

Centrifugal Pumps for Petroleum, Petrochemical, and Natural Gas Industries

API STANDARD 610
TWELFTH EDITION, JANUARY 2021



This is a preview. [Click here to purchase the full publication.](#)

Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed. The use of API publications is voluntary. In some cases, third parties or authorities having jurisdiction may choose to incorporate API standards by reference and may mandate compliance.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

All rights reserved. No part of this work may be reproduced, translated, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the Publisher, API Publishing Services, 200 Massachusetts Avenue NW, Suite 1100, Washington, DC 20001.

Copyright © 2020 American Petroleum Institute

[This is a preview. Click here to purchase the full publication.](#)

Foreword

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

The verbal forms used to express the provisions in this document are as follows.

Shall: As used in a standard, “shall” denotes a minimum requirement in order to conform to the standard.

Should: As used in a standard, “should” denotes a recommendation or that which is advised but not required in order to conform to the standard.

May: As used in a standard, “may” denotes a course of action permissible within the limits of a standard.

Can: As used in a standard, “can” denotes a statement of possibility or capability.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 200 Massachusetts Avenue, Suite 1100, Washington, DC 20001. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 200 Massachusetts Avenue, Suite 1100, Washington, DC 20001.

Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, Suite 1100, Washington, DC 20001, standards@api.org.

Contents

	Page
1 Scope	1
2 Normative References	1
3 Terms, Definitions, Acronyms, and Abbreviations	4
3.1 Terms and Definitions	4
3.2 Acronyms and Abbreviations	11
4 General	13
4.1 Unit Responsibility	13
4.2 Classification and Designation	13
5 Requirements	22
5.1 Units	22
5.2 Statutory Requirements	22
5.3 Hierarchy of Requirements	22
6 Basic Design	22
6.1 General	22
6.2 Pump Types	28
6.3 Pressure Casings	28
6.4 Nozzles and Pressure Casing Connections	31
6.5 External Nozzle Forces and Moments	34
6.6 Rotors	41
6.7 Wear Rings and Running Clearances	42
6.8 Mechanical Shaft Seals	44
6.9 Dynamics	48
6.10 Bearings and Bearing Housings	60
6.11 Lubrication	66
6.12 Materials	66
6.13 Nameplates and Rotation Arrows	71
7 Accessories	72
7.1 Drivers	72
7.2 Couplings	75
7.3 Guards	76
7.4 Baseplates	77
7.5 Instrumentation	81
7.6 Piping and Appurtenances	82
7.7 Special Tools	84
8 Inspection, Testing, and Preparation for Shipment	84
8.1 General	84
8.2 Inspection	85
8.3 Testing	87
8.4 Preparation for Shipment	95
9 Specific Pump Types	97
9.1 Single-stage Overhung Pumps	97
9.2 Between-bearings Pumps (Types BB1, BB2, BB3, and BB5)	98
9.3 Vertically Suspended Pumps (Types VS1 Through VS7)	103
10 Vendor's Data	110

Contents

	Page
Annex A (normative) Specific Speed and Suction-specific Sppeed	111
Annex B (normative) Cooling Water Schematics	112
Annex C (normative) Hydraulic Power Recovery Turbines	120
Annex D (informative) Standard Baseplates	124
Annex E (informative) Inspector's Checklist	126
Annex F (normative) Criteria for Piping Design	128
Annex G (informative) Materials Class Selection Guidance	142
Annex H (normative) Materials and Material Specifications for Pump Parts	144
Annex I (normative) Lateral Analysis	153
Annex J (normative) Determination of Residual Unbalance	159
Annex K (informative) Shaft Stiffness and Bearing System Life	165
Annex L (informative) Contract Documents and Engineering Design Data	171
Annex M (informative) Test Data Summary	185
Annex N (informative) Pump Data Sheets and Electronic Data Exchange	190
Annex O (informative) Special-purpose Centrifugal Pumps	213
Bibliography	218
Figures	
1 Pump Type OH1	15
2 Pump Type OH2	15
3 Pump Type OH3	15
4 Pump Type OH4	16
5 Pump Type OH5	16
6 Pump Type OH6	17
7 Pump Types BB1-A and BB1-B	17
8 Pump Type BB2	18
9 Pump Type BB3	18
10 Pump Type BB4	18
11 Pump Type BB5	19
12 Pump Type VS1	19
13 Pump Type VS2	19
14 Pump Type VS3	20
15 Pump Type VS4	20
16 Pump Type VS5	20
17 Pump Type VS6	21
18 Pump Type VS7	21
19 Machined Face Suitable for Gasket Containment if Using Cylindrical Threads	33
20 Typical Gusset Design	34
21 Coordinate System for the Forces and Moments in Table 5, Vertical In-line Pumps	37
22 Coordinate System for the Forces and Moments in Table 5, Horizontal Pumps with End Suction and Top Discharge Nozzles	38

Contents

	Page
23	Coordinate System for the Forces and Moments in Table 5, Horizontal Pumps with Top Nozzles. 39
24	Coordinate System for the Forces and Moments in Table 5, Horizontal Pumps with Side Suction and Side Discharge Nozzles 40
25	Coordinate System for the Forces and Moments in Table 5, Vertically Suspended, Double-casing Pumps. 41
26	Chamber Diagrams 45
27	Seal Chamber Concentricity 47
28	Seal Chamber Face Runout 47
29	Torsional Analysis Flow Chart. 49
30	Rotating Component Dimensions to Determine if Single-plane Balancing is Allowable 52
31	Relationship Between Flow and Vibration 54
32	Locations for Taking Vibration Readings on OH and BB Type Pumps. 55
33	Locations for Taking Vibration Readings on Vertically Suspended (VS) Pumps 56
34	Locations for Taking Vibration Readings on Vertical In-line (OH3) and High-speed Integrally Geared (OH6) Pumps. 57
35	Bearing Housing Vibration Limits for Horizontal Pumps Running Above 3600 r/min or Absorbing More Than 400 hp (300 kW) per Stage 60
36	Vertical Pump Drivers—Tolerances Required for the Driver Shaft and Base 74
37	Flat Deck Plate with Sloping Gutter Drain 77
38	Sloped Full Deck Plate 78
39	Sloped Partial Deck Plate 78
40	Location for Seal Flush Plan or Auxiliaries Mounted on the Baseplate 79
41	Maximum Spacing Between Shaft Guide Bushings 105
42	Thrust Bearing Arrangement with Two Couplings 107
43	Optional Mounting for Vertically Suspended, Double-case Pumps (VS6 and VS7) with Sole Plate . 108
B.1	Symbols Used in Figures B.2 to B.7 112
B.2	Piping for Overhung Pumps—Plan A, Cooling to Bearing Housing. 112
B.3	Piping for Overhung Pumps—Plan K, Cooling to Bearing Housing with Parallel Flow to Seal Heat Exchanger 113
B.4	Piping for Overhung Pumps—Plan M, Cooling to Seal Heat Exchanger. 114
B.5	Piping for Overhung Pumps—Plan M, Cooling to Seal Heat Exchanger and Reservoir 115
B.6	Piping for Between-bearing Pumps—Plan A, Cooling to Bearing Housings 116
B.7	Piping for Between-bearing Pumps—Plan K, Cooling to Bearing Housings with Parallel Flow to Seal Heat Exchangers 117
B.8	Piping for Between-bearing Pumps—Plan M, Cooling to Seal Heat Exchangers. 118
B.9	Piping for Between-bearing Pumps—Plan M, Cooling to Seal Heat Exchangers and Reservoirs . 119
C.1	Typical HPRT Arrangements 122
C.2	HPRT Test Performance Tolerances 123
D.1	Standard Baseplate. 125
I.1	Damping Factor vs Frequency Ratio 156
I.2	Typical Campbell Diagram 157
J.1	Residual Unbalance Worksheet. 161
J.2	Residual Unbalance Worksheet—Polar Chart. 162
J.3	Example of Completed Residual Unbalance Worksheet 163
J.4	Example of Completed Residual Unbalance Worksheet—Best-fit Circle for Residual Unbalance . 164
K.1	Simple Overhung Rotor 165
K.2	Overhung Pump Shaft Flexibility Index vs Size Factor (SI Units) 167
K.3	Overhung Pump Shaft Flexibility Index vs Size Factor (USC Units) 168
L.1	Example Distribution Record. 177

Contents

	Page
M.1 Test Data Summary Form	185
M.2 Test Curve Format (USC Units)	187
M.3 Example of Test Curve Format (SI Units)	188
M.4 Test Points Shown on Typical Performance Curve	189
N.1 USC Units Pump Process Data Sheet	191
N.2 SI Units Pump Process Data Sheet	198
N.3 Data List	205
N.4 API Project Design Data Sheet	212

Tables

1 Pump Classification Type Identification	14
2 Water-cooling System—Conditions on the Water Side	26
3 Special Design Features of Particular Pump Types	28
4 Casting Factors	29
5 Nozzle Loadings	35
6 Minimum Internal Running Clearances	44
7 Standard Dimensions for Seal Chambers, Seal Gland Mounting, and Cartridge Mechanical Seal Sleeves	46
8 Vibration Limits for Overhung and Between-bearings Pumps	58
9 Vibration Limits for Vertically Suspended Pumps	59
10 Bearing Selection	61
11 Welding Requirements	70
12 Power Ratings for Motor Drives	73
13 Stiffness Test Acceptance Criteria	81
14 Pressure Casing and Process Piping Material Inspection Requirements	86
15 Materials Inspection Standards	87
16 Performance Tolerances	91
17 Shaft and Rotor Runout Requirements	99
18 Decision Logic for Rotor Lateral Analysis	100
19 Rotor Balance Requirements	101
D.1 Dimensions of Standard Baseplates	124
E.1 Inspector's Checklist	126
F.1 Nozzle Sizes and Location Coordinates for Example 1A	132
F.2 Applied Nozzle Loadings for Example 1A	132
F.3 Proposed Applied Nozzle Loadings for Example 2A	134
F.4 Nozzle Sizes and Location Coordinates for Example 1B	136
F.5 Applied Nozzle Loadings for Example 1B	137
F.6 Proposed Applied Nozzle Loadings for Example 2B	140
G.1 Materials Class Selection Guidance	142
H.1 Material Classes for Pump Parts	145
H.2 Material Specifications for Pump Parts	147
H.3 Nonmetallic Wear Part Materials	151
H.4 Piping Materials	152
I.1 Rotor Lateral Analysis Logic Diagram	153
L.1 Recommended Spare Parts	176

Introduction

It is necessary that users of this standard be aware that further or differing requirements can be needed for individual applications. This standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This can be particularly appropriate where there is innovative or developing technology. Where an alternative is offered, it is necessary that the vendor identify any variations from this standard and provide details.

A bullet (•) at the beginning of a section or subsection indicates that either a decision is required or the purchaser is required to provide further information. It is necessary that this information be indicated on data sheets or stated in the inquiry or purchase order (see examples in Annex N).

This standard shows U.S. customary (USC) units with other units in parentheses for information.

Centrifugal Pumps for Petroleum, Petrochemical, and Natural Gas Industries

1 Scope

This standard specifies requirements for centrifugal pumps, including pumps running in reverse as hydraulic power recovery turbines (HPRTs), for use in petroleum, petrochemical, and gas industry process services.

This standard is applicable to overhung pumps, between-bearings pumps, and vertically suspended pumps (see Table 1). Section 9 provides requirements applicable to specific types of pumps. All other sections of this standard are applicable to all pump types. Illustrations are provided of the various specific pump types and the designations assigned to each specific type.

Relevant industry operating experience suggests pumps produced to this standard are suitable for pumping liquids at conditions exceeding any one of the following:

- discharge pressure (gauge): 275 psi; 19.0 bar (1900 kPa);
- suction pressure (gauge): 75 psi; 5.0 bar (500 kPa);
- pumping temperature: 300 °F (150 °C);
- rotational speed: 3600 r/min;
- rated total head: 400 ft (120 m);
- impeller diameter, overhung pumps 13 in. (330 mm).

NOTE For sealless pumps, reference can be made to API 685.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) at the time of quotation applies.

API Standard 5L, *Line Pipe*

API Standard 541, *Form-wound Squirrel Cage Induction Motors—375 kW (500 Horsepower) and Larger*

API Standard 547, *General Purpose Form-wound Squirrel Cage Induction Motors—185 kW (250 hp) through 2240 kW (3000 hp)*

API Standard 611, *General-purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services*

ANSI ¹/API Standard 614, *Lubrication, Shaft-sealing and Oil-control Systems and Auxiliaries*

API Standard 670, *Machinery Protection Systems*

API Standard 671, *Special-purpose Couplings for Petroleum, Chemical, and Gas Industry Services*

API Standard 677, *General-purpose Gear Units for Petroleum, Chemical and Gas Industry Services*

¹ American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, New York 10036, www.ansi.org.

API Standard 682, *Pumps—Shaft Sealing Systems for Centrifugal and Rotary Pumps*

ANSI B11.19-2010, *Performance Criteria for Safeguarding*

ANSI/ABMA 7 ², *Shaft and Housing Fits for Metric Radial Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plan*

ANSI/AGMA 9000 ³, *Flexible Couplings—Potential Unbalance Classification*

ANSI/AGMA 9002, *Bores and Keyways for Flexible Couplings (Inch Series)*

ANSI/ASME B1.1 ⁴, *Unified Inch Screw Threads (UN, UNR, and UNJ Thread Forms)*

ANSI/AWS D1.1, *Structural Welding Code—Steel*

ANSI/HI 14.6 ⁵, *Rotodynamic Pumps for Hydraulic Performance Acceptance Tests*

ASME B1.13M, *Metric Screw Threads: M Profile*

ASME B16.5, *Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard*

ASME B16.11, *Forged Fittings, Socket-Welding and Threaded*

ASME B16.47, *Larger Diameter Steel Flanges NPS 26 Through NPS 60 Metric/Inch Standard*

ASME B18.18.2M, *Inspection and Quality Assurance for High-Volume Machine Assembly Fasteners*

ASME B31.3, *Process Piping*

ASME Boiler and Pressure Vessel Code (BPVC), Section V, *Nondestructive Examination*

ASME Boiler and Pressure Vessel Code (BPVC), Section VIII, *Rules for Construction of Pressure Vessels*

ASME Boiler and Pressure Vessel Code (BPVC), Section IX, *Welding, Brazing and Fusing Qualifications*

DIN 910 ⁶, *Hexagon head screw plugs with collar—Cylindrical thread*

EN 287 ⁷, *Qualification test of welders—Fusion welding—Steels*

EN 953 , *Safety of machinery—Guards—General requirements for the design and construction of fixed and movable guards*

EN 1092-1, *Flanges and their joints—Circular flanges for pipes, valves, fittings and accessories, PN designated—Steel flanges*

EN 13445 (all parts), *Unfired pressure vessels*

EN 13445-4, *Unfired pressure vessels—Fabrication*

² American Bearing Manufacturers Association, 1001 N. Fairfax Street, Suite 500, Alexandria, VA 22314, www.americanbearings.org.

³ American Gear Manufacturers Association, 1001 N. Fairfax Street, Suite 500, Alexandria, VA 22314-1587, www.agma.org.

⁴ ASM International, 9639 Kinsman Road, Materials Park, Ohio 44073, www.asminternational.org.

⁵ Hydraulic Institute, 6 Campus Drive, First Floor North, Parsippany, New Jersey 07054-4406, www.pumps.org.

⁶ DIN Deutsches Institut für Normung e. V., Saatwinkler Damm 42/43, 13627 Berlin, Germany, www.din.de.

⁷ European Committee for Standardization (CEN-CENELEC), Avenue Marnix 17, B-1000 Brussels, Belgium, www.cen.eu.

EN 13463-1, *Non-electrical equipment for use in potentially explosive atmospheres—Part 1: Basic method and requirements*

IEC 60034-1⁸, *Rotating electrical machines—Part 1: Rating and performance*

IEC 60034-2-1, *Rotating electrical machines—Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)*

IEC 60079 (all parts), *Explosive atmospheres*

IEEE 841⁹, *Petroleum and Chemical Industry—Premium-Efficiency, Severe Duty, Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors—Up to and Including 370 kW (500 hp)*

ISO 228-1¹⁰, *Pipe threads where pressure-tight joints are not made on the threads—Part 1: Dimensions, tolerances and designation*

ISO 261, *ISO general purpose metric screw threads—General plan*

ISO 262, *ISO general purpose metric screw threads—Selected sizes for screws, bolts and nuts*

ISO 281:2007, *Rolling bearings—Dynamic load ratings and rating life*

ISO 286 (all parts), *System of limits and fits*

ISO 3117, *Tangential keys and keyways*

ISO 3183, *Petroleum and natural gas industries—Steel pipe for pipeline transportation systems*

ISO 4200, *Plain end steel tubes, welded and seamless—General tables of dimensions and masses per unit length*

ISO 5753 (all parts), *Rolling bearings—Internal clearance*

ISO 7005-1, *Pipe flanges—Part 1: Steel flanges for industrial and general service piping systems*

ISO 8501 (all parts), *Preparation of steel substrates before application of paints and related products—Visual assessment of surface cleanliness*

ISO 9606 (all parts), *Qualification testing of welders—Fusion welding*

ISO 9906, *Rotodynamic pumps—Hydraulic performance acceptance tests—Grades 1, 2 and 3*

ISO 10441, *Flexible couplings for mechanical power transmission—Special-purpose applications*

ISO 10721-2, *Steel structures—Part 2: Fabrication and erection*

ISO 11342, *Mechanical vibration—Methods and criteria for the mechanical balancing of flexible rotors*

ISO 14120, *Safety of machinery—Guards—General requirements for the design and construction of fixed and movable guards*

⁸ International Electrotechnical Commission, 3 rue de Varembé, 1st Floor, PO Box 131, CH-1211 Geneva 20, Switzerland, www.iec.ch.

⁹ Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, New Jersey 08854, www.ieee.org.

¹⁰ International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.