



American National Standard for

Rotodynamic Pumps

for Pump Piping



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American National Standard

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Contents

	Page
Foreword	vii
Flowchart for use of standard (mechanical considerations)	x
Flowchart for use of standard (hydraulic considerations)	xi
9.6.6 Rotodynamic pumps for pump piping	1
9.6.6.1 Introduction	1
9.6.6.1.1 Purpose	1
9.6.6.1.2 Scope	1
9.6.6.1.2.1 Piping	1
9.6.6.1.2.2 Viscosity considerations	1
9.6.6.2 Pump Piping Design General	2
9.6.6.3 Inlet (suction) piping requirements	3
9.6.6.3.2 Inlet (suction) pipe size/velocity requirements	4
9.6.6.3.3 Effect of piping-generated swirl	5
9.6.6.3.4 Required straight pipe lengths	5
9.6.6.3.5 Need for physical hydraulic model study	12
9.6.6.3.6 Use of computational fluid dynamics (CFD)	13
9.6.6.3.6.1 Acceptable uses of CFD modeling in pump suction hydraulics	14
9.6.6.3.6.2 Unacceptable uses of CFD modeling in pump suction hydraulics	14
9.6.6.3.7 Pump suction piping/wet-well connection	14
9.6.6.3.8 Pump suction elbows	15
9.6.6.3.9 Pump station retrofit or modification	16
9.6.6.4 Outlet (discharge) piping requirements	16
9.6.6.4.1 Pipe size/velocity requirements	16
9.6.6.4.2 Outlet (discharge) straight pipe lengths	17
9.6.6.4.3 Recommended valves	17
9.6.6.4.3.1 Shut-off/Isolation valves	17
9.6.6.4.3.2 Check valves	17
9.6.6.4.3.3 Pump control valves	18
9.6.6.4.3.4 Triple-duty valves	18
9.6.6.4.3.5 Air release valves	19
9.6.6.4.4 Water hammer	19

9.6.6.5	Inlet (suction) and outlet (discharge) general piping requirements	20
9.6.6.5.1	Pipe nozzle alignment/pipe expansion load	20
9.6.6.5.1.1	Pump nozzle analysis	20
9.6.6.5.2	Pipe supports/anchors	21
9.6.6.5.2.2	Design considerations	22
9.6.6.5.2.3	Cold spring	22
9.6.6.5.2.4	Final installation	22
9.6.6.5.2.5	Field adjustment	23
9.6.6.5.3	Parallel operation	23
Appendices	Introuction	26
Appendix A	System curves	27
A.1	Calculation of the system curve	27
A.2	Pipe head loss calculation methods	28
Appendix B	Water hammer	30
B.1	Water hammer	30
Appendix C	Selecting and locating pipe supports and restraints	34
C.1	Restraint and stops	34
C.2	Pipe supports for vertical loads	34
C.3	Guides and restraints	35
C.4	True anchors	36
C.5	Spring supports	36
C.6	Friction from supports	37
Appendix D	Expansion joints	38
D.1	Expansion joint types	38
D.2	Expansion joint application	40
Appendix E	Specialty piping components and applications	42
E.1	Check valves and strainers	42
E.2	Devices to improve flow to the pump	44
E.3	Piping for suction lift applications	49
E.4	Solids/slurry	49
E.5	Air valves	50
Appendix F	Pressure pulsation and acoustic resonance	52
F.1	General	52
F.2	Piping acoustics	52
Appendix G	Modifications or improvements to non-conforming existing systems	54
G.1	Introduction	54
G.2	In-Kind Replacement	54

G.3	Assessment of Non-Compliant Piping	55
G.4	Mitigation of Non-Compliant Piping	55
Appendix H	References	56
Appendix I	Sources of additional information	58
Appendix J	List of acronyms	59

Figures

9.6.6.3	Suction pipe design for systems with suction lift	4
9.6.6.3.4a	General example of requirement 9.6.6.3.4.5 with eccentric reducer downstream of the suction pipe from above	6
9.6.6.3.4b	General example – pump suction with a required L_2 length for a flow-disturbing fitting	8
9.6.6.3.4c	General example – pump suction with an allowed fitting connected directly and a required L_2 length for a flow-disturbing fitting	8
9.6.6.3.4d	Specific example – pump suction with a required L_2 length for a short-radius reducing elbow (< 30% area reduction)	8
9.6.6.3.4e	Specific example – pump suction with a concentric reducer (1 pipe size reduction), and a required L_2 length for a short-radius elbow	9
9.6.6.3.4f	Specific example – pump suction with a required L_2 length for a suction header (tee or branch flow)	9
9.6.6.3.4g	Specific example – pump suction with an eccentric reducer (2 pipe size reduction), a required L_2 length for a concentric reducer (4 pipe size reduction), and a short-radius elbow	9
9.6.6.3.4h	Specific example – pump suction with a required L_2 length for a concentric reducer (4 pipe size reduction) and a long-radius elbow	10
9.6.6.3.4i	Specific example – pump suction with a manufacturer-approved 90° elbow, an eccentric reducer (1 pipe size reduction), and a required L_2 length for long-radius elbow	10
9.6.6.3.4j	Specific example – pump suction with a manufacturer-approved 90° elbow and a required L_2 length for an eccentric reducer (4 pipe size reduction)	10
9.6.6.3.4k	Specific example (top view) – between bearing split case (double suction) pump with an eccentric reducer (1 pipe size reduction), a required L_2 length for a concentric reducer (4 pipe size reduction), and a short-radius elbow (*added one diameter for double suction with elbow in plane with pump shaft)	11
9.6.6.3.4l	Undesirable effect of an elbow mounted directly on suction nozzle of double suction pump with flow direction into the elbow inlet parallel to the shaft (applies to all double suction applications with either horizontal or vertical shaft orientation on either side or bottom suction)	11
9.6.6.3.4m	Examples of suction pipe fittings near the pump that require approval of the pump manufacturer	12
9.6.6.4.3	Triple-duty valve	19
9.6.6.5.3a	Minimum required suction pipe length and spacing for parallel pumps	24
9.6.6.5.3b	Parallel pump installation L_2	24
9.6.6.5.3c	Constant-velocity manifold design, parallel pumps	25
9.6.6.5.3d	Alternatives for suction header to suction lateral transition	25
C.1	Pipe supports for vertical loads	35
C.2	Solid pipe hanger supports	35

C.3 — Constant-effort spring supports	35
C.4 — Pipe guides	36
C.5 — Spring supports	37
D.1 — Slip/packing expansion joint	38
D.2 — Rubber expansion joints	39
D.3 — Metal bellows expansion joint	39
D.4 — Expansion joint bolting arrangement.	40
E.1 — Foot valve and screen.	43
E.2 — Foot valve (rubber flapper check valve without screen)	43
E.3 — Foot valve installation	43
E.4 — Typical temporary strainer.	44
E.5 — Second upstream perpendicular elbow.	44
E.6 — Straightening vanes	45
E.7 — Straightening vanes downstream from bend.	46
E.8 — Straightening vanes for solids-bearing liquids.	47
E.9 — Turning vanes	48
E.10 — Grating or flow grid	48
E.11 — Self-priming piping arrangement.	49
Tables	
9.6.6.3.4 — Minimum required straight pipe length (L_2) before pump suction nozzle	7
B.1 — Magnitude of pressure	32

Foreword [Not part of American National Standard (ANSI)]

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The purpose and aims of the Hydraulic Institute are to drive all Pump System stakeholders towards a sustainable future by:

- a) Advancing Solutions for Pump System Performance and Efficiency
- b) Developing Standards and Technical Resources
- c) Educating the Global Marketplace
- d) Advocating for the Industry

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Units of measurement

Metric units of measurement are used, and corresponding US customary units appear in parentheses. Charts, graphs, and sample calculations are also shown in both metric and US customary units. Because values given in metric units are not exact equivalents to values given in US customary units, it is important that the selected units of measure to be applied be stated in reference to this standard. If no such statement is provided, metric units shall govern.

Consensus

Consensus for this American National Standard was achieved by use of the canvass method. The following organizations, recognized as having an interest in the standardization of 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.

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Hydraulic, Measurement, and Inspection Consulting, LLC	Peerless Pump Company
Budris Consulting	Formerly Sulzer
4B Engineering & Consulting, LLC	Summit Pump Inc
CDM Smith	Pentair
DynaTech Engineering, Inc.	Weir Minerals NA
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Kennedy Jenks	Westinghouse Electric Co.
Brown and Caldwell	LAS VEGAS VALLEY WATER DIS
Carollo Engineers	Irving Oil
Trillium Pumps USA, Inc.	Syncrude Canada

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:

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- Vice-chair** – Steven Fehniger, CDM Smith, Water Services Group
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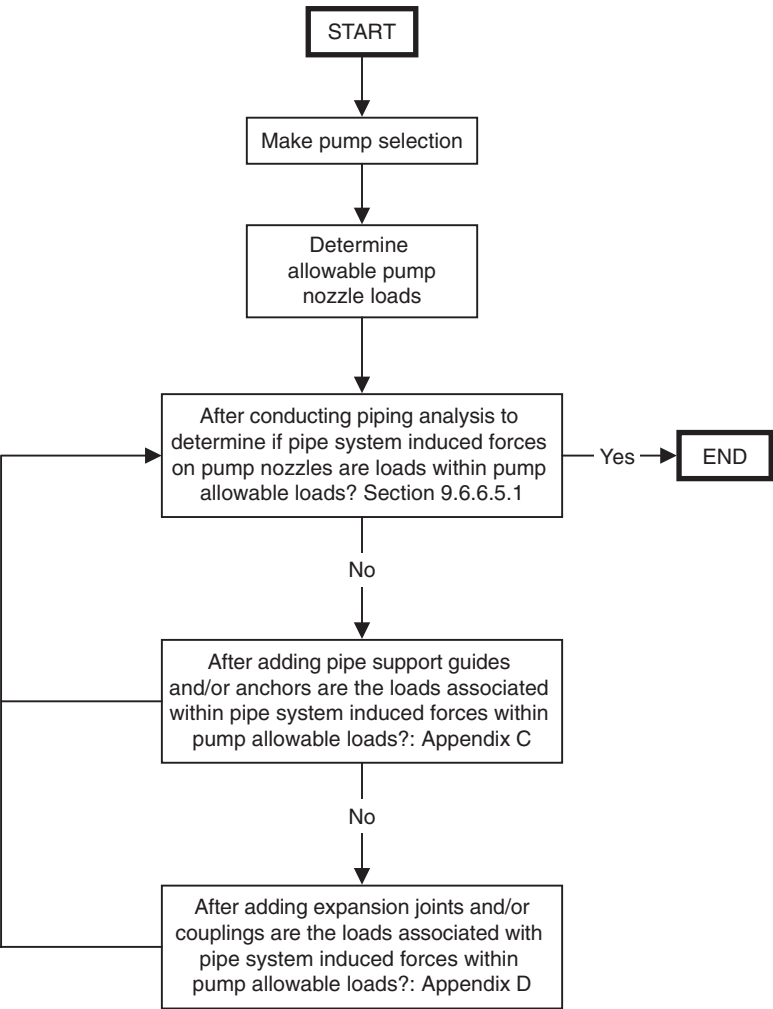
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CIRCOR Pumping Technologies
Stantec
AECOM
Flowserve Corporation
Applied Flow Technology
INGETEA INDAR MACHINES
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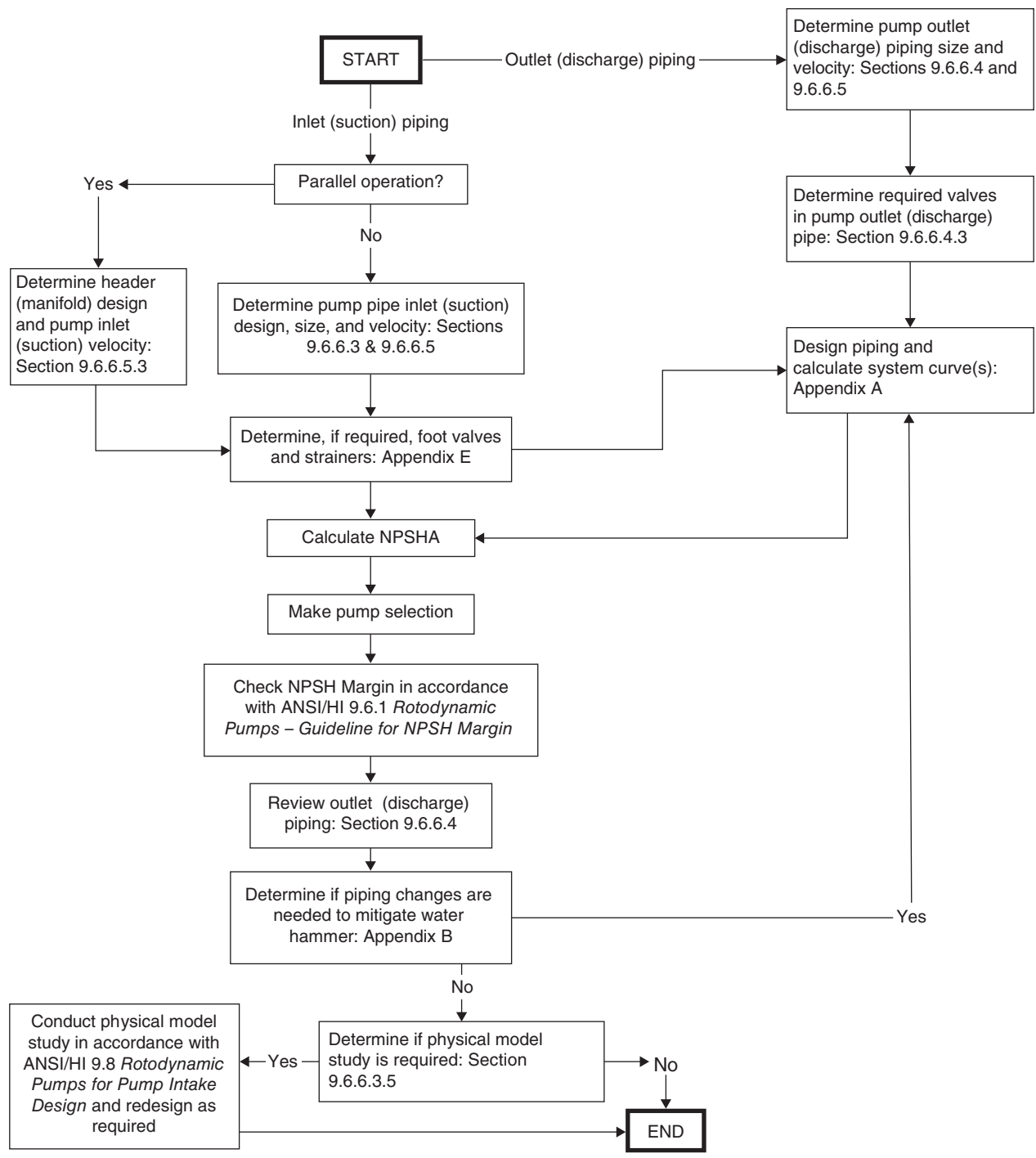
Flowchart for use of standard (mechanical considerations)

NOTE: This flowchart is intended as a guide to the use of this standard and can be used to locate the appropriate sections in this standard. The chart is not a substitute for comprehension of the complete standard.



Flowchart for use of standard (hydraulic considerations)

NOTE: This flowchart is intended as a guide to the use of this standard and can be used to locate the appropriate sections in this standard. The chart is not a substitute for comprehension of the complete standard.



9.6.6 Rotodynamic pumps for pump piping

9.6.6.1 Introduction

This most recent revision of the standard has been divided into numbered requirements followed by guidance (indicated by the word “Notes”) for the user. Any lettered list within a numbered requirement are also requirements. For guidance on the use of this standard for mechanical and hydraulic piping design, refer to the flow charts preceding this introduction.

9.6.6.1.1 Purpose

The objectives of this standard are to provide the requirements for rotodynamic pump piping and to educate users about the effects and interactions of inlet (suction) and outlet (discharge) piping on rotodynamic pump performance and service life.

9.6.6.1.2 Scope

This standard applies to inlet (suction) and outlet (discharge) piping for rotodynamic pumps of radial, mixed and axial flow types, in all worldwide markets. It identifies and details the required and recommended practices for pump piping that will serve to reduce the risk of the pump failure to perform due to system interaction.

9.6.6.1.2.1 Piping

This document is intended to complement ANSI/HI 9.8 *Rotodynamic Pumps for Pump Intake Design*. To eliminate the possibility of overlap and conflict with other standards, this document is applicable as follows:

- All piping upstream from the pump, regardless of pump suction orientation (e.g. side-suction, bottom-suction, etc.) and installation configuration (e.g. horizontal and vertical).
- All piping downstream from the pump, regardless of pump suction orientation (e.g. side-suction, bottom-suction, etc.) and installation configuration (e.g. horizontal or vertical).

The standard excludes the following:

- 1) Any piping integral to the pump unit, such as auxiliary or lubricant piping.
- 2) Requirements for suction piping when the pipe enters a tank, vessel, or other pump intake structure as described in ANSI/HI 9.8 where specific suction piping requirements are provided.

The standard covers the following topics as they relate to rotodynamic pump suction and discharge piping:

- Effects of piping on liquid suction conditions (such as the effect on net positive suction head available [NPSHA], which influences cavitation).
- Effects on pressure development of the pump, hydraulic and piping loads on the pump, piping system considerations (water hammer, parallel pump operation, valving, and pipe supports), pump noise, and pump vibration.

9.6.6.1.2.2 Viscosity considerations

The fundamental recommendations and requirements of this standard do not change with increases in liquid viscosities for Reynolds numbers above 1×10^5 .

Effects of changes in liquid viscosity on pump performance are described in ANSI/HI 9.6.7 *Rotodynamic Pumps – Guideline for Effects of Liquid Viscosity on Performance*.

Head and rate of flow will normally decrease as viscosity increases. Power will increase, as will net positive suction head required (NPSH3) in most circumstances. Starting torque may also be affected. Likewise, liquid flow within a piping system will also be similarly affected by changes in liquid viscosity.

Friction in the pipe and fittings will be increased with higher viscosity. It is appropriate that these effects be taken into consideration when determining the design of a piping system. For Reynolds numbers below 1×10^5 physical modeling and CFD analysis studies may be considered as a means by which to simulate these effects. See sections 9.6.6.3.5 and 9.6.6.3.6.

9.6.6.2 Pump Piping Design General

In order to mitigate the risk of pump or system malfunction or failure, the piping system requirements shall be identified and met. These requirements can be identified as the manifestation of the known best practices. This standard presents known and accepted best practices based on information available to the Hydraulic Institute at the date of publication.

9.6.6.2.1 In the application of this standard, the flow rate at pump rated condition point shall be used as the design flow rate for the basis of the piping design. Refer to Notes 1 and 2.

Notes:

1. Other considerations in the pump system design and contemplated modes of operation may require the pumps to frequently function under higher rates of flow. In such instances, the maximum flow rate should be considered for the purpose of piping design unless specified otherwise.
2. Refer to ANSI/HI 9.8 appendix titled “Influence of pump selection on intake design” for discussion on this topic.
3. Velocity to be interpreted as the average velocity of the pipe calculated using the internal cross sectional area unless otherwise indicated. Velocity of liquid inside the pipe should be determined using the pipe internal diameter rather than nominal pipe diameter.
4. Reference pipe diameters relate to nominal pipe size (NPS), not the pipe inside diameter.
5. In the case of existing pump installations, it is recognized that site conditions and constraints will often prevent full compliance with the requirements of this standard. Refer to Appendix G for guidance in these circumstances.
6. The function of pump piping is to provide a conduit for the flow of liquid to and from a pump, while not adversely affecting the pump performance or reliability. Well-designed piping systems will normally be more energy efficient than a poorly designed system.
7. The function of suction piping is to provide a uniform velocity profile or symmetric approach flow to the pump suction nozzle with sufficient pressure to avoid damaging cavitation in the pump. An uneven distribution of flow is characterized by strong local currents and swirls. The ideal approach is a straight pipe, connected directly to the pump, with no turns or flow-disturbing fittings close to the pump. Failure of the suction piping to deliver the liquid to the pump in this condition can result in noisy operation, random axial load oscillations, premature bearing or seal failure, cavitation damage to the impeller and suction portions of the casing, early onset of suction recirculation, and occasionally damage due to liquid separation on the discharge side. For additional intake design recommendations see references 1, 2, and 3 in Appendix H.
8. Discharge piping flow characteristics normally will not affect the performance or reliability of a rotodynamic pump, with a few exceptions.
 - a. Sudden stopping and starting of pumps during emergency power failure, sudden valve closures can cause water hammer and generate damaging high pressures to the pump and/or piping system components. To evaluate the water hammer effect, a transient flow analysis may be required (see Section 9.6.6.4.4 and Appendix B).

- b. Discharge piping can affect the starting, stopping, and priming of the pump.
 - c. The discharge piping configuration can also influence any discharge flow recirculation that might extend into the discharge piping at very low flow rates.
9. It is a good practice to provide a pipe coupling or dismantling joint at the pump nozzles to facilitate maintenance or removal of the pump.
10. Common detrimental effects caused by poor pump piping and pipe support design include:
- a. Excessive piping loads on a pump because of pipe misalignment with the pump connections.
 - b. Failure to properly restrain the pump to the foundation support. For example, when pump anchor fasteners are loosened, modified, or removed to aid in alignment with piping, robust pump anchorage may be compromised and impact pump operation.
 - c. Excessive loads on piping resulting from unsupported or poorly supported valves, fittings, or vertical inline pumps. Excessive pump nozzle loads are caused by thermal expansion of the pipe, unsupported piping and equipment weight, axially unrestricted couplings, and misaligned piping. Excessive pump nozzle loads lead to misalignment of the pump shaft with the driver shaft, mechanical seal failures, bearing failures, binding or rubbing of the pump rotor, and in extreme cases, failure of pump nozzles or mounting feet.

9.6.6.3 Inlet (suction) piping requirements

Suction flow disturbances such as swirl, non-uniformity in the distribution of velocities and pressures, and sudden variations in velocity can be harmful to the hydraulic performance of a pump, its mechanical behavior, and its reliability. Usually the higher the power, rotative speed, and specific speed of a pump, and the lower the NPSH margin, the more sensitive the pump's performance is to suction hydraulic conditions. This section provides requirements and guidance to minimize suction flow disturbances at the pump suction nozzle.

9.6.6.3.1 All suction fitting joints shall be tight, especially when the pressure in the piping is below atmospheric, to preclude air leaking into the liquid.

Notes:

1. Any valve in the suction pipe should be installed with stems oriented to minimize the possibility of air (gas) accumulation unless this stem orientation creates an approach flow disturbance.
2. For most pumping systems, an suction shut-off valve should be installed in the suction piping for system or pump isolation. The shut-off valve should be selected with consideration of impact on NPSH margin.
3. For pumps operating with a suction lift, suction pipe should slope constantly upwards toward the pump, with a minimum slope of 1% (Figure 9.6.6.3). In general, as liquid travels through a piping network, entrained air tends to rise to the highest point. If the pipe slopes upward toward the pump, then the velocity of the liquid will move the air bubbles towards this high point at the pump. In contrast, if the pipe is fairly flat and the inside surface of the pipe is very rough, or the pipe slopes downward toward the pump, then the fluid velocity may not be sufficient to keep the air bubbles moving. As a consequence, it is possible for a pocket of air to collect at localized high points and gradually reduce the effective liquid flow area. This reduction in area can create a throttling effect similar to a partially closed valve.

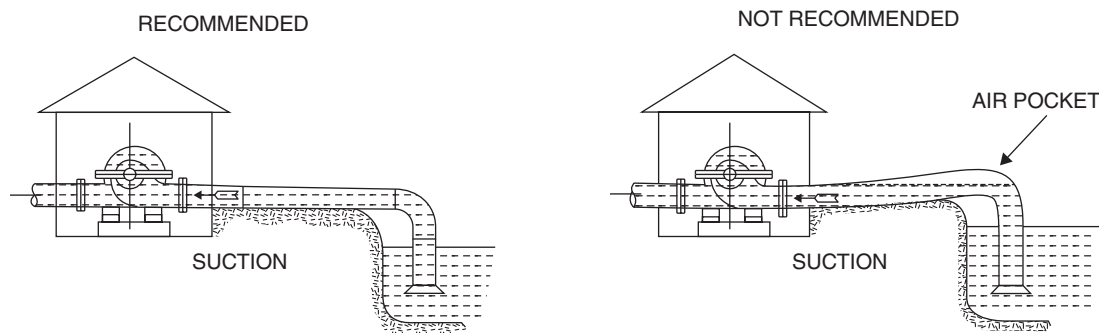


Figure 9.6.6.3 — Suction pipe design for systems with suction lift

It is also possible that a slug of air may be swept into the pump during a restart or normal operation, causing a partial or complete loss of pump prime, especially in applications where the suction pipe is kept full by a foot valve at its intake (see Appendix E).

4. Any amount of entrained air in the liquid may adversely affect pump performance. Check with the pump manufacturer to determine allowable levels of entrained air, and review ANSI/HI 14.3 *Rotodynamic Pumps for Design and Application* for more information on the topic.

9.6.6.3.2 Inlet (suction) pipe size/velocity requirements

This subsection provides guidance on velocity variation throughout the suction piping as well as guidance regarding maximum recommended suction velocity. The resultant suction piping size(s) can be determined based on this guidance and recommendations at the design flow rate. For closed conduit flow applications in fully turbulent flow regime, the magnitude of the velocity does not measurably influence the flow distribution characteristics.

- 9.6.6.3.2.1** The velocity in the suction piping shall be constant or increasing as the flow approaches the pump.
- 9.6.6.3.2.2** Transitions resulting in flow deceleration at the pump shall not be used.
- 9.6.6.3.2.3** The suction pipe shall be at least as large as the pump suction nozzle. Refer to Note 1.
- 9.6.6.3.2.4** For liquids close to the vapor pressure, the velocity shall be kept low enough to avoid flashing of the liquid in the piping, especially when fittings are present. Refer to Note 2.

Notes:

1. The velocity at any point along the suction piping is recommended to be a maximum of 2.4 meters per second (m/s) (8 feet per second [ft/s]), unless the liquid is a slurry. However, this velocity recommendation does not apply to the straight run of pipe immediately upstream of the pump suction nozzle provided this pipe is the same diameter as the pump suction nozzle and directly connected to the pump.
 - a. See section 9.6.6.2 (Pump Piping Design General) for design flow rate guidance.
 - b. In all cases, especially for those with velocities in excess of 2.4 m/s (8 ft/s), suction velocities should be evaluated with respect to noise, erosion, NPSH margin, water hammer, cavitation, pump and valve manufacturer's recommendations and pump system life cycle cost.
 - c. If the liquid is a slurry, velocity may need to be higher to maintain solids in suspension (refer to Appendix E.4). Minimum velocity in range of 2 to 4 m/s (6.5 to 13 ft/s) typically recommended due to the high specific gravity of solids for most slurries.
 - d. For many common solids-bearing liquids (such as raw wastewater with primarily organic solids or primary sludge), a minimum velocity of 1.0 m/s (3 ft/s) is recommended to reduce sedimentation in horizontal piping.
 - e. A velocity as low as 0.6 m/s (2 ft/s) is generally sufficient for organic solids (such as mixed liquor in an activated sludge biological wastewater treatment process).

2. A reduction in pressure and/or flashing can liberate dissolved air and vapor, which can be carried into the suction of the pump resulting in loss of performance and also potentially loss of prime.
3. In some cases, smaller pipe sizes may be beneficial by allowing for more straight pipe length upstream of the pump suction nozzle. Refer to requirement 9.6.6.3.2.3
4. The suction piping should be designed with gradual transitions if changing pipe sizes.
5. The suction piping should be designed to minimize changes in flow direction.
6. Valves and other flow-disturbing fittings located in pump suction piping should be at least one pipe size larger than the pump suction nozzle, with the exception of continuous-bore, 100% open valves (such as full-ported ball valves and gate valves).

9.6.6.3.3 Effect of piping-generated swirl

The most disturbing flow patterns entering a pump are those that result from swirling liquid that has traversed several changes of direction in various planes. When fittings, such as tees and elbows (especially two elbows at right angles), are located too close to the pump suction, a spinning action, or swirl, is induced. This swirl may adversely affect pump performance by reducing efficiency, head, NPSHA, and potentially causing noise, vibration, and damage.

9.6.6.3.3.1 Liquid in the suction pipe shall approach the pump in a state of straight, steady (uniform) flow.

9.6.6.3.3.2 A straight and uninterrupted section of pipe be installed between the pump and the nearest flow-disturbing fitting. Refer to Notes 1-2.

Notes:

1. See Figures 9.6.6.3.4a - k, which demonstrate the minimum required lengths specified in Table 9.6.6.3.4.
2. If the minimum recommended pipe lengths cannot be provided, then conformance with the Standard may be demonstrated with a physical model study. Modifications identified in the model study to address adverse hydraulic conditions could include the use of flow-straightening devices (see Appendix E.2).

9.6.6.3.4 Required straight pipe lengths

The minimum required suction pipe lengths stated in Table 9.6.6.3.4, the related requirements, and guidance are provided to maximize the potential for uniform approach flow at the suction nozzle. Following the requirements and guidance, will minimize the impact on pump hydraulic performance and improve the service life.

9.6.6.3.4.1 In general, pumps shall have an uninterrupted and unthrottled flow into the suction nozzle (no flow-disturbing fittings for the required minimum length identified with Table 9.6.6.3.4).

9.6.6.3.4.2 The use of flow-disturbing fittings on the suction of the pump shall be carefully evaluated.

9.6.6.3.4.3 Flow-disturbing fittings not specifically allowed by Table 9.6.6.3.4 shall not be connected directly to the pump suction nozzle without approval from the pump manufacturer.

9.6.6.3.4.4 Isolation valves and other devices used on the suction side of the pump shall be sized and located to minimize disturbance of the flow into the pump (Table 9.6.6.3.4).

9.6.6.3.4.5 In horizontal suction piping, the flat side of the eccentric reducer shall be located on the top. In horizontal suction piping where flow approaches from above, either a concentric reducer or an eccentric reducer with flat side on the bottom shall be used (Refer to Note 4 and figure 9.6.6.3.4a).

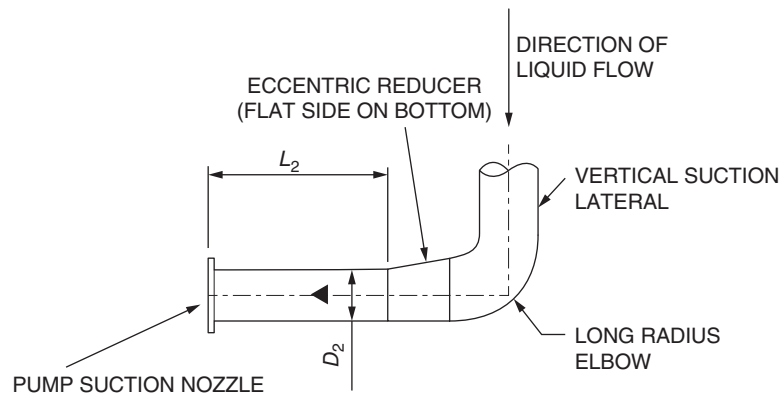


Figure 9.6.6.3.4a - General example of requirement 9.6.6.3.4.5 with eccentric reducer downstream of the vertical suction pipe from above

9.6.6.3.4.6 Table 9.6.6.3.4 shall be utilized to determine the minimum length of straight pipe (L_2) required immediately upstream of the pump suction nozzle for a variety of commonly used fittings and valve types. Refer to Notes 5 – 7.

- A. Reference example Figures 9.6.6.3.4a - k.
- B. The velocity recommendations of Section 9.6.6.3.2 do not apply to this section of pipe (i.e., the L_2/D_2 section).
- C. If several fittings are adjacent, the fitting with the greatest length requirement shall govern and that length requirement shall be applied to the most downstream fitting (reference Figures 9.6.6.3.4g, h, and j).

Notes:

1. Flow disturbances on the suction side of the pump can lead to deterioration in performance (lower head and/or lower NPSHA), and damage leading to reduced impeller, mechanical seal, and bearing life due to cavitation, pulsation surges, and excessive radial and axial forces.
2. The effect of flow disturbances from fittings installed in the suction piping will diminish with increasing distance. For example, short suction piping is less effective in moderating disturbances before the flow reaches the pump.
3. For VS6 and VS7 pump types, the straight run requirements summarized herein do not apply to suction can piping which is covered in ANSI/HI 9.8.
4. A concentric reducer is typically applied in vertical suction pipes or horizontal pipe installations where there is no potential for air or vapor accumulation. Eccentric reducers are normally used for horizontal installations where there is potential for air or vapor accumulation. Eccentric reducers typically positioned with flat side up to avoid trapping air or vapor. However, in vertical suction lateral which approaches from above eccentric reducer flat side is positioned down as shown in Figure 9.6.6.3.4a to facilitate continuous removal of air or vapor through the vertical lateral.
5. Failure to provide the minimum pipe lengths specified in Table 9.6.6.3.4 can lead to the hydraulic and mechanical issues described above.
6. Double suction pumps are a sensitive application because an elbow in the plane of the pump shaft mounted on the suction nozzle will direct more flow to one side of the impeller than the other (see Figure 9.6.6.3.4l).
7. Figure 9.6.6.3.4m shows examples of flow-disturbing fittings attached directly to the pump that require approval by the pump manufacturer.

Table 9.6.6.3.4 — Minimum required straight pipe length (L_2) before pump suction nozzle
(refer to Figures 9.6.6.3.4a – k)

Fitting	Number of pipe diameters ^{a,b}		Comments
	Long radius	Short radius	
90° elbow	4	5	For double suction pumps, add one pipe diameter if the elbow and pump shaft are in the same plane. Area reduction (%) = $(A_{in} - A_{out})/A_{in}$
Reducing elbow with < 30% area reduction	3	4	
Reducing elbow with 30% to ≤ 50% area reduction	2	3	
Reducing elbow with > 50% area reduction	0	1	
Reducers	Concentric	Eccentric	
1 pipe size reduction	0 (<10°) ^c	0 (<20°) ^c	
2 pipe size reductions	0 (<20°)	0 (<30°)	
3 pipe size reductions	0 (<20°)	1 (<30°)	
4 pipe size reductions	2 (<20°)	3 (<40°)	
5 pipe size reductions	3 (<30°)	4 (<40°)	
≤ 45° lateral	4		
Tee, branch flow, > 45°	5		
Continuous-bore valve (100% open)	0		(Continuous-bore ball and gate valves)
Eccentric plug valve - rectangular 80% port	4		
Eccentric plug valve - rectangular 100% port	3		
Butterfly valve ^d	2		

Notes:

1)

If an allowed fitting is connected directly to the pump, the next fitting upstream shall have a length L_2 between it and the pump at least equal to the number of straight pipe diameters referenced in this table. The length of the allowed fitting is not to be included as a part of this distance. If several fittings are adjacent, longest L_2 governs. See Figure 9.6.6.3.4g. Allowed fittings include a concentric reducer of 1 - 3 pipe size reduction, an eccentric reducer of 1 - 2 pipe size reduction, a continuous bore valve or a fitting approved by the pump manufacturer.

2)

Butterfly valves installed on the suction side of pumps with double suction impellers shall be oriented such that the valve operating shaft is in a parallel plane to the pump shaft.

3)

Globe valves and diaphragm valves shall not be used on the suction side of the pumps.

4)

For vertical in-line pumps, elbows may be installed on the suction side with an orientation parallel to the pump shaft a distance L_2 a minimum of two pipe diameters for long radius elbows and three pipe diameters for short radius elbows.

5)

Length of straight pipe between fitting and pump may be reduced from that presented in the above table with approval of the pump manufacturer.

6)

Alternative values may be used if substantiated by a physical model study. See Section 9.6.6.3.5

7)

The data in this table are based on commercially available fittings.

8)

Flow-straightening devices do not serve as a substitute for the L_2 requirements in this table unless validated by a physical model study. Refer to Appendix E.2 for information on flow straightening devices, and section 9.6.6.3.5 for information on physical model studies.

9)

Refer to the information provided in subsection 9.6.6.3.4 for further guidance

^a For fittings that require less than two pipe diameters of straight pipe length, space shall be sufficient for ease of pump installation and removal.

^b The pump manufacturer is responsible for guaranteeing pump performance when providing designs for fittings (or furnishing fittings) that are directly connected to the pump, whether or not they conform to the requirements of this table. When contractually agreed to by both the purchaser and pump manufacturer, the pump manufacturer shall guarantee pump performance including the furnished fitting(s) at the guarantee point(s) as tested in accordance with ANSI/HI 14.6 *Rotodynamic Pumps for Hydraulic Performance Test*. If the directly connected fittings are supplied by others and do not conform to the table requirements, the pump manufacturer shall be consulted for acceptability of the fitting type and location.

^c The angles given are the maximum per side for standard commercial fittings. Nonstandard fittings having a greater angle per side shall use the number of pipe diameters corresponding to that angle, regardless of the number of pipe size reductions.

^d Care must be taken when placing a butterfly valve downstream from a fitting such as an elbow or tee. The valve operating shaft and disk shall be oriented in the same plane as an elbow or tee. In cases where this is in conflict with table 9.6.6.3.4 Note 2, then Note 2 governs and additional distance (1-3 pipe diameters) between the tee or elbow and valve should be considered to avoid more adverse hydraulic conditions and loading on the valve.

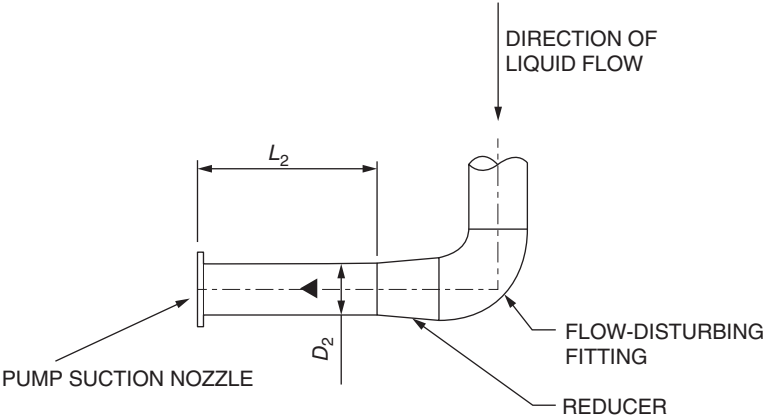


Figure 9.6.6.3.4b — General example – pump suction with a required L_2 length for a flow-disturbing fitting

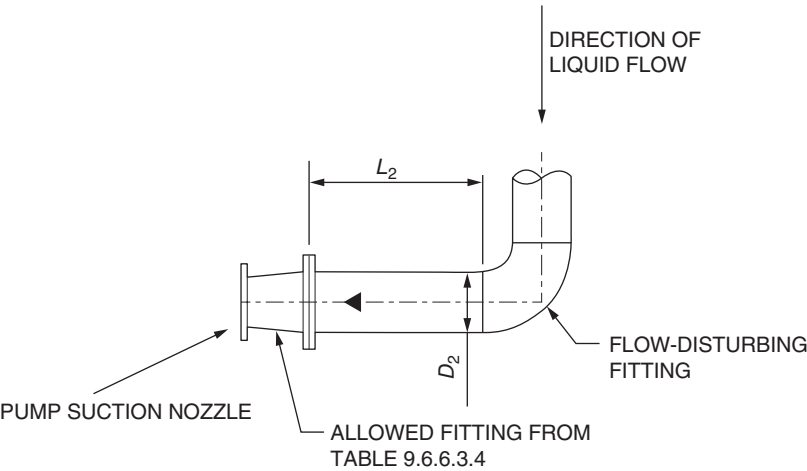


Figure 9.6.6.3.4c — General example – pump suction with an allowed fitting connected directly and a required L_2 length for a flow-disturbing fitting

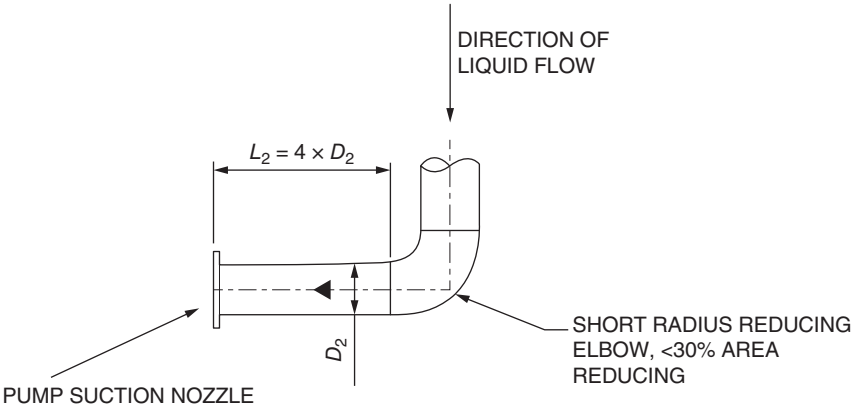


Figure 9.6.6.3.4d — Specific example – pump suction with a required L_2 length for a short-radius reducing elbow (< 30% area reduction)

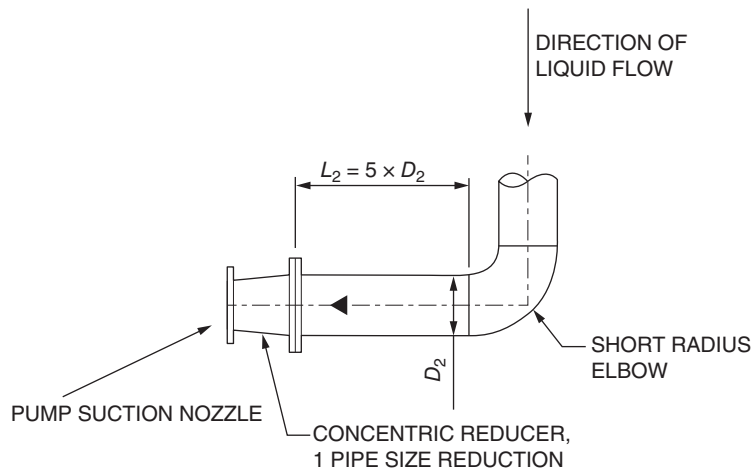


Figure 9.6.6.3.4e — Specific example – pump suction with a concentric reducer (1 pipe size reduction), and a required L_2 length for a short-radius elbow

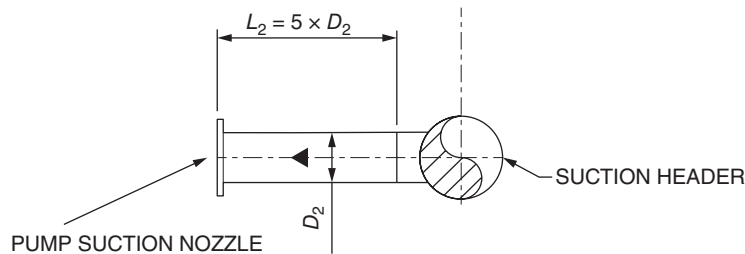


Figure 9.6.6.3.4f — Specific example – pump suction with a required L_2 length for a suction header (tee or branch flow)

NOTE THAT THE L_2 LENGTH OF $5 \times$ PIPE DIAMETER IS DRIVEN BY THE LONGEST GOVERNING LENGTH OF THE 90 DEGREE SHORT-RADIUS ELBOW (THE CONCENTRIC REDUCER ONLY REQUIRES AN L_2 OF $2 \times$ PIPE DIAMETER)

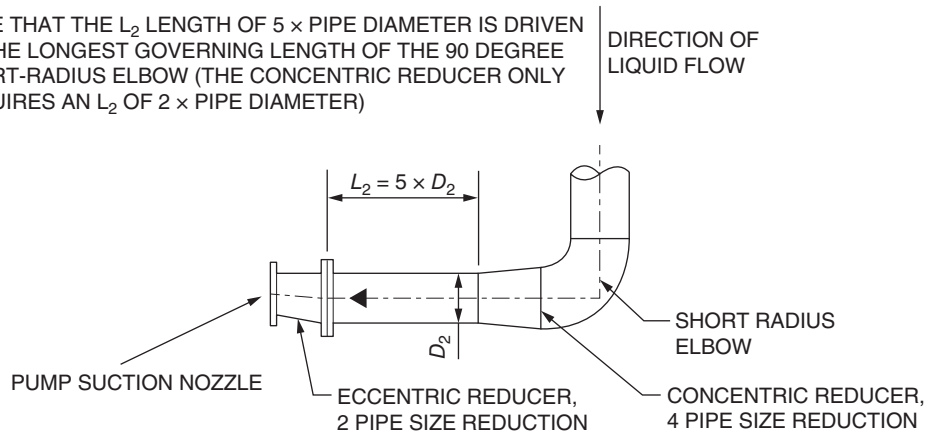


Figure 9.6.6.3.4g — Specific example – pump suction with an eccentric reducer (2 pipe size reduction), a required L_2 length for a concentric reducer (4 pipe size reduction), and a short-radius elbow