulated maximum forces and moments load values is required if any of the following occur:

a) Temperature is above 100 °F.

b) The pump material construction is not ASTM A351/A351M - Grade CF8M.

c) The base is not a fully grouted metal baseplate with anchor bolts.

Table 9.6.2.1.4a — Equation sets 1 through 5 (Using the maximum forces and moments of the referenced tables, applied loads shall satisfy the criteria defined by these equations.)

Set	Equation	Reference	Remarks
1	$\left\lvert\frac{F_{xs}}{F_{xs\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{F_{ys}}{F_{ys\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{F_{zs}}{F_{zs\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{M_{xs}}{M_{xs\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{M_{ys}}{M_{ys\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{M_{zs}}{M_{zs\,max}}\right\rvert \le 1.0,$ $\left\lvert\frac{F_{xd}}{F_{xd\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{F_{yd}}{F_{yd\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{F_{zd}}{F_{zd\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{M_{xd}}{M_{xd\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{M_{yd}}{M_{yd\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{M_{zd}}{M_{zd\,max}}\right\rvert \le 1.0,$	Table 9.6.2.1.4b	Individual loading
2	$\frac{1}{2} \times \left[\left\lvert\frac{F_{xs}}{F_{xs\,max}}\right\rvert + \left\lvert\frac{F_{ys}}{F_{ys\,max}}\right\rvert + \left\lvert\frac{F_{zs}}{F_{zs\,max}}\right\rvert + \left\lvert\frac{M_{xs}}{M_{xs\,max}}\right\rvert + \left\lvert\frac{M_{ys}}{M_{ys\,max}}\right\rvert + \left\lvert\frac{M_{zs}}{M_{zs\,max}}\right\rvert + \left\lvert\frac{F_{xd}}{F_{xd\,max}}\right\rvert + \left\lvert\frac{F_{yd}}{F_{yd\,max}}\right\rvert + \left\lvert\frac{F_{zd}}{F_{zd\,max}}\right\rvert + \left\lvert\frac{M_{xd}}{M_{xd\,max}}\right\rvert + \left\lvert\frac{M_{yd}}{M_{yd\,max}}\right\rvert + \left\lvert\frac{M_{zd}}{M_{zd\,max}}\right\rvert\right] \le 1.0$	Table 9.6.2.1.4c	Nozzle stress, hold-down bolt stress, pumps slippage
3	$-1.0 \le a = \frac{F_{ys}}{F_{ys\,max}} + \frac{M_{xs}}{M_{xs\,max}} + \frac{M_{ys}}{M_{ys\,max}} + \frac{M_{zs}}{M_{zs\,max}} + \frac{F_{yd}}{F_{yd\,max}} + \frac{M_{xd}}{M_{xd\,max}} + \frac{M_{yd}}{M_{yd\,max}} + \frac{M_{zd}}{M_{zd\,max}} \le 1.0$	Table 9.6.2.1.4d	y-axis movement
4	$-1.0 \le b = \frac{F_{xs}}{F_{xs\,max}} + \frac{F_{zs}}{F_{zs\,max}} + \frac{M_{xs}}{M_{xs\,max}} + \frac{M_{ys}}{M_{ys\,max}} + \frac{M_{zs}}{M_{zs\,max}} +$ $\frac{F_{xd}}{F_{xd\,max}} + \frac{F_{yd}}{F_{yd\,max}} + \frac{F_{zd}}{F_{zd\,max}} + \frac{M_{xd}}{M_{xd\,max}} + \frac{M_{yd}}{M_{yd\,max}} + \frac{M_{zd}}{M_{zd\,max}} \le 1.0$	Table 9.6.2.1.4e	z-axis movement
5	$\sqrt{a^2 + b^2} \le 1.0$	Equation sets 4 and 5	Combined axis movement

Table 9.6.2.1.4b — Maximum forces and moments for use with equation set 1 to assess applied loads

ASME B73 Designation	Pump Size	Suction						Discharge					
		Forces (lb)			Moments (lb•ft)			Forces (lb)			Moments (lb•ft)		
		$F_{xs\,max}$	$F_{ys\,max}$	$F_{zs\,max}$	$M_{xs\,max}$	$M_{ys\,max}$	$M_{zs\,max}$	$F_{xd\,max}$	$F_{yd\,max}$	$F_{zd\,max}$	$M_{xd\,max}$	$M_{yd\,max}$	$M_{zd\,max}$
AA	1.5 × 1 × 6	1050	750	750	720	170	170	800	1350	3000	410	410	410
AB	3 × 1.5 × 6	1050	1240	1250	900	490	490	800	1350	3000	500	550	510
A10	3 × 2 × 6	1050	1050	1050	900	220	220	800	1350	3000	500	1000	510
AA	1.5 × 1 × 8	1050	1210	1210	720	190	190	800	1350	3000	360	360	360
---	3 × 1.5 × 8[a]	1050	1240	1250	900	490	490	800	1350	3000	440	440	440
A50	3 × 1.5 × 8	2700	1350	1500	1300	370	370	1400	1350	3250	460	460	460
A60	3 × 2 × 8	2700	1350	1500	1300	600	600	1400	1350	3250	660	660	660
A70	4 × 3 × 8	2700	1350	1500	1300	350	350	1400	1350	3250	1200	1460	690
A05	2 × 1 × 10	2340	960	960	1270	220	220	1400	1350	3250	660	660	660
A50	3 × 1.5 × 10	2700	1350	1500	1300	420	420	1400	1350	3250	370	370	370
A60	3 × 2 × 10	2700	1350	1480	1300	310	310	1400	1350	3250	560	560	560
A70	4 × 3 × 10	2300	1350	1500	1300	310	310	1400	1350	3250	1200	1460	690
A80	6 × 4 × 10	2700	1350	1500	1300	1100	1100	1400	1350	3250	1200	1500	690
A20	3 × 1.5 × 13	2700	1350	1500	1300	670	670	1400	1350	3250	530	530	530
A30	3 × 2 × 13	1920	1230	1230	1300	350	350	1400	1350	3250	1200	1270	690
A40	4 × 3 × 13	2700	1350	1500	1300	400	400	1400	1350	3250	1200	1500	690
A80	6 × 4 × 13	2700	1350	1500	1300	1300	1100	1400	1350	3250	1200	1500	690
A90	8 × 6 × 13	3500	3180	2000	1500	1170	1170	1500	3000	3500	1250	2840	2840
A100	10 × 8 × 13	3500	3180	2000	1500	2000	2150	1500	3000	3500	1250	2840	2840
A110	8 × 6 × 15	3500	3180	2000	1500	1480	1480	1500	3000	3500	1250	2840	2840
A120	10 × 8 × 15	3500	3180	2000	1500	1130	1130	1500	3000	3500	1250	2840	2840

NOTE: Please note that certain sizes do not follow a trend of increased allowable nozzle loads with increased pump size. This is due to interaction of individual pump geometry (i.e., nozzle wall thickness, distance from flange face to nozzle connection with casing, etc.).

[a] This is not an ASME size. It is included here as a special Group 1 size that is common among manufacturers.

Table 9.6.2.1.4c — Maximum forces and moments for use with equation set 2 to assess applied loads

		Suction						Discharge					
		Forces (lb)			Moments (lb•ft)			Forces (lb)			Moments (lb•ft)		
ASME B73 Designation	Pump Size	$F_{xs\ max}$	$F_{ys\ max}$	$F_{zs\ max}$	$M_{xs\ max}$	$M_{ys\ max}$	$M_{zs\ max}$	$F_{xd\ max}$	$F_{yd\ max}$	$F_{zd\ max}$	$M_{xd\ max}$	$M_{yd\ max}$	$M_{zd\ max}$
AA	1.5 × 1 × 6	2020	750	750	1830	170	170	2020	1350	6240	410	410	410
AB	3 × 1.5 × 6	2020	1240	2110	2290	490	490	2020	1350	6240	550	550	510
A10	3 × 2 × 6	2020	1050	1050	2290	220	220	2020	1350	6240	1030	1030	510
AA	1.5 × 1 × 8	2020	1210	1210	1830	190	190	2020	1350	6240	360	360	360
—	3 × 1.5 × 8[a]	2020	1240	1640	2290	490	490	2020	1350	6240	440	440	440
A50	3 × 1.5 × 8	2700	1350	1820	3730	370	370	2020	1350	6240	460	460	460
A60	3 × 2 × 8	2700	1350	2490	3730	600	600	1970	1350	6240	660	660	660
A70	4 × 3 × 8	2700	1350	1840	3730	350	350	2020	1350	6240	1460	1460	690
A05	2 × 1 × 10	2340	960	960	3640	220	220	2020	1350	6240	660	660	660
A50	3 × 1.5 × 10	2700	1350	1910	3730	420	420	1940	1350	6240	370	370	370
A60	3 × 2 × 10	2700	1350	1480	3730	310	310	2020	1350	6240	560	560	560
A70	4 × 3 × 10	2300	1350	1640	3730	310	310	2020	1350	6240	1460	1460	690
A80	6 × 4 × 10	2700	1350	6240	3730	1100	1100	2020	1350	6240	3100	3100	690
A20	3 × 1.5 × 13	2700	1350	3060	3730	670	670	2020	1350	6240	530	530	530
A30	3 × 2 × 13	1920	1230	1230	3730	350	350	2020	1350	6240	1460	1460	690
A40	4 × 3 × 13	2700	1350	2390	3730	400	400	2020	1350	6240	1730	1730	690
A80	6 × 4 × 13	2700	1350	6240	3730	4980	1100	2020	1350	6240	2150	2150	690
A90	8 × 6 × 13	6360	3180	5080	8970	1170	1170	6360	3180	13,460	6780	3850	2840
A100	10 × 8 × 13	6360	3180	13,460	8970	2450	2150	6360	3180	13,460	8970	7220	2840
A110	8 × 6 × 15	6360	3180	6680	8970	1480	1480	6360	3180	13,460	6560	3720	2840
A120	10 × 8 × 15	6360	3180	5130	8970	1130	1130	6360	3180	13,460	8970	9060	2840

[a] This is not an ASME size. It is included here as a special Group 1 size that is common among manufacturers.

Table 9.6.2.1.4d — Maximum forces and moments for use with equation set 3 to assess applied loads

	Suction						Discharge					
	Forces (lb)			Moments (lb•ft)			Forces (lb)			Moments (lb•ft)		
Pump Group		$F_{ys\ max}$		$M_{xs\ max}$	$M_{ys\ max}$	$M_{zs\ max}$		$F_{yd\ max}$		$M_{xd\ max}$	$M_{yd\ max}$	$M_{zd\ max}$
Group 1		–2000		900	1200	1250		1500		–500	1500	1250
Group 2		–3500		1300	1300	3000		2500		–1200	1500	3000
Group 3		–5000		1500	2000	4000		3000		–1250	5000	4000

Table 9.6.2.1.4e — Maximum forces and moments for use with equation set 4 to assess applied loads

Pump Group	Suction						Discharge					
	Forces (lb)			Moments (lb•ft)			Forces (lb)			Moments (lb•ft)		
	$F_{xs\ max}$		$F_{zs\ max}$	$M_{xs\ max}$	$M_{ys\ max}$	$M_{zs\ max}$	$F_{xd\ max}$	$F_{yd\ max}$	$F_{zd\ max}$	$M_{xd\ max}$	$M_{yd\ max}$	$M_{zd\ max}$
Group 1	1050		–1250	1500	1200	–2500	800	2000	–3000	–1500	1000	–2500
Group 2	3500		–1500	1500	1300	–3500	1400	2500	–3250	–1500	2150	–3500
Group 3	3500		–2000	1500	4100	–4000	1500	4000	–3500	–1500	5000	–4000

Refer to Section 9.6.2.1.7 for adjustment factors.

9.6.2.1.5 ANSI/ASME B73.3 sealless pump assessment of applied nozzle loads

Assessment of nozzle loads applied to pumps built to ASME B73.3, *Specification for Sealless Horizontal End Suction Centrifugal Pumps for Chemical Process* is identical to ASME B73.1 pumps. Refer to Section 9.6.2.1.4.

9.6.2.1.6 ANSI/ASME B73.5M composite pump assessment of applied nozzle loads

By reducing the values in Tables 9.6.2.1.4b through 9.6.2.1.4e to 90% of their original values, the values are applicable for ASME B73.5 pumps mounted on a grouted metal baseplate with anchor bolts. Use equation sets 1 – 5 with these adjusted values.

If mounting the pump on a base other than a fully grouted metal baseplate with anchor bolts, refer to Section 9.6.2.1.7 for adjustment factor.

9.6.2.1.7 Nozzle load adjustment factors

The loads in the tables must be multiplied by adjustment factors when applicable. The lowest correction factor should be applied when more than one adjustment factor is involved. For instance, if the pump is an ASME B73.5 pump (90% reduction factor) mounted on a fully grouted nonmetallic baseplate (80% reduction factor), then the reduction factor for Tables 9.6.2.1.4b through 9.6.2.1.4e would be 80%.

There may be cases where one adjustment factor is applied to Table 9.6.2.1.4c and another adjustment factor is applied to Tables 9.6.2.1.4d and 9.6.2.1.4e. These cases are denoted in the text.

Refer to Appendix A for further discussion of nozzle load reduction factors.

9.6.2.1.7.1 Alternate pump mounting

For alternate mounting conditions, the pump must be mounted on a base that can, as a minimum, withstand the applied nozzle loads combined with normal operating loads.

9.6.2.1.7.1.1 Stilt-mounted metal baseplate

Use 100% of the values in Table 9.6.2.1.4c and 90% of the values in Tables 9.6.2.1.4d and 9.6.2.1.4e. If after adjusting the value for a particular load in Tables 9.6.2.1.4d and 9.6.2.1.4e, the absolute value of any adjusted value is lower than the corresponding load in Table 9.6.2.1.4b, then substitute the lower value into Table 9.6.2.1.4b. All of the values in Tables 9.6.2.1.4b through 9.6.2.1.4e may be used if it can be demonstrated that the baseplate design (see Figure 9.6.2.1.7.1.1) meets the deflection criteria contained in ANSI/HI 1.3 *Rotodynamic (Centrifugal) Pumps for Design and Application*.

Warning: Forces and moments must be limited to values lower than that which will initiate overturning or lifting of the pump, base, and driver assembly.

9.6.2.1.7.1.2 Ungrouted metal baseplate that is anchored down

Use 100% of the values in Table 9.6.2.1.4c and 80% of the values in Tables 9.6.2.1.4d and 9.6.2.1.4e. If after adjusting the value for a particular load in Tables 9.6.2.1.4d or 9.6.2.1.4e, the absolute value of any adjusted value is lower than the corresponding load in Table 9.6.2.1.4b, then substitute the lower value into Table 9.6.2.1.4b.

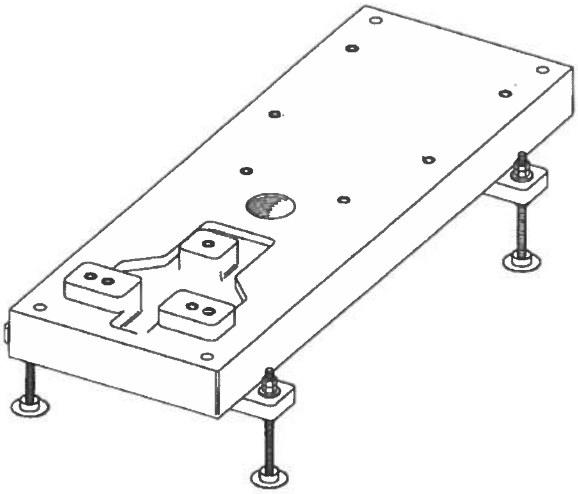


Figure 9.6.2.1.7.1.1 — Stilt-mounted baseplate

9.6.2.1.7.1.3 Grouted nonmetal baseplate with anchor bolts

Use 80% of the values in Tables 9.6.2.1.4b through 9.6.2.1.4e. All of the values in Tables 9.6.2.1.4b through 9.6.2.1.4e may be used if it can be demonstrated that the baseplate design meets the deflection criteria contained in ANSI/HI 1.3 *Rotodynamic (Centrifugal) Pumps for Design and Application.*

9.6.2.1.7.1.4 Ungrouted nonmetal baseplate that is anchored down

Use 70% of the values in Tables 9.6.2.1.4b through 9.6.2.1.4e. All of the values in Tables 9.6.2.1.4b through 9.6.2.1.4e may be used if it can be demonstrated that the baseplate design meets the deflection criteria contained in ANSI/HI 1.3 *Rotodynamic (Centrifugal) Pumps for Design and Application.*

9.6.2.1.7.1.5 Spring-mounted metal baseplate

This standard is not applicable to spring-mounted metal baseplates. Refer to the pump manufacturer for allowable loads.

9.6.2.1.7.2 Temperature and material adjustment factors for ASME B73.1 and ASME B73.3 pumps

9.6.2.1.7.2.1 Adjustment factor basis

Adjustment factors were determined by taking the ANSI/ASME B16.5 Class 300 pressure–temperature rating of the flange material being used and dividing by the pressure–temperature rating of ASTM A 351 - Grade CF8M Class 300 at 100 °F as specified in ANSI/ASME B16.5.

In the case of ductile iron, adjustment factors were determined by taking the ANSI/ASME B16.42 Class 300 pressure–temperature ratings and dividing by the pressure–temperature rating of ASTM A 351 - Grade CF8M Class 300 at 100 °F as specified in ANSI/ASME B16.5.

Table 9.6.2.1.7.2.2a — List of material specifications as used in Table 9.6.2.1.7.2.2b

Material Groups		Castings	
Material Group No.	Nominal Designation	Spec. No.	Grade(s)
1.0	Ductile Iron	A395	---
1.1	Carbon Steel	A216	WCB
2.1	Type 304	A744	CF-8
2.2	Type 316	A744	CF-8M
2.3	Type 304L Type 316L	A744	CF-3 CF-3M
2.4	Type 321	---	---
2.8	CD-4MCu CD-4MCu	A744 A890	CD-4MCu CD-4MCu Grade 1A, 1B
3.1	Alloy 20	A744	CN-7M
3.2	Nickel	A494	CZ-100
3.4	Monel	A744	M-35-1 M-30C M-35-2
3.5	Inconel 600 Inconel 625 Inconel 825	A744 A744 A744	CY-40 CW-6MC Cu-5MCuC
3.7	Hastelloy B	A494	N-12MV N-7M
3.8	Hastelloy C	A494	CW-6M CW-2M CW-12MW CX-2MW

9.6.2.1.7.2.2 Adjustment factors

For temperatures above 100 °F and/or the use of a material other than ASTM A351/A351M - Grade CF8M, the loads in Table 9.6.2.1.4c should be reduced by multiplying them by the proper adjustment factor from Table 9.6.2.1.7.2.2b.

For intermediate temperatures not shown in Table 9.6.2.1.7.2.2b, linear interpolation is permitted.

If after adjusting the value for a particular load in Table 9.6.2.1.4c, any adjusted value is lower than the corresponding load in Table 9.6.2.1.4b, then substitute the lower value into Table 9.6.2.1.4b.

Material group numbers used in Table 9.6.2.1.7.2.2b are defined in Table 9.6.2.1.7.2.2a.

Table 9.6.2.1.7.2.2b — ASME B73.1 metallic pump temperature and material adjustment values to be used on Table 9.6.2.1.4c values. Use for both Class 150 and Class 300 flanges

	Material Group No.:												
	1.0	1.1	2.1	2.2	2.3	2.4	2.8	3.1	3.2	3.4	3.5	3.7	3.8
			Austenitic Steels					Nickel and Nickel Alloys					
Temp, °F	Ductile Iron	Carbon Steel	Type 304	Type 316	Type 304L Type 316L	Type 321	CD-4M Cu	Alloy 20	Nickel	Monel	Inconel	Hast. B	Hast. C
–20 to 100	0.89	1.00	1.00	1.00	0.83	1.00	1.00	0.83	0.50	0.83	1.00	1.00	1.00
200	0.83	0.94	0.83	0.86	0.70	0.98	1.00	0.77	0.50	0.74	0.93	1.00	1.00
300	0.78	0.91	0.74	0.78	0.63	0.83	1.00	0.73	0.50	0.69	0.89	1.00	1.00
400	0.73	0.88	0.65	0.72	0.58	0.69	0.98	0.67	0.50	0.67	0.85	0.98	0.98
500	0.69	0.83	0.60	0.67	0.53	0.64	0.92	0.65	0.50	0.66	0.83	0.92	0.92
600	0.65	0.76	0.58	0.63	0.50	0.60	0.84	0.63	0.50	0.66	0.80	0.84	0.84
650	0.63	0.74	0.57	0.62	0.49	0.60	0.82	0.63	---	0.66	0.78	0.82	0.82
700	---	0.74	0.56	0.60	0.48	0.58	0.79	0.62	---	0.66	0.77	0.79	0.79

9.6.2.2 Vertical in-line pumps

9.6.2.2.1 Scope

This section covers assessment of applied nozzle loads for pumps designed and constructed in accordance with ANSI/ASME B73.2, Specifi*cation for Vertical In-Line Centrifugal Pumps for Chemical Process*, with Class 150 and 300 flanges. To be applicable, the pump casing and seal chamber or stuffing box must be constructed of a material listed in Table 9.6.2.2.4c and subjected to temperatures between –20 and 500 °F unless otherwise specified.

9.6.2.2.2 Nomenclature and definitions

9.6.2.2.2.1 Source

The nomenclature and definitions of pump components shall be in accordance with those promulgated by the Hydraulic Institute.

9.6.2.2.2.2 Definitions (refer to Figure 9.6.2.2.2.2)

F_{xs} = applied force on x-axis on suction nozzle, to be assessed using equation set 6
F_{ys} = applied force on y-axis on suction nozzle, to be assessed using equation set 6
F_{zs} = applied force on z-axis on suction nozzle, to be assessed using equation set 6
M_{xs} = applied moment about x-axis on suction nozzle, to be assessed using equation set 6
M_{ys} = applied moment about y-axis on suction nozzle, to be assessed using equation set 6
M_{zs} = applied moment about z-axis on suction nozzle, to be assessed using equation set 6
F_{xd} = applied force on x-axis on discharge nozzle, to be assessed using equation set 6
F_{yd} = applied force on y-axis on discharge nozzle, to be assessed using equation set 6

F_{zd} = applied force on z-axis on discharge nozzle, to be assessed using equation set 6

M_{xd} = applied moment about x-axis on discharge nozzle, to be assessed using equation set 6

M_{yd} = applied moment about y-axis on discharge nozzle, to be assessed using equation set 6

M_{zd} = applied moment about z-axis on discharge nozzle, to be assessed using equation set 6

$F_{x\,max}$ = maximum value of force on x-axis on suction or discharge nozzle, to be used with equation set 6

$F_{y\,max}$ = maximum value of force on y-axis on suction or discharge nozzle, to be used with equation set 6

$F_{z\,max}$ = maximum value of force on z-axis on suction or discharge nozzle, to be used with equation set 6

$M_{x\,max}$ = maximum value of moment about x-axis on suction or discharge nozzle, to be used with equation set 6

$M_{y\,max}$ = maximum value of moment about y-axis on suction or discharge nozzle, to be used with equation set 6

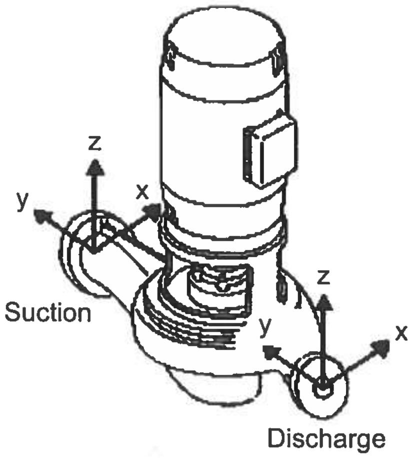


Figure 9.6.2.2.2.2 — Coordinate system for ASME B73.2 vertical in-line pumps

$M_{z\,max}$ = maximum value of moment about z-axis on suction or discharge nozzle, to be used with equation set 6

9.6.2.2.3 Criteria for loading allowances

9.6.2.2.3.1 Flange stress

The maximum stresses developed in the pump nozzles and flanges, constructed of a material listed in Table 9.6.2.2.4c, by the applied nozzle loads, combined with internal pressure, shall not exceed 26,250 psi tensile and 13,125 psi shear. By applying the temperature and material adjustment factors of Section 9.6.2.2.5.2, applied nozzle loads may be increased for stronger materials and must be decreased for weaker materials.

The allowable flange stress was based on the method contained in the ASME Boiler and Pressure Vessel Code, 1995 edition, Section III, Division 1, Appendix XI – Rules for Bolted Flange Connections for Class 2 and 3 Components and Class MC Vessels.

The maximum bending (M_x, M_z) and torsional (M_y) moments are those moments that, when applied to the flange, will develop the maximum allowed flange stress.

The maximum shear force (F_x, F_z) equals the maximum bending moment divided by overall pump length: *SD*, as defined by ASME B73.2.

The maximum axial force (F_y) is that force that will develop tensile stress of 7000 psi in the flange bolts. This tensile stress is in addition to the stress developed by internal pressure and flange gasket seating loads. The total combined stress must be assessed for the service conditions and bolts of adequate strength must be used. The minimum required bolt strength is equal to the sum of 7000 psi plus bolt stress due to internal pressure plus bolt stress due to gasket loads. Higher nozzle loads may be permitted if bolting of higher than minimum required strength is used.

9.6.2.2.3.2 Pressure/temperature

Any temperature referenced in Section 9.6.2.2 is the temperature of the pressure-containing components of the pump. In general, this temperature is the same as that of the contained liquid.

Use of a pressure rating as specified in ANSI/ASME B16.5 corresponding to a temperature other than that of the contained liquid is the responsibility of the user, subject to the requirements of the applicable code or regulation.

Low-temperature and high-temperature considerations addressed in ANSI/ASME B16.5 should be examined.

9.6.2.2.4 ANSI/ASME B73.2 pump assessment of applied nozzle loads

Loads given in Table 9.6.2.2.4b are applicable for ASME B73.2 pumps constructed of ASTM A351/A351M - Grade CF8M (Type 316SS) operated between –20 and 100 °F.

For an individual force or moment or for a combination of more than one force and/or moment, pumps must be capable of satisfactory operation when subjected to loads shown in Table 9.6.2.2.4b (adjusted if applicable) while meeting the criteria of equation set 6 in Table 9.6.2.2.4a. Each load in Table 9.6.2.2.4b is such that it is the maximum value for that particular load regardless of whether or not any other external loads are applied.

When applying loads, the absolute value of any individual load must not exceed the value given in Table 9.6.2.2.4b.

Table 9.6.2.2.4a — Equation set 6 (Using the maximum forces and moments of the referenced table, applied loads shall satisfy the criteria defined by these equations.)

Set	Equation	Reference	Remarks
6	$\left\lvert\frac{F_{xs}}{F_{x\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{F_{ys}}{F_{y\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{F_{zs}}{F_{z\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{M_{xs}}{M_{x\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{M_{ys}}{M_{y\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{M_{zs}}{M_{z\,max}}\right\rvert \le 1.0,$ $\left\lvert\frac{F_{xd}}{F_{x\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{F_{yd}}{F_{y\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{F_{zd}}{F_{z\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{M_{xd}}{M_{x\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{M_{yd}}{M_{y\,max}}\right\rvert \le 1.0,\ \left\lvert\frac{M_{zd}}{M_{z\,max}}\right\rvert \le 1.0$	Table 9.6.2.2.4a	Individual loading

Table 9.6.2.2.4b — Maximum forces and moments for use with equation set 6 to assess applied loads

Discharge Nozzle Size (in)	Nominal Impeller Diameter (in)	Nominal overall length, flange face to flange face (in)	Forces (lb)			Moments (lb•ft)		
			$F_{x\,max}$	$F_{y\,max}$	$F_{z\,max}$	$M_{x\,max}$	$M_{y\,max}$	$M_{z\,max}$
1.5	6	15	410	3976	410	510	720	510
1.5	8	17	360	3976	360	510	720	510
1.5	10	19	320	3976	320	510	720	510
1.5	13	24	255	3976	255	510	720	510
2	6	17	635	6328	635	900	1270	900
2	8 & 10	20	540	6328	540	900	1270	900
2	13	24	450	6328	450	900	1270	900
3	8	22	725	6328	725	1330	1880	1330
3	10	25	638	6328	638	1330	1880	1330
3	13	28	570	6328	570	1330	1880	1330
4	10	28	700	18,704	700	1630	2300	1630
4	13	30	650	18,704	650	1630	2300	1630

Table 9.6.2.2.4c — List of material specifications as used in Table 9.6.2.2.5.2

Material Groups (See NOTE 1)		Castings		
Material Group No.	Nominal Designation	Spec. No.	Grade(s)	NOTES
1.0	Ductile Iron	A395	---	(2)
1.1	Carbon Steel	A216	WCB	
2.1	Type 304	A744	CF-8	
2.2	Type 316	A744	CF-8M	
2.3	Type 304L Type 316L	A744	CF-3 CF-3M	
2.4	Type 321	---	---	
2.8	CD-4MCu CD-4MCu	A744 A890	CD-4MCu CD-4MCu Grade 1A, 1B	
3.1	Alloy 20	A744	CN-7M	
3.2	Nickel	A494	CZ-100	(3)
3.4	Monel	A744	M-35-1 M-30C M-35-2	
3.5	Inconel 600 Inconel 625 Inconel 825	A744 A744 A744	CY-40 CW-6MC Cu-5MCuC	
3.7	Hastelloy B	A494	N-12MV N-7M	
3.8	Hastelloy C	A494	CW-6M CW-2M CW-12MW CX-2MW	

NOTES:
(1) Material groups are similar to material classes taken from ANSI B16.5 except for Class 1.0 - ductile iron, which is not listed in ANSI B16.5. Note that the material grades are not the same as listed in ANSI B16.5. However, they are comparable grades as far as strength is concerned.

(2) Operating temperature range is 20 °F to 650 °F for ductile iron.

(3) Operating temperature range is –20 °F to 600 °F for nickel.

9.6.2.2.5 Temperature and material adjustment factors

Adjustment of allowable load values is required if any of the following occur:

a) Temperature is above 100 °F.

b) The pump material construction is not ASTM A351/A351M - Grade CF8M.

9.6.2.2.5.1 Adjustment factor basis

Adjustment factors were determined by taking the ANSI/ASME B16.5 Class 300 pressure–temperature rating of the flange material being used and dividing by the pressure–temperature rating of ASTM A 351 – Grade CF8M Class 300 at 100 °F as specified in ANSI/ASME B16.5.

In the case of ductile iron, adjustment factors were determined by taking the ANSI/ASME B16.42 Class 300 pressure–temperature ratings and dividing by the pressure–temperature rating of ASTM A 351 - Grade CF8M Class 300 at 100 °F as specified in ANSI/ASME B16.5.

9.6.2.2.5.2 Adjustment factors

For temperatures above 100 °F and/or the use of a material other than ASTM A351/A351M - Grade CF8M, the loads in Table 9.6.2.2.4b should be reduced by multiplying them by the proper adjustment factor from Table 9.6.2.2.5.2.

Table 9.6.2.2.5.2 — ASME B73.2 metallic pump temperature and material adjustment values to be used on Section 9.6.2.2.4 values. Use for both Class 150 and Class 300 flanges

	Material Group No.:												
	1.0	1.1	2.1	2.2	2.3	2.4	2.8	3.1	3.2	3.4	3.5	3.7	3.8
			Austenitic Steels					Nickel and Nickel Alloys					
Temp, °F	Ductile Iron	Carbon Steel	Type 304	Type 316	Type 304L Type 316L	Type 321	CD-4M Cu	Alloy 20	Nickel	Monel	Inconel	Hast. B	Hast. C
–20 to 100	0.89	1.00	1.00	1.00	0.83	1.00	1.00	0.83	0.50	0.83	1.00	1.00	1.00
200	0.83	0.94	0.83	0.86	0.70	0.98	1.00	0.77	0.50	0.74	0.93	1.00	1.00
300	0.78	0.91	0.74	0.78	0.63	0.83	1.00	0.73	0.50	0.69	0.89	1.00	1.00
400	0.73	0.88	0.65	0.72	0.58	0.69	0.98	0.67	0.50	0.67	0.85	0.98	0.98
500	0.69	0.83	0.60	0.67	0.53	0.64	0.92	0.65	0.50	0.66	0.83	0.92	0.92

For intermediate temperatures not shown in Table 9.6.2.2.5.2, linear interpolation is permitted.

Material group numbers used in Table 9.6.2.2.5.2 are defined in Table 9.6.2.2.4c.

9.6.2.3 Axial split case pumps (single-stage double suction and two-stage single suction)

9.6.2.3.1 Scope

This section covers assessment of nozzle loads applied to single-stage double suction and two-stage horizontal axial split case pumps with discharge nozzles 2-in through 10-in with class 125 and 250 flanges per ANSI/ASME B16.1 and with casings made of cast iron and mounted on a fully grouted baseplate by four bolts. For larger flanges, allowable nozzle loads should be established by the pump manufacturer, applied nozzle loads predicted by the purchaser, and differences, if any, negotiated and resolved by the two parties.

9.6.2.3.2 Definitions (refer to Figure 9.6.2.3.2)

F_{xs} = applied force on x-axis on suction nozzle, to be assessed using equation 1
F_{ys} = applied force on y-axis on suction nozzle, to be assessed using equation 1
F_{zs} = applied force on z-axis on suction nozzle, to be assessed using equation 1
M_{xs} = applied moment about x-axis on suction nozzle, to be assessed using equation 1
M_{ys} = applied moment about y-axis on suction nozzle, to be assessed using equation 1
M_{zs} = applied moment about z-axis on suction nozzle, to be assessed using equation 1
F_{xd} = applied force on x-axis on discharge nozzle, to be assessed using equation 1

F_{yd} = applied force on y-axis on discharge nozzle, to be assessed using equation 1

F_{zd} = applied force on z-axis on discharge nozzle, to be assessed using equation 1

M_{xd} = applied moment about x-axis on discharge nozzle, to be assessed using equation 1

M_{yd} = applied moment about y-axis on discharge nozzle, to be assessed using equation 1

M_{zd} = applied moment about z-axis on discharge nozzle, to be assessed using equation 1

$F_{x\,max}$ = maximum value of force on x-axis of either nozzle, to be used with equation 1

$F_{y\,max}$ = maximum value of force on y-axis of either nozzle, to be used with equation 1

$F_{z\,max}$ = maximum value of force on z-axis of either nozzle, to be used with equation 1

$M_{x\,max}$ = maximum value of moment about x-axis of either nozzle, to be used with equation 1

$M_{y\,max}$ = maximum value of moment about y-axis of either nozzle, to be used with equation 1

$M_{z\,max}$ = maximum value of moment about z-axis of either nozzle, to be used with equation 1

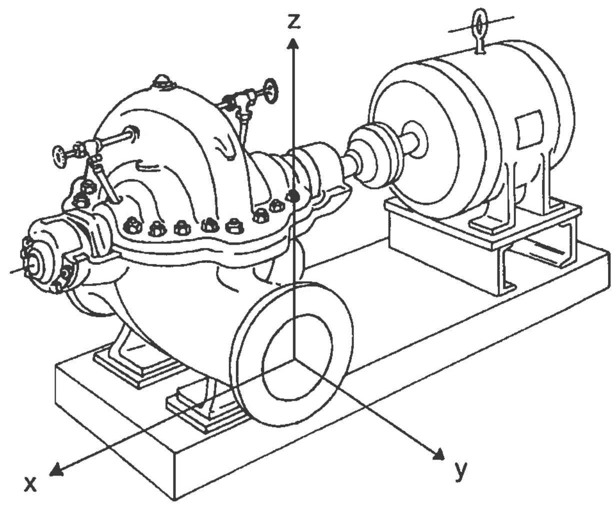


Figure 9.6.2.3.2 — Coordinate system for axial split case pumps

9.6.2.3.3 Criteria for loading allowances

Testing of nozzle loads on the above-described pumps have shown that misalignment between the pump and driver shaft occurs from movement of the casing relative to the baseplate. For alternate baseplate construction, maximum allowable nozzle loads should be established by the pump manufacturer, applied nozzle loads predicted by the purchaser, and differences, if any, negotiated and resolved by the two parties. The amount of loading that results in movement depends on the sizes of hold-down bolts, the amount of torque applied to the bolts, and the grade of bolts. See Table 9.6.2.3.3a.

The shown nozzle loads are for those applied to cast-iron casings mounted on machined mounting surface(s) of carbon-steel baseplate. The loads are for SAE J429 Grade 1 bolts with no lubrication to the bolt threads.

Calculation of stress in the pump suction or discharge nozzle shows that such stress may also limit nozzle loads. See Table 9.6.2.3.2b.

9.6.2.3.3.1 Driver and pump

The radial movement of the pump shaft at the coupling hub due to nozzle loading shall not exceed 0.005 in. parallel to the initial alignment. Axial movement of the pump shaft at the coupling is not considered. Allowable axial displacement of the pump shaft at the coupling hub after application of forces and moments should be established by the pump manufacturer and, if in conflict with the purchaser's requirements, negotiated and resolved by the two parties.

9.6.2.3.3.2 Limiting factors

Review of the effects of the nozzle loads suggests that the common limiting factors are:

a) Allowable tensile stress of the hold-down bolts (pump casing to the baseplate).

b) Allowable displacement of the drive end of the shaft.

c) Allowable tensile load on the hold-down bolts (embedded in concrete).

d) Allowable bending stress in the nozzles.

For pumps equipped with mechanical seals, internal distortion of parts may cause excessive displacement of stationary and rotating seal components and become a limiting factor.

9.6.2.3.3.3 Casing hold-down bolts

The maximum allowable tensile stress for the hold-down bolts is 90% of fastener's yield strength. Fasteners used for hold-down bolts should have yield strength of 36,000 psi or greater, i.e., greater than or equal to the yield strength of SAE J429 Grade 1 fasteners. The maximum allowable shear stress for the hold-down bolts is 25% of fastener's yield strength.

The casing shall be bolted to the baseplate by four bolts and sufficiently tightened to prevent slippage or movement relative to the baseplate. (Refer to API 686, Appendix E, for the required torque values.) It may be necessary to arrange for periodic tightening of the bolts to maintain the required torque.

The criterion for acceptable nozzle loads with respect to casing hold-down bolts is that the forces and moments involved shall not move the pump. Although it is possible that some of the bolts will contact the edge of the bolt hole, the assumption is made that contact does not occur. Therefore the only restraining force exerted on the pump by the casing hold-down bolts is considered to be the friction developed between the pump and base when the casing hold-down bolts are tightened.

Assumed effect of nozzle loading:

Shear forces in the x and y directions, and the moments about the z-axis (see Figure 9.6.2.3.2), are assumed to be distributed equally to the hold-down fasteners in all four feet. Movement of the pump occurs when the force overcomes the static horizontal friction force on all four feet induced by the torque of the hold-down bolts. The static weight of the pump is relatively small compared to the force induced by the torque of the bolts and therefore is not considered in the analysis.

Forces in the z direction, and moments about the x- or y-axis, are assumed to be distributed to fasteners in two feet, resulting in tensile loading in the fasteners. The effect of bolt torque on the joint is not considered. Therefore, the stress on the fasteners is assumed to be the combined value of the resulting tensile stress caused by the external forces plus the torque stress. This stress must be less than the yield strength of the fasteners.

It is also assumed that the piping does not provide restraint to pump movement.

It is also assumed that the static coefficient of friction between cast iron and carbon steel is 0.4.

9.6.2.3.4 Axial split case pumps (single-stage double suction and two-stage single suction) assessment of applied loads

Using the lowest values of maximum forces and moments from Tables 9.6.2.3.3a and 9.6.2.3.3b, combined applied loads shall satisfy the criteria defined by equation 1:

$$\left\{\begin{array}{l}\left(\frac{F_{xs}}{F_{x\,max}}\right)^2+\left(\frac{F_{ys}}{F_{y\,max}}\right)^2+\left(\frac{F_{zs}}{F_{z\,max}}\right)^2+\left(\frac{M_{xs}}{M_{x\,max}}\right)^2+\left(\frac{M_{ys}}{M_{y\,max}}\right)^2+\left(\frac{M_{zs}}{M_{z\,max}}\right)^2+\\ \left(\frac{F_{xd}}{F_{x\,max}}\right)^2+\left(\frac{F_{yd}}{F_{y\,max}}\right)^2+\left(\frac{F_{zd}}{F_{z\,max}}\right)^2+\left(\frac{M_{xd}}{M_{x\,max}}\right)^2+\left(\frac{M_{yd}}{M_{y\,max}}\right)^2+\left(\frac{M_{zd}}{M_{z\,max}}\right)^2\end{array}\right\}^{0.5}\leq 1 \qquad \text{(Eq. 1)}$$

Table 9.6.2.3.3a — Maximum forces and moments for use with equation 1 to assess applied loads based on hold-down bolts

Nominal Bolt Diameter (in)	Forces (lb)		Moments (lb•ft)	
	$F_{x\,max}$ and $F_{y\,max}$	$F_{z\,max}$	$M_{x\,max}$ and $M_{y\,max}$	$M_{z\,max}$
0.625	600	4000	6000	450
0.75	800	6000	12,000	800
0.875	1200	8000	17,000	1500
1.00	5000	11,000	22,000	2400

Table 9.6.2.3.3b — Maximum forces and moments for use with equation 1 to assess applied loads based on nozzle stress

Nozzle size (in)	Force (lb)			Moment (lb•ft)		
	$F_{x\,max}$	$F_{y\,max}$	$F_{z\,max}$	$M_{x\,max}$	$M_{y\,max}$	$M_{z\,max}$
2	1800	1400	1800	600	720	600
3	2400	2700	2400	734	900	734
4	3300	2700	3300	1200	1300	1200
6	4400	2700	4400	2400	1300	2400
8	6500	3500	6500	3800	1500	3800
10	8200	3500	8200	5400	1500	5400

9.6.2.4 Vertical turbine short set pumps

9.6.2.4.1 Scope

This standard deals solely with the maximum permissible loads on a vertical pump when the pump and system flanges are rigidly connected. It does not cover flexible or deformable connections such as bellows or flexible spool pieces.

The choices of vertical pump configurations are numerous and their construction details are as varied as the pump manufacturers who produce them. Consequently, the scope of the analysis of forces and moments on vertical pump flanges has been restricted within certain limits, as defined below:

Flange sizes between 2 and 36 in. This excludes larger pumps, which are frequently custom built and require technical coordination between the manufacturer and user.

Submerged suction with either above pump base (floor) or below pump base (floor) discharge short set pumps.

Pump units that supply clear liquids with a maximum specific gravity of 1.2.

Vibration limits should not be used in conjunction with this standard, unless agreed to by all involved parties. This is because external loads applied can make certain vibration levels unattainable.

9.6.2.4.2 Definitions

(See Figures 9.6.2.4.2a and 9.6.2.4.2b.)

f_x, f_y, and f_z are actual applied nozzle forces in their respective coordinate direction.

m_x, m_y, and m_z are actual applied nozzle moments in their respective coordinate direction.

F_x, F_y, and F_z are tabulated maximum permissible nozzle forces in their respective coordinate direction.

M_x, M_y, and M_z are tabulated maximum permissible nozzle moments in their respective coordinate direction.

l_y and l_z are the flange centerline distances to the baseplate centerline in the y and z direction, respectively.

D is the nominal discharge nozzle size.

A is the distance from the discharge case to pump base (applicable only on below pump base discharge pump).

F_x', F_y', F_z', M_x', M_y', and M_z' are the maximum permissible nozzle loads after compensation for centerline distance, temperature, and/or material variation.

P_{tab} is the pressure rating of 150-psi, carbon-steel flange at 100 °F from ANSI/ASME B16.5.

P_{new} is the pressure rating of the actual material at a given temperature from ANSI/ASME B16.5.

9.6.2.4.3 Methodology

Consider the x-y-z coordinate system origin to be at the discharge flange face centerline.

The included tables show maximum permissible forces and moments for each coordinate direction on each flange. Each value in the tables represents the maximum allowable load in a particular direction acting alone. For cases in which more than one load is applied simultaneously, the following formula should be used:

$$\frac{f_x}{F_x} + \frac{f_y}{F_y} + \frac{f_z}{F_z} + \frac{m_x}{M_x} + \frac{m_y}{M_y} + \frac{m_z}{M_z} \le 1 \qquad \text{(Eq. 2)}$$

The tabulated values were generated by holding the following relationships:

$$\frac{l_y}{D} \le 1 \qquad \frac{l_z}{D} \le 1 \qquad \text{(Eq. 3)}$$

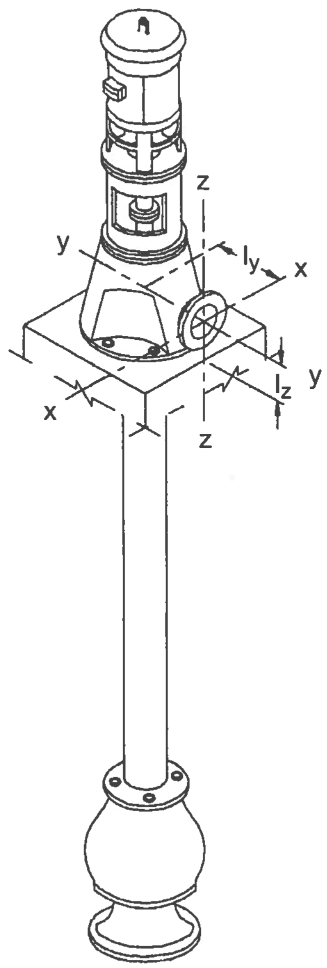
For the case where equation 3 cannot be maintained, the maximum permissible nozzle loads in their respective direction can be obtained from the following equations:

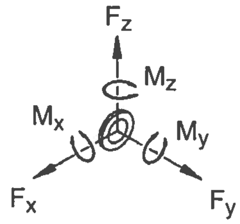
$$F_x' = F_x\left[\frac{D^2}{(l_y \times l_z)}\right]^3 \qquad \text{(Eq. 4)}$$

$$F_y' = F_y\left(\frac{D}{l_z}\right)^3 \qquad \text{(Eq. 5)}$$

$$F_z' = F_z\left(\frac{D}{l_y}\right)^3 \qquad \text{(Eq. 6)}$$

Category	Configuration	Flange Position	Application Limits		
			Max. Pressure (psi)	Max. Temp. (°F)	Max. Nozzle Size (in)
Shaft-driven, suspended pump, for water	Submerged suction	Discharge above base	300	100	36





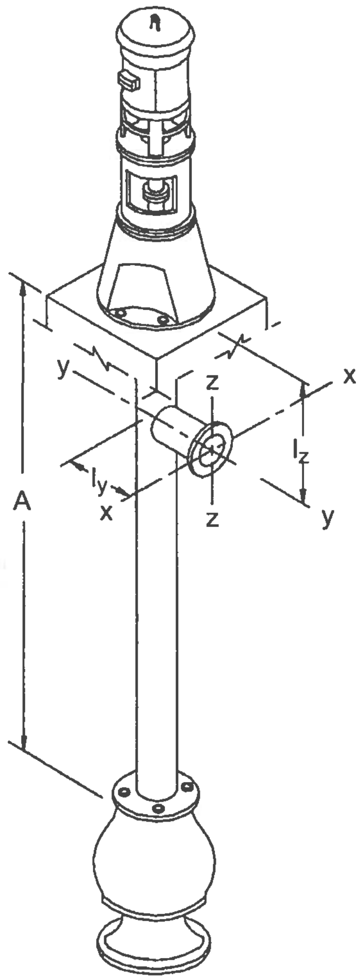
Maximum Allowable Individual Nozzle Loads						
Nozzle Size	Nozzle Material: Steel					
Dia (in)	Forces (lb)			Moments (lb•ft)		
	F_x	F_y	F_z	M_x	M_y	M_z
2	202	182	225	302	409	260
3	323	291	360	474	619	407
4	404	364	450	588	753	506
6	606	546	674	892	1099	770
8	808	728	899	1244	1499	1076
10	1010	910	1124	1667	1994	1445
12	1212	1092	1349	2178	2613	1890
14	1414	1274	1574	2790	3372	2422
16	1616	1456	1798	3507	4272	3043
18	1818	1638	2023	4329	5306	3753
20	2020	1820	2248	5251	6450	4545
22	2222	2002	2473	6260	7669	5406
24	2424	2184	2698	7338	8916	6319
30	3079	2774	3426	10,980	12,343	9327
36	3694	3329	4111	13,691	15,528	11,367

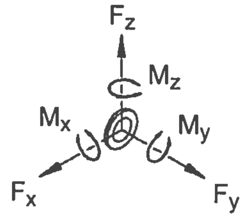
Tables based on: $\frac{l_y}{D} = \frac{l_z}{D} \leq 1$

Deviation from the tables is acceptable provided the following relationship is maintained: $\frac{f_x}{F_x} + \frac{f_y}{F_y} + \frac{f_z}{F_z} + \frac{m_x}{M_x} + \frac{m_y}{M_Y} + \frac{m_z}{M_z} \leq 1$

Figure 9.6.2.4.2a — Nozzle loads for above pump base (floor) discharge pumps

Category	Configuration	Flange Position	Application Limits		
Shaft-driven, suspended pump, for water	Submerged suction	Discharge below base	Max. Pressure (psi)	Max. Temp. (°F)	Max. Nozzle Size (in)
			300	100	36





Maximum Allowable Individual Nozzle Loads						
Nozzle Size	Nozzle Material: Steel					
Dia (in)	Forces (lb)			Moments (lb•ft)		
	F_x	F_y	F_z	M_x	M_y	M_z
2	67	60	75	122	150	106
3	108	97	119	183	223	159
4	134	121	149	220	269	191
6	202	181	224	314	383	272
8	269	242	299	420	513	363
10	336	302	373	551	672	476
12	403	363	448	715	873	619
14	470	423	523	918	1121	796
16	538	484	567	1161	1419	1008
18	605	544	672	1442	1762	1252
20	672	605	747	1755	2142	1524
22	739	665	822	2091	2548	1815
24	806	726	896	2435	2962	2112
30	1024	922	1138	3378	4061	2908
36	1229	1106	1366	4029	4920	3523

Tables based on: $\frac{l_y}{D} = \frac{l_z}{D} \leq 1$

Deviation from the tables is acceptable provided the following relationship is maintained: $\frac{f_x}{F_x} + \frac{f_y}{F_y} + \frac{f_z}{F_z} + \frac{m_x}{M_x} + \frac{m_y}{M_Y} + \frac{m_z}{M_z} \leq 1$

Figure 9.6.2.4.2b — Nozzle loads for below pump base (floor) discharge pumps

$$M_x' = M_x\left[\frac{D^2}{(l_y \times l_z)}\right]^2 \qquad \text{(Eq. 7)}$$

$$M_y' = M_y\left(\frac{D}{l_z}\right)^2 \qquad \text{(Eq. 8)}$$

$$M_z' = M_z\left(\frac{D}{l_y}\right)^2 \qquad \text{(Eq. 9)}$$

Materials conform to carbon steel, either cast, forged, or plate. For higher temperatures and other materials, the loads should be revised using the methodology of ASME B16.5 for flanges.

$$F_x' = F_x\left(\frac{P_{new}}{P_{tab}}\right) \qquad \text{(Eq. 10)}$$

$$F_y' = F_y\left(\frac{P_{new}}{P_{tab}}\right) \qquad \text{(Eq. 11)}$$

$$F_z' = F_z\left(\frac{P_{new}}{P_{tab}}\right) \qquad \text{(Eq. 12)}$$

$$M_x' = M_x\left(\frac{P_{new}}{P_{tab}}\right) \qquad \text{(Eq. 13)}$$

$$M_y' = M_y\left(\frac{P_{\mathrm{new}}}{P_{\mathrm{tab}}}\right) \qquad \text{(Eq. 14)}$$

$$M_z' = M_z\left(\frac{P_{\mathrm{new}}}{P_{\mathrm{tab}}}\right) \qquad \text{(Eq. 15)}$$

For below pump base discharge pumps, one additional factor must be held to the following relationship.

$$A \le 10D \qquad \text{(Eq. 16)}$$

For the case where equation 16 cannot be maintained, the maximum permissible nozzle loads, in their respective direction, can be obtained from the following equations:

$$F_x' = F_x\left[\frac{29D}{(D-3A)}\right]^2 \qquad \text{(Eq. 17)}$$

$$F_y' = F_y\left[\frac{29D}{(D-3A)}\right] \qquad \text{(Eq. 18)}$$

$$F_z' = F_z\left[\frac{29D}{(D-3A)}\right] \qquad \text{(Eq. 19)}$$

$$M_x' = M_x\left[\frac{19D^2}{(2AD - D^2)}\right]^2 \quad \text{(Eq. 20)}$$

$$M_y' = M_y\left[\frac{19D^2}{(2AD - D^2)}\right] \quad \text{(Eq. 21)}$$

$$M_z' = M_z\left[\frac{19D^2}{(2AD - D^2)}\right] \quad \text{(Eq. 22)}$$

Appendix C shows examples to illustrate usage of the previous equations.

Criteria for the maximum individual loads are based on operating experiences with existing products and the following:

- Deflection – The maximum allowable lateral deflection at the stuffing box area is 0.002 in. This restriction on deflection is because most mechanical seals are designed to operate within these limits.
- No contact between moving and stationary parts (e.g., impeller and bowls). The maximum allowable lateral deflection at the pump bowl is 0.002 in.
- Pump tie-down fasteners – baseplate anchor bolts sufficiently torqued to prevent any movement of the pump. The base will be fully grouted.

Appendix A

Example assessments of applied nozzle loads – ASME B73.1 and ASME B73.5M pumps

This appendix is not part of Hydraulic Institute Standard 9.6.2, and is included for informational purposes only.

Example 1: An ASME B73.1 1.5×1-8 CF8M (Type 316) pump with Class 150 flanges is to be operated at 100 °F. It is mounted on a fully grouted metal baseplate held down by anchor bolts.

Applied nozzle loads:

F_x, suction = 100 lb	F_x, discharge = 100 lb
F_y, suction = –100 lb	F_y, discharge = –100 lb
F_z, suction = 100 lb	F_z, discharge = 100 lb
M_x, suction = –100 lb•ft	M_x, discharge = –100 lb•ft
M_y, suction = 100 lb•ft	M_y, discharge = 100 lb•ft
M_z, suction = –100 lb•ft	M_z, discharge = –100 lb•ft

The applied loads are assessed below.

1) Derating loads.

   On comparing temperature and material parameters with the scope of this standard, it is found that this is an applicable scenario. Since CF8M is the material, and temperature of operation is less than 100 °F, no adjustment of the tabulated maximum forces and moments is necessary. Also, since the unit is mounted on a fully grouted metal baseplate with anchor bolts, no adjustment of the tabulated maximum forces and moments is necessary.

2) Individual nozzle load assessment.

   The applied loads are entered into the numerators of equation set 1, and the maximum values from Table 9.6.2.1.4b for the pump size being evaluated are entered into the denominators.

$$\left|\frac{F_{xs}}{F_{xs\ max}}\right| \le 1.0,\ \left|\frac{F_{ys}}{F_{ys\ max}}\right| \le 1.0,\ \left|\frac{F_{zs}}{F_{zs\ max}}\right| \le 1.0 \qquad \left|\frac{100}{1050}\right| = 0.10 \quad \left|\frac{-100}{1210}\right| = 0.08 \quad \left|\frac{100}{1210}\right| = 0.08$$

$$\left|\frac{M_{xs}}{M_{xs\ max}}\right| \le 1.0,\ \left|\frac{M_{ys}}{M_{ys\ max}}\right| \le 1.0,\ \left|\frac{M_{zs}}{M_{zs\ max}}\right| \le 1.0 \qquad \left|\frac{-100}{720}\right| = 0.14 \quad \left|\frac{100}{190}\right| = 0.53 \quad \left|\frac{-100}{190}\right| = 0.53$$

$$\left|\frac{F_{xd}}{F_{xd\ max}}\right| \le 1.0,\ \left|\frac{F_{yd}}{F_{yd\ max}}\right| \le 1.0,\ \left|\frac{F_{zd}}{F_{zd\ max}}\right| \le 1.0 \qquad \left|\frac{100}{800}\right| = 0.13 \quad \left|\frac{-100}{1350}\right| = 0.07 \quad \left|\frac{100}{3000}\right| = 0.03$$

$$\left|\frac{M_{xd}}{M_{xd\ max}}\right| \le 1.0,\ \left|\frac{M_{yd}}{M_{yd\ max}}\right| \le 1.0,\ \left|\frac{M_{zd}}{M_{zd\ max}}\right| \le 1.0 \qquad \left|\frac{-100}{360}\right| = 0.28 \quad \left|\frac{100}{360}\right| = 0.28 \quad \left|\frac{-100}{360}\right| = 0.28$$

   From above assessment, all values are less than 1.0, so proceed to assessing combination of loads.

3) Nozzle stress, bolt stress, and pump slippage on baseplate assessment.

The applied loads are entered into the numerators of equation set 2, and the maximum values from Table 9.6.2.1.4c for the pump size being assessed are entered into the denominators.

$$\frac{1}{2} \times \left[\begin{array}{l} \left|\frac{F_{xs}}{F_{xs\ max}}\right| + \left|\frac{F_{ys}}{F_{ys\ max}}\right| + \left|\frac{F_{zs}}{F_{zs\ max}}\right| + \left|\frac{M_{xs}}{M_{xs\ max}}\right| + \left|\frac{M_{ys}}{M_{ys\ max}}\right| + \left|\frac{M_{zs}}{M_{zs\ max}}\right| + \\ \left|\frac{F_{xd}}{F_{xd\ max}}\right| + \left|\frac{F_{yd}}{F_{yd\ max}}\right| + \left|\frac{F_{zd}}{F_{zd\ max}}\right| + \left|\frac{M_{xd}}{M_{xd\ max}}\right| + \left|\frac{M_{yd}}{M_{yd\ max}}\right| + \left|\frac{M_{zd}}{M_{zd\ max}}\right| \end{array} \right] \le 1.0$$

$$\frac{1}{2} \times \left[\begin{array}{l} \left|\frac{100}{2020}\right| + \left|\frac{-100}{1210}\right| + \left|\frac{100}{1210}\right| + \left|\frac{-100}{1830}\right| + \left|\frac{100}{190}\right| + \left|\frac{-100}{190}\right| + \\ \left|\frac{100}{2020}\right| + \left|\frac{-100}{1350}\right| + \left|\frac{100}{6240}\right| + \left|\frac{-100}{360}\right| + \left|\frac{100}{360}\right| + \left|\frac{-100}{360}\right| \end{array} \right] = 1.15$$

From above assessment, the summation is greater than 1.0, so the loading scenario is too high. The loads must be reduced and reassessed until this summation is less than or equal to 1.0 before proceeding to the next step.

New applied loads:

F_x, suction = 75 lb	F_x, discharge = 75 lb
F_y, suction = – 75 lb	F_y, discharge = – 75 lb
F_z, suction = 75 lb	F_z, discharge = 75 lb
M_x, suction = – 75 lb•ft	M_x, discharge = – 75 lb•ft
M_y, suction = 75 lb•ft	M_y, discharge = 75 lb•ft
M_z, suction = – 75 lb•ft	M_z, discharge = – 75 lb•ft

4) Individual nozzle load assessment (new loads).

The applied loads are entered into the numerators of equation set 1, and the maximum values from Table 9.6.2.1.4b for the pump size being assessed are entered into the denominators.

$$\left|\frac{F_{xs}}{F_{xs\ max}}\right| \le 1.0,\quad \left|\frac{F_{ys}}{F_{ys\ max}}\right| \le 1.0,\quad \left|\frac{F_{zs}}{F_{zs\ max}}\right| \le 1.0 \qquad \left|\frac{75}{1050}\right| = 0.07 \quad \left|\frac{-75}{1210}\right| = 0.06 \quad \left|\frac{75}{1210}\right| = 0.06$$

$$\left|\frac{M_{xs}}{M_{xs\ max}}\right| \le 1.0,\quad \left|\frac{M_{ys}}{M_{ys\ max}}\right| \le 1.0,\quad \left|\frac{M_{zs}}{M_{zs\ max}}\right| \le 1.0 \qquad \left|\frac{-75}{720}\right| = 0.10 \quad \left|\frac{75}{190}\right| = 0.39 \quad \left|\frac{-75}{190}\right| = 0.39$$

$$\left|\frac{F_{xd}}{F_{xd\ max}}\right| \le 1.0,\quad \left|\frac{F_{yd}}{F_{yd\ max}}\right| \le 1.0,\quad \left|\frac{F_{zd}}{F_{zd\ max}}\right| \le 1.0 \qquad \left|\frac{75}{800}\right| = 0.09 \quad \left|\frac{-75}{1350}\right| = 0.06 \quad \left|\frac{75}{3000}\right| = 0.03$$

$$\left|\frac{M_{xd}}{M_{xd\ max}}\right| \le 1.0,\quad \left|\frac{M_{yd}}{M_{yd\ max}}\right| \le 1.0,\quad \left|\frac{M_{zd}}{M_{zd\ max}}\right| \le 1.0 \qquad \left|\frac{-75}{360}\right| = 0.21 \quad \left|\frac{75}{360}\right| = 0.21 \quad \left|\frac{-75}{360}\right| = 0.21$$

From above assessment, all values are less than 1.0, so proceed to assessing combination of loads.

5) Nozzle stress, bolt stress, and pump slippage on baseplate assessment (new loads).

The applied loads are entered into the numerators of equation set 2, and the maximum values from Table 9.6.2.1.4c for the pump size being assessed are entered into the denominators.

$$\frac{1}{2} \times \left[\begin{array}{l} \left|\frac{F_{xs}}{F_{xs\ max}}\right| + \left|\frac{F_{ys}}{F_{ys\ max}}\right| + \left|\frac{F_{zs}}{F_{zs\ max}}\right| + \left|\frac{M_{xs}}{M_{xs\ max}}\right| + \left|\frac{M_{ys}}{M_{ys\ max}}\right| + \left|\frac{M_{zs}}{M_{zs\ max}}\right| + \\ \left|\frac{F_{xd}}{F_{xd\ max}}\right| + \left|\frac{F_{yd}}{F_{yd\ max}}\right| + \left|\frac{F_{zd}}{F_{zd\ max}}\right| + \left|\frac{M_{xd}}{M_{xd\ max}}\right| + \left|\frac{M_{yd}}{M_{yd\ max}}\right| + \left|\frac{M_{zd}}{M_{zd\ max}}\right| \end{array} \right] \leq 1.0$$

$$\frac{1}{2} \times \left[\begin{array}{l} \left|\frac{75}{2020}\right| + \left|\frac{-75}{1210}\right| + \left|\frac{75}{1210}\right| + \left|\frac{-75}{1830}\right| + \left|\frac{75}{190}\right| + \left|\frac{-75}{190}\right| + \\ \left|\frac{75}{2020}\right| + \left|\frac{-75}{1350}\right| + \left|\frac{75}{6240}\right| + \left|\frac{-75}{360}\right| + \left|\frac{75}{360}\right| + \left|\frac{-75}{360}\right| \end{array} \right] = 0.86$$

6) Y-axis deflection assessment (new loads).

The applied loads are entered into the numerators of equation set 3, and the maximum values from Table 9.6.2.1.4d for the pump size being assessed are entered into the denominators.

$$-1.0 \leq a = \frac{F_{ys}}{F_{ys\ max}} + \frac{M_{xs}}{M_{xs\ max}} + \frac{M_{ys}}{M_{ys\ max}} + \frac{M_{zs}}{M_{zs\ max}} + \frac{F_{yd}}{F_{yd\ max}} + \frac{M_{xd}}{M_{xd\ max}} + \frac{M_{yd}}{M_{yd\ max}} + \frac{M_{zd}}{M_{zd\ max}} \leq 1.0$$

$$a = \frac{-75}{-2000} + \frac{-75}{900} + \frac{75}{1200} + \frac{-75}{1250} + \frac{-75}{1500} + \frac{-75}{-500} + \frac{75}{1500} + \frac{-75}{1250} \leq 0.05$$

From the above assessment, the summation is between –1.0 and +1.0, so proceed to assessing equation set 4.

7) Z-axis deflection assessment (new loads).

The applied loads are entered into the numerators of equation set 4, and the maximum values from Table 9.6.2.1.4e for the pump size being assessed are entered into the denominators.

$$\begin{array}{l} -1.0 \leq b = \frac{F_{xs}}{F_{xs\ max}} + \frac{F_{zs}}{F_{zs\ max}} + \frac{M_{xs}}{M_{xs\ max}} + \frac{M_{ys}}{M_{ys\ max}} + \frac{M_{zs}}{M_{zs\ max}} + \\ \qquad \frac{F_{xd}}{F_{xd\ max}} + \frac{F_{yd}}{F_{yd\ max}} + \frac{F_{zd}}{F_{zd\ max}} + \frac{M_{xd}}{M_{xd\ max}} + \frac{M_{yd}}{M_{yd\ max}} + \frac{M_{zd}}{M_{zd\ max}} \leq 1.0 \end{array}$$

$$b = \frac{75}{1050} + \frac{75}{-1250} + \frac{-75}{1500} + \frac{75}{1200} + \frac{-75}{-2500} + \frac{75}{800} + \frac{-75}{2000} + \frac{75}{-3000} + \frac{-75}{-1500} + \frac{75}{1000} + \frac{-75}{-2500} = 0.24$$

From the above assessment, the summation is between –1.0 and +1.0, so proceed to assessing equation set 5.

8) Combined axis deflection assessment.

The results from equation sets 3 and 4 are evaluated with the equation set 5 below.

$$\sqrt{a^2 + b^2} \leq 1.0$$

$$\sqrt{(0.05)^2 + (0.24)^2} = 0.25$$

From the above assessment, since the summation is less than 1.0, the assessment is complete. New loading scenario is satisfactory.

Example 2: An ASME-B73.1 3×1.5-13 Alloy 20 pump with Class 300 flanges is to be operated at 400 °F. It is mounted on a fully grouted metal baseplate held down by anchor bolts.

Applied nozzle loads:

F_x, suction = 50 lb
F_y, suction = – 50 lb
F_z, suction = 50 lb
M_x, suction = – 50 lb•ft
M_y, suction = 50 lb•ft
M_z, suction = – 50 lb•ft

F_x, discharge = 50 lb
F_y, discharge = – 50 lb
F_z, discharge = 50 lb
M_x, discharge = – 50 lb•ft
M_y, discharge = 50 lb•ft
M_z, discharge = – 50 lb•ft

The applied loads are assessed below.

1) Derating loads.

On comparing operating temperature and material parameters with the scope of this standard, it is found that this is an applicable scenario. Since Alloy 20 is the material and operation is occurring at 400 °F, an adjustment of Table 9.6.2.1.4c loads is necessary. No adjustment for mounting is necessary because the unit is on a fully grouted metal baseplate with anchor bolts.

Using Table 9.6.2.1.7.2.2b, a derating value of 0.67 is found under Alloy 20 at 400 °F. Derate the values in Table 9.6.2.1.4c as shown below.

Line in Table 9.6.2.1.4c before derating:

	F_{xs}	F_{ys}	F_{zs}	M_{xs}	M_{ys}	M_{zs}	F_{xd}	F_{yd}	F_{zd}	M_{xd}	M_{yd}	M_{zd}
3 × 1.5 × 13	2700	1350	3060	3730	670	670	2020	1350	6240	530	530	530

Line in Table 9.6.2.1.4c after derating by a factor of 0.67:

	F_{xs}	F_{ys}	F_{zs}	M_{xs}	M_{ys}	M_{zs}	F_{xd}	F_{yd}	F_{zd}	M_{xd}	M_{yd}	M_{zd}
3 × 1.5 × 13	1809	905	2050	2499	449	449	1353	905	4181	355	355	355

If any value in the derated line of Table 9.6.2.1.4c is lower than the corresponding value in Table 9.6.2.1.4b, use the absolute value of the lower absolute value of the two when evaluating equation set 1. In this case, F_{xs}, F_{ys}, M_{ys}, M_{zs}, F_{xd}, F_{yd}, M_{xd}, M_{yd}, and M_{zd} are all less in Table 9.6.2.1.4c than in Table 9.6.2.1.4b and the lower values should replace the corresponding values in Table 9.6.2.1.4b. The new line in Table 9.6.2.1.4b is as below.

New line in Table 9.6.2.1.4b:

	F_{xs}	F_{ys}	F_{zs}	M_{xs}	M_{ys}	M_{zs}	F_{xd}	F_{yd}	F_{zd}	M_{xd}	M_{yd}	M_{zd}
3 × 1.5 × 13	1809	905	1500	1300	449	449	1353	905	3250	355	355	355

2) Individual nozzle load assessment.

The applied loads are entered into the numerators of equation set 1, and the maximum values from Table 9.6.2.1.4b for the pump size being evaluated are entered into the denominators.

$$\left|\frac{F_{xs}}{F_{xs\,max}}\right| \le 1.0,\ \left|\frac{F_{ys}}{F_{ys\,max}}\right| \le 1.0,\ \left|\frac{F_{zs}}{F_{zs\,max}}\right| \le 1.0 \qquad \left|\frac{50}{1809}\right| = 0.03 \quad \left|\frac{-50}{905}\right| = 0.06 \quad \left|\frac{50}{1500}\right| = 0.03$$

$$\left|\frac{M_{xs}}{M_{xs\,max}}\right| \le 1.0,\ \left|\frac{M_{ys}}{M_{ys\,max}}\right| \le 1.0,\ \left|\frac{M_{zs}}{M_{zs\,max}}\right| \le 1.0 \qquad \left|\frac{-50}{1300}\right| = 0.04 \quad \left|\frac{50}{449}\right| = 0.11 \quad \left|\frac{-50}{449}\right| = 0.11$$

$$\left|\frac{F_{xd}}{F_{xd\,max}}\right| \le 1.0,\ \left|\frac{F_{yd}}{F_{yd\,max}}\right| \le 1.0,\ \left|\frac{F_{zd}}{F_{zd\,max}}\right| \le 1.0 \qquad \left|\frac{50}{1353}\right| = 0.04 \quad \left|\frac{-50}{905}\right| = 0.06 \quad \left|\frac{50}{3250}\right| = 0.02$$

$$\left|\frac{M_{xd}}{M_{xd\,max}}\right| \le 1.0,\ \left|\frac{M_{yd}}{M_{yd\,max}}\right| \le 1.0,\ \left|\frac{M_{zd}}{M_{zd\,max}}\right| \le 1.0 \qquad \left|\frac{-50}{355}\right| = 0.14 \quad \left|\frac{50}{355}\right| = 0.14 \quad \left|\frac{-50}{355}\right| = 0.14$$

From the above assessment, all values are less than 1.0, so proceed to assessing combination of loads.

3) Nozzle stress, bolt stress, and pump slippage on baseplate assessment.

The applied loads are entered into the numerators of equation set 2, and the adjusted maximum values from Table 9.6.2.1.4c above for the pump size being assessed are entered into the denominators.

$$\frac{1}{2} \times \left[\begin{array}{l} \left|\frac{F_{xs}}{F_{xs\,max}}\right| + \left|\frac{F_{ys}}{F_{ys\,max}}\right| + \left|\frac{F_{zs}}{F_{zs\,max}}\right| + \left|\frac{M_{xs}}{M_{xs\,max}}\right| + \left|\frac{M_{ys}}{M_{ys\,max}}\right| + \left|\frac{M_{zs}}{M_{zs\,max}}\right| + \\ \left|\frac{F_{xd}}{F_{xd\,max}}\right| + \left|\frac{F_{yd}}{F_{yd\,max}}\right| + \left|\frac{F_{zd}}{F_{zd\,max}}\right| + \left|\frac{M_{xd}}{M_{xd\,max}}\right| + \left|\frac{M_{yd}}{M_{yd\,max}}\right| + \left|\frac{M_{zd}}{M_{zd\,max}}\right| \end{array}\right] \le 1.0$$

$$\frac{1}{2} \times \left[\begin{array}{l} \left|\frac{50}{1809}\right| + \left|\frac{-50}{905}\right| + \left|\frac{50}{2050}\right| + \left|\frac{-50}{2499}\right| + \left|\frac{50}{449}\right| + \left|\frac{-50}{449}\right| + \\ \left|\frac{50}{1353}\right| + \left|\frac{-50}{905}\right| + \left|\frac{50}{4181}\right| + \left|\frac{-50}{355}\right| + \left|\frac{50}{355}\right| + \left|\frac{-50}{355}\right| \end{array}\right] = 0.44$$

From the above assessment, since all values are less than 1.0, continue assessing combination of loads with equation set 3.

4) Y-axis deflection assessment.

The applied loads are entered into the numerators of equation set 3, and the maximum values from Table 9.6.2.1.4d for the pump size being evaluated are entered into the denominators. No adjustment is required is this case.

From the above assessment, the summation is between –1.0 and +1.0, so proceed to evaluating equation set 4.

$$-1.0 \le a = \frac{F_{ys}}{F_{ys\ max}} + \frac{M_{xs}}{M_{xs\ max}} + \frac{M_{ys}}{M_{ys\ max}} + \frac{M_{zs}}{M_{zs\ max}} + \frac{F_{yd}}{F_{yd\ max}} + \frac{M_{xd}}{M_{xd\ max}} + \frac{M_{yd}}{M_{yd\ max}} + \frac{M_{zd}}{M_{zd\ max}} \le 1.0$$

$$a = \frac{-50}{-3500} + \frac{-50}{1300} + \frac{50}{1300} + \frac{-50}{3000} + \frac{-50}{2500} + \frac{-50}{-1200} + \frac{50}{1500} + \frac{-50}{3000} = 0.04$$

5) Z-axis deflection assessment.

The applied loads are entered into the numerators of equation set 4, and the maximum values from Table 9.6.2.1.4e for the pump size being evaluated are entered into the denominators. No adjustment is required is this case.

$$-1.0 \le b = \frac{F_{xs}}{F_{xs\ max}} + \frac{F_{zs}}{F_{zs\ max}} + \frac{M_{xs}}{M_{xs\ max}} + \frac{M_{ys}}{M_{ys\ max}} + \frac{M_{zs}}{M_{zs\ max}} +$$
$$\frac{F_{xd}}{F_{xd\ max}} + \frac{F_{yd}}{F_{yd\ max}} + \frac{F_{zd}}{F_{zd\ max}} + \frac{M_{xd}}{M_{xd\ max}} + \frac{M_{yd}}{M_{yd\ max}} + \frac{M_{zd}}{M_{zd\ max}} \le 1.0$$

$$b = \frac{50}{3500} + \frac{50}{-1500} + \frac{-50}{1500} + \frac{50}{1300} + \frac{-50}{-3500} + \frac{50}{1400} + \frac{-50}{2500} + \frac{50}{-3250} + \frac{-50}{-1500} + \frac{50}{2150} + \frac{-50}{-3500} = 0.07$$

From the above assessment, the summation is between –1.0 and +1.0, so proceed to evaluating equation set 5.

6) Combined axis deflection assessment.

The results from equation set 3 and 4 are evaluated with equation set 5 below.

$$\sqrt{a^2 + b^2} \le 1.0$$

$$\sqrt{(0.04)^2 + (0.07)^2} = 0.08$$

From the above assessment, since the summation is less than 1.0, the assessment is complete. The loading scenario is satisfactory.

Example 3: An ASME B73.5M 1.5×1-8 pump having a material with a modulus of elasticity greater than 1.0 × 10^6 is to be operated at 110 °F. It is mounted on a fully grouted nonmetal baseplate.

Applied nozzle loads:

F_x, suction = 150 lb $\qquad$ F_x, discharge = 50 lb

F_y, suction	=	0 lb	F_y, discharge	=	0 lb
F_z, suction	=	0 lb	F_z, discharge	=	50 lb
M_x, suction	=	– 50 lb•ft	M_x, discharge	=	– 50 lb•ft
M_y, suction	=	200 lb•ft	M_y, discharge	=	0 lb•ft
M_z, suction	=	– 50 lb•ft	M_z, discharge	=	– 50 lb•ft

The applied loads are assessed as follows:

1) Derating loads.

On comparing operating temperature and material parameters with the scope of this standard, it is found that this is an applicable scenario. An adjustment must be made to the tabulated maximum forces and moments due to the following reasons:

- ASME B73.5M design and construction
- Fully grouted nonmetal baseplate with anchor bolts

The lower of the two derating values is to be used for derating Tables 9.6.2.1.4b – 9.6.2.1.4e. Referring to Section 9.6.2.1.6, a derating value of 0.9 is to be used on Tables 9.6.2.1.4b – 9.6.2.1.4e for all pumps with ASME B73.5M construction. Referring to Section 9.6.2.1.7.1.3, a derating value of 0.8 is to be used on Tables 9.6.2.1.4b – 9.6.2.1.4e when using fully grouted, nonmetal baseplates. Using the lower of the two values, Tables 9.6.2.1.4b – 9.6.2.1.4e must be multiplied by 0.8.

Line in Table 9.6.2.1.4b before derating:

	F_{xs}	F_{ys}	F_{zs}	M_{xs}	M_{ys}	M_{zs}	F_{xd}	F_{yd}	F_{zd}	M_{xd}	M_{yd}	M_{zd}
1.5 × 1 × 8	1050	1210	1210	720	190	190	800	1350	3000	360	360	360

Line in Table 9.6.2.1.4b after derating with 0.8 factor:

	F_{xs}	F_{ys}	F_{zs}	M_{xs}	M_{ys}	M_{zs}	F_{xd}	F_{yd}	F_{zd}	M_{xd}	M_{yd}	M_{zd}
1.5 × 1 × 8	840	968	968	576	152	152	640	1080	2400	288	288	288

Line in Table 9.6.2.1.4c before derating:

	F_{xs}	F_{ys}	F_{zs}	M_{xs}	M_{ys}	M_{zs}	F_{xd}	F_{yd}	F_{zd}	M_{xd}	M_{yd}	M_{zd}
1.5 × 1 × 8	2020	1210	1210	1830	190	190	2020	1350	6240	360	360	360

Line in Table 9.6.2.1.4c after derating with 0.8 factor:

	F_{xs}	F_{ys}	F_{zs}	M_{xs}	M_{ys}	M_{zs}	F_{xd}	F_{yd}	F_{zd}	M_{xd}	M_{yd}	M_{zd}
1.5 × 1 × 8	1616	968	968	1464	152	152	1616	1080	4992	288	288	288

Line in Table 9.6.2.1.4d before derating:

	F_{xs}	F_{ys}	F_{zs}	M_{xs}	M_{ys}	M_{zs}	F_{xd}	F_{yd}	F_{zd}	M_{xd}	M_{yd}	M_{zd}
1.5 × 1 × 8		–2000		900	1200	1250		1500		–500	1500	1250

Line in Table 9.6.2.1.4d after derating with 0.8 factor:

	F_{xs}	F_{ys}	F_{zs}	M_{xs}	M_{ys}	M_{zs}	F_{xd}	F_{yd}	F_{zd}	M_{xd}	M_{yd}	M_{zd}
1.5 × 1 × 8		–1600		720	960	1000		1200		–400	1200	1000

Line in Table 9.6.2.1.4e before derating:

	F_{xs}	F_{ys}	F_{zs}	M_{xs}	M_{ys}	M_{zs}	F_{xd}	F_{yd}	F_{zd}	M_{xd}	M_{yd}	M_{zd}
1.5 × 1 × 8	1050		–1250	1500	1200	–2500	800	2000	–3000	–1500	1000	–2500

Line in Table 9.6.2.1.4e after derating with 0.8 factor:

	F_{xs}	F_{ys}	F_{zs}	M_{xs}	M_{ys}	M_{zs}	F_{xd}	F_{yd}	F_{zd}	M_{xd}	M_{yd}	M_{zd}
1.5 × 1 × 8	840		–1000	1200	960	–2000	640	1600	–2400	–1200	800	–2000

2) Individual nozzle load assessment.

The applied loads are entered into the numerators of equation set 1, and the maximum values from Table 9.6.2.1.4b for the pump size being assessed are entered into the denominators.

$$\left|\frac{F_{xs}}{F_{xs\ max}}\right| \le 1.0,\ \left|\frac{F_{ys}}{F_{ys\ max}}\right| \le 1.0,\ \left|\frac{F_{zs}}{F_{zs\ max}}\right| \le 1.0 \qquad \left|\frac{150}{840}\right| = 0.18 \qquad \left|\frac{0}{968}\right| = 0.00 \qquad \left|\frac{0}{968}\right| = 0.00$$

$$\left|\frac{M_{xs}}{M_{xs\ max}}\right| \le 1.0,\ \left|\frac{M_{ys}}{M_{ys\ max}}\right| \le 1.0,\ \left|\frac{M_{zs}}{M_{zs\ max}}\right| \le 1.0 \qquad \left|\frac{-50}{576}\right| = 0.09 \qquad \left|\frac{200}{152}\right| = 1.32 \qquad \left|\frac{-50}{152}\right| = 0.33$$

$$\left|\frac{F_{xd}}{F_{xd\ max}}\right| \le 1.0,\ \left|\frac{F_{yd}}{F_{yd\ max}}\right| \le 1.0,\ \left|\frac{F_{zd}}{F_{zd\ max}}\right| \le 1.0 \qquad \left|\frac{50}{640}\right| = 0.08 \qquad \left|\frac{0}{1080}\right| = 0.00 \qquad \left|\frac{50}{2400}\right| = 0.02$$

$$\left|\frac{M_{xd}}{M_{xd\ max}}\right| \le 1.0,\ \left|\frac{M_{yd}}{M_{yd\ max}}\right| \le 1.0,\ \left|\frac{M_{zd}}{M_{zd\ max}}\right| \le 1.0 \qquad \left|\frac{-50}{288}\right| = 0.17 \qquad \left|\frac{50}{288}\right| = 0.17 \qquad \left|\frac{-50}{288}\right| = 0.17$$

From above assessment, the value for M_{ys} is too high. The loads must be reduced and reassessed until this result is less than or equal to 1.0 before continuing.

Appendix B

Example assessments of applied nozzle loads – ASME B73.2 pumps

This appendix is not part of Hydraulic Institute Standard 9.6.2, and is included for informational purposes only.

Example 1: An ASME B73.2 Size 2015/17 (1.5-in discharge, 8-in nominal impeller) CF8M (Type 316) pump with Class 150 flanges is to be operated at 100 °F.

Applied nozzle loads:

F_x, suction	=	150 lb	F_x, discharge	=	200 lb
F_y, suction	=	– 2100 lb	F_y, discharge	=	– 2200 lb
F_z, suction	=	175 lb	F_z, discharge	=	275 lb
M_x, suction	=	– 260 lb•ft	M_x, discharge	=	– 360 lb•ft
M_y, suction	=	430 lb•ft	M_y, discharge	=	530 lb•ft
M_z, suction	=	– 340 lb•ft	M_z, discharge	=	– 440 lb•ft

The applied loads are assessed below.

1) Derating loads.

   On comparing temperature and material parameters with the scope of this standard, it is found that this is an applicable scenario. Since CF8M is the material, and temperature of operation is less than or equal to 100 °F, no adjustment of the tabulated maximum forces and moments is necessary.

2) Nozzle load assessment.

   The applied loads are entered into the numerators of equation set 6 and the maximum values from Table 9.6.2.2.4b for the pump size being assessed are entered into the denominators.

$$\left|\frac{F_{xs}}{F_{x\ max}}\right| \le 1.0,\ \left|\frac{F_{ys}}{F_{y\ max}}\right| \le 1.0,\ \left|\frac{F_{zs}}{F_{z\ max}}\right| \le 1.0 \qquad \left|\frac{150}{360}\right| = 0.42 \quad \left|\frac{-2100}{3976}\right| = 0.53 \quad \left|\frac{175}{360}\right| = 0.49$$

$$\left|\frac{M_{xs}}{M_{x\ max}}\right| \le 1.0,\ \left|\frac{M_{ys}}{M_{y\ max}}\right| \le 1.0,\ \left|\frac{M_{zs}}{M_{z\ max}}\right| \le 1.0 \qquad \left|\frac{-260}{510}\right| = 0.51 \quad \left|\frac{430}{720}\right| = 0.60 \quad \left|\frac{-340}{510}\right| = 0.67$$

$$\left|\frac{F_{xd}}{F_{x\ max}}\right| \le 1.0,\ \left|\frac{F_{yd}}{F_{y\ max}}\right| \le 1.0,\ \left|\frac{F_{zd}}{F_{z\ max}}\right| \le 1.0 \qquad \left|\frac{200}{360}\right| = 0.56 \quad \left|\frac{-2200}{3976}\right| = 0.55 \quad \left|\frac{275}{360}\right| = 0.76$$

$$\left|\frac{M_{xd}}{M_{x\ max}}\right| \le 1.0,\ \left|\frac{M_{yd}}{M_{y\ max}}\right| \le 1.0,\ \left|\frac{M_{zd}}{M_{z\ max}}\right| \le 1.0 \qquad \left|\frac{-360}{510}\right| = 0.71 \quad \left|\frac{530}{720}\right| = 0.74 \quad \left|\frac{-440}{510}\right| = 0.86$$

From the above assessment, since each value is less than 1.0, the assessment is complete. The loading scenario is satisfactory.

Example 2: An ASME B73.2 4030/28 (2-in discharge, 13-in nominal impeller) Alloy 20 pump with Class 300 flanges is to be operated at 400 °F.

Applied nozzle loads:

F_x, suction	=	150 lb	F_x, discharge	=	200 lb
F_y, suction	=	– 2100 lb	F_y, discharge	=	– 2200 lb
F_z, suction	=	175 lb	F_z, discharge	=	275 lb
M_x, suction	=	– 260 lb•ft	M_x, discharge	=	– 360 lb•ft
M_y, suction	=	430 lb•ft	M_y, discharge	=	530 lb•ft
M_z, suction	=	– 340 lb•ft	M_z, discharge	=	– 440 lb•ft

The applied loads are assessed below.

1) Derating loads.

On comparing operating temperature and material parameters with the scope of this standard, it is found that this is an applicable scenario. Since Alloy 20 is the material and operation is occurring at 400 °F, an adjustment of Table 9.6.2.2.4b loads is necessary.

Using Table 9.6.2.2.5, a derating value of 0.67 is found under Alloy 20 at 400 °F. Derate the values in Table 9.6.2.2.4b as shown below.

Line in Table 9.6.2.2.4b before derating:

			F_x	F_y	F_z	M_x	M_y	M_z
2	13	24	450	6328	450	900	1270	900

Line in Table 9.6.2.2.4b after derating by a factor of 0.67:

			F_x	F_y	F_z	M_x	M_y	M_z
2	13	24	302	4240	302	603	851	603

2) Individual nozzle load assessment.

The applied loads are entered into the numerators of equation set 6, and the maximum values from Table 9.6.2.2.4b, after derating, for the pump size being assessed are entered into the denominators.

$$\left|\frac{F_{xs}}{F_{x\,max}}\right| \le 1.0,\quad \left|\frac{F_{ys}}{F_{y\,max}}\right| \le 1.0,\quad \left|\frac{F_{zs}}{F_{z\,max}}\right| \le 1.0 \qquad \left|\frac{150}{302}\right| = 0.5 \qquad \left|\frac{-2100}{4240}\right| = 0.50 \qquad \left|\frac{175}{302}\right| = 0.58$$

$$\left|\frac{M_{xs}}{M_{x\,max}}\right| \le 1.0,\quad \left|\frac{M_{ys}}{M_{y\,max}}\right| \le 1.0,\quad \left|\frac{M_{zs}}{M_{z\,max}}\right| \le 1.0 \qquad \left|\frac{-260}{603}\right| = 0.43 \qquad \left|\frac{430}{851}\right| = 0.51 \qquad \left|\frac{-340}{603}\right| = 0.56$$

$$\left|\frac{F_{xd}}{F_{x\,max}}\right| \le 1.0,\quad \left|\frac{F_{yd}}{F_{y\,max}}\right| \le 1.0,\quad \left|\frac{F_{zd}}{F_{z\,max}}\right| \le 1.0 \qquad \left|\frac{200}{302}\right| = 0.66 \qquad \left|\frac{-2200}{4240}\right| = 0.52 \qquad \left|\frac{275}{302}\right| = 0.91$$

$$\left|\frac{M_{xd}}{M_{x\,max}}\right| \le 1.0,\quad \left|\frac{M_{yd}}{M_{y\,max}}\right| \le 1.0,\quad \left|\frac{M_{zd}}{M_{z\,max}}\right| \le 1.0 \qquad \left|\frac{-360}{603}\right| = 0.60 \qquad \left|\frac{530}{851}\right| = 0.62 \qquad \left|\frac{-440}{603}\right| = 0.73$$

From the above assessment, since each value is less than 1.0, the assessment is complete. The loading scenario is satisfactory.

Appendix C

Example assessments of applied nozzle loads – vertical turbine pumps

This appendix is not part of Hydraulic Institute Standard 9.6.2, and is included for informational purposes only.

Example 1:

A 20-in mixed flow pump with an above pump base steel discharge nozzle is subjected to a maximum pressure of 150 psi. The dimensions l_y and l_z are 18 in each. The temperature of the pumped fluid is 100 °F. What is the maximum permissible nozzle load allowed on the discharge flange?

Answer 1:

From the table in Figure 9.6.2.4.2b for a 20-in nozzle, the loads are:

F_x = 2020 lb M_x = 5251 lb•ft

F_y = 1820 lb M_y = 6450 lb•ft

F_z = 2248 lb M_z = 4545 lb•ft

Example 2:

A 20-in mixed flow pump with an aboveground stainless-steel type 316 discharge nozzle is subjected to a maximum pressure of 150 psi. The dimensions for l_y and l_z are 30 and 45 in, respectively. The temperature of the pumped fluid is 500 °F. What is the maximum permissible nozzle load allowed on the discharge flange in the z direction?

Answer 2:

a) From example 1:

F_z = 2248 lb M_z = 4545 lb•ft

b) From ANSI B16.5, Class 150 pressure and temperature ratings

P_{new} = 170 psig (316 stainless steel at 500 °F)

P_{tab} = 285 psig (carbon steel at 100 °F)

c) Using the appropriate equations (Section 9.6.2.4.3), correct the nozzle loads for the flange centerline distance to baseplate centerline and pressure–temperature ratings.

l_y = 30 in D = 20 in

$$F_z' \text{ (Eq. 6)} = 2248\left(\frac{20}{30}\right)^3 = 666 \text{ lb}$$

$$F_z' \text{ (Eq. 12)} = 666\left(\frac{170}{285}\right) = 397 \text{ lb}$$

$$M_z' \text{ (Eq. 9)} = 4545\left(\frac{20}{30}\right)^2 = 2020 \text{ lb}\bullet\text{ft}$$

$$M_z' \text{ (Eq. 15)} = 2020\left(\frac{170}{285}\right) = 1205 \text{ lb}\bullet\text{ft}$$

Appendix D

References

This appendix is not part of Hydraulic Institute Standard 9.6.2, and is included for informational purposes only.

American National Standards and American Society of Mechanical Engineers Standards

The following are available from the American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036. ASME standards are also available from The American Society of Mechanical Engineers, 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300 (www.asme.org). When the following American National Standards referred to in this document are superseded by a revision approved by the American National Standards Institute, the revision shall apply.

ANSI/ASME B16.42, *Ductile Iron Pipe Flanges and Flanged Fittings*

ANSI/ASME B16.5, *Pipe Flanges and Flanged Fittings*

ANSI/ASME B73.1, *Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process*

ANSI/ASME B73.2, *Specification for Vertical-in-Line Centrifugal Pumps for Chemical Process*

ANSI/ASME B73.3, *Specification for Sealless Horizontal End Suction Centrifugal Pumps for Chemical Process*

ANSI/ASME B73.5M, *Specification for Thermoplastic and Thermoset Polymer Material Horizontal End Suction Centrifugal Pumps for Chemical Process*

ASME Boiler and Pressure Vessel Code, 1983 Edition, Section III, NC 3653

ASTM publications

The following are published by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959 (www.astm.org).

ASTM A 216/A 216M, *Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High Temperature Service*

ASTM A351/A351M, *Standard Specification for Castings, Austenitic, for Pressure-Containing Parts*

ASTM A 395, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*

ASTM A 494/A 494M, *Standard Specification for Castings, Nickel and Nickel Alloy*

ASTM A 744/A 744M, *Standard Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service*

ASTM A 890/A 890M, *Standard Specification for Castings, Iron - Chromium - Nickel - Molybdenum Corrosion Resistant, Duplex (Austenitic/Ferritic) for General Application*

API publications

The following are published by The American Petroleum Institute, 1220 L Street, N.W., Washington, DC 20005 (www.api.org).

API Recommend Practice 686[1] *Recommended Practices for Machinery Installation and Installation Design*

HI publications

The following are published by the Hydraulic Institute, 6 Campus Drive, 1st Floor North, Parsippany, NJ 07054-4406 (www.Pumps.org).

ANSI/HI 1.1–1.2 *Rotodynamic (Centrifugal) Pumps for Nomenclature and Definitions*

ANSI/HI 1.3 *Rotodynamic (Centrifugal) Pumps for Design and Application*

ANSI/HI 1.4 *Rotodynamic (Centrifugal) Pumps for Manuals Describing Installation, Operation, and Maintenance*

SAE publications

SAE J429, *Mechanical and Material Requirements for Externally Threaded Fasteners*

[1] Published as a cooperative effort with Process Industry Practices REIE686. PIP REIE686 can be obtained from the Construction Industry Institute - PIP, The University of Texas at Austin, 3208 Red River, Austin, TX 78705.

Appendix E

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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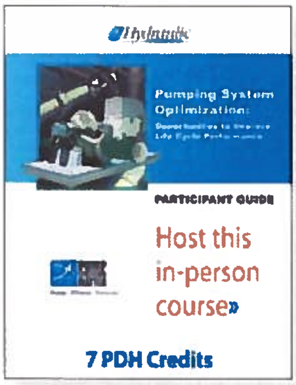

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