

# **Pulsation and Vibration Control for Positive Displacement Machinery Systems for Petroleum, Chemical, and Natural Gas Industry Services**

API STANDARD 688  
SECOND EDITION, OCTOBER 2023

ERRATA 1, MARCH 2024



## 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.

## 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 NW, 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 NW, Suite 1100, Washington, DC 20001.

Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue NW, Suite 1100, Washington, DC 20001, [standards@api.org](mailto:standards@api.org).

## **Important Information Concerning Use of Asbestos or Alternative Materials**

Asbestos is specified or referenced for certain components of the equipment described in some API standards. It has been of extreme usefulness in minimizing fire hazards associated with petroleum processing. It has also been a universal sealing material, compatible with most refining fluid services.

Certain serious adverse health effects are associated with asbestos, among them the serious and often fatal diseases of lung cancer, asbestosis, and mesothelioma (a cancer of the chest and abdominal linings). The degree of exposure to asbestos varies with the product and the work practices involved.

Consult the most recent edition of the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, Occupational Safety and Health Standard for Asbestos, Tremolite, Anthophyllite, and Actinolite, 29 *Code of Federal Regulations* Section 1910.1001; the U.S. Environmental Protection Agency, National Emission Standard for Asbestos, 40 *Code of Federal Regulations* Sections 61.140 through 61.156; and the U.S. Environmental Protection Agency (EPA) rule on labeling requirements and phased banning of asbestos products (Sections 763.160-179).

There are currently in use and under development a number of substitute materials to replace asbestos in certain applications. Manufacturers and users are encouraged to develop and use effective substitute materials that can meet the specifications for, and operating requirements of, the equipment to which they would apply.

**SAFETY AND HEALTH INFORMATION WITH RESPECT TO PARTICULAR PRODUCTS OR MATERIALS CAN BE OBTAINED FROM THE EMPLOYER, THE MANUFACTURER OR SUPPLIER OF THAT PRODUCT OR MATERIAL, OR THE MATERIAL SAFETY DATASHEET.**

## Contents

	Page
1 Scope.....	1
2 Normative References .....	1
3 Terms, Definitions, Acronyms, and Abbreviations.....	2
3.1 Terms and Definitions .....	2
3.2 Acronyms, Abbreviations, and Symbols .....	6
4 General .....	7
4.1 Dimensions and Units .....	7
4.2 Responsibility .....	7
5 Requirements.....	7
5.1 Reciprocating Compressors (Ref. API 618).....	7
5.2 Rotary Type PD Compressors (Ref. API 619) .....	19
5.3 PD Pumps—Reciprocating and Controlled Volume (Ref. API 674 and API 675) .....	22
5.4 Pulsation and Vibration Control Techniques for PD Pumps—Rotary.....	31
Annex A (informative) Description of Work Processes for Reciprocating Compressors and Plunger Pumps .....	33
Annex B (normative) Stepless Capacity Control for Reciprocating Compressor Cylinders .....	116
Annex C (informative) Design Approach Flowchart.....	121
Annex D (informative) Design Approach 3 Flowchart.....	122
Annex E (informative) Mechanical Forced Response Analysis .....	123
Annex F (informative) Small-bore Piping Design and Analysis .....	128
Annex G (informative) Pulsation Considerations for Flow Metering Equipment.....	135
Annex H (informative) $V_i$ and Pressure Ratio Considerations for Rotary Screw Compressors .....	140
Annex I (informative) Design Approach Flowchart for PD Pumps .....	142
Annex J (informative) Cavitation Considerations for PD Pump Systems.....	143
Bibliography .....	147
Figures	
1 Piping Vibration Design Trigger Level at Discrete Frequencies.....	16
2 Allowable Pulsation vs Absolute Line Pressure .....	21
3 Suction Complex Wave for Triplex Pump Relative to Vapor Pressure .....	27
4 Pressure Pulsation at Relief Valve for a Non-cavitating Pump.....	28
5 Piping Design Trigger Level at Discrete Frequencies .....	29
A.1 Piston Motion and Velocity for a Slider Crank Mechanism.....	34
A.2 Single-acting Compressor Cylinder with Rod Length/Stroke = $\infty$ and No Valve Losses .....	35
A.3 Symmetrical, Double-acting Compressor Cylinder with Rod Length/Stroke = $\infty$ and No Valve Losses.....	35
A.4 Unsymmetrical, Double-acting Compressor Cylinder with Rod Length/Stroke = 5 and No Valve Losses.....	36
A.5 Traveling Wave in Infinite Length Pipe.....	36
A.6 Mode Shapes of Half-wave Responses .....	37
A.7 Mode Shapes of Quarter-wave Responses.....	37
A.8 Elbow with Dynamic Forces .....	39
A.9 Reducer with Dynamic Forces .....	40
A.10 Tee with Dynamic Forces.....	41
A.11 Elbow with Dynamic Forces .....	42
A.12 Pulsation Suppression Device with Dynamic Forces.....	42

A.13	Shaking Force for Sample Pulsation Damper.....	43
A.14	Shaking Force for Sample Pipe Lateral.....	44
A.15	Head End (HE) Pressure-Volume Card.....	45
A.16	Ideal (Adiabatic) PV Diagrams.....	47
A.17	Valve Losses .....	51
A.18	Losses Due to Pulsation.....	52
A.19	Losses Due to Pressure Drop .....	53
A.20	Effect of Clearance Volume, Condition 1 .....	55
A.21	Effect of Clearance Volume, Condition 2 .....	56
A.22	Effect of Clearance Volume, Condition 3 .....	57
A.23	Effect of Suction Temperature, Condition 4 .....	58
A.24	Effect of Suction Temperature, Condition 5 .....	59
A.25	Effect of Suction Pressure, Condition 6.....	61
A.26	Effect of Suction Pressure, Condition 7.....	62
A.27	Amplification Factor for Various Damping Ratios .....	67
A.28	Effect of Separation Margin from MNF on Amplification Factor.....	68
A.29	API 618 Design Vibration Guideline.....	69
A.30	Example of Internal Cylinder Pressure Force vs Crank Angle and Frequency Spectrum.....	70
A.31	Example of Rod Loads Due to Gas Force, Inertial Force, and Combined Rod Load .....	71
A.32	Frequency Factors for Idealized Pipe Spans and Bends (1st and 2nd Natural Frequencies).....	73
A.33	Frequency Factor ( $\lambda$ ) vs Ratio ( $L/h$ ) for Uniform U-bend.....	74
A.34	Concentrated Weight-Correction Factors for Ideal Piping Spans.....	75
A.35	Typical Compressor Flange Deflections .....	77
A.36	Plot of a Pipe System .....	79
A.37	Lowest Mode Shape .....	79
A.38	Typical Branch Connection Finite Element Model.....	80
A.39	Example of a Partial Finite Element Model of a Compressor.....	81
A.40	Typical Dynamically Fixed Clamps.....	82
A.41	Example of a Hold-down-type Support with No Allowance for Thermal Displacement in the Vertical Direction.....	83
A.42	Example of a Spring Hold-down-type Support That Allows Thermal Motion in the Vertical Direction.....	84
A.43	Lumped Acoustic Model .....	89
A.44	Analogous Electrical Model.....	89
A.45	Electronic Analog for One Pipe Section (Simplified Version Without Flow Resistance).....	90
A.46	Compressor Configuration.....	100
A.47	Cylinder Nozzle Pulsation (Predicted vs Guideline) .....	100
A.48	Pulsation Suppression Device Line-side Pulsation (Predicted vs Guideline) .....	101
A.49	Pulsation Suppression Device Shaking Force (Predicted vs Guideline).....	101
A.50	Compressor System Finite Element Model.....	102
A.51	Typical Display of Valve Motion vs Crank Angle, Cylinder Pressure vs Volume, and Analysis Results Table .....	107
A.52	Nonsymmetrical Filter .....	112
B.1	Example Effects of Reverse Flow on Suction and Discharge Flow Pulses.....	116
B.2	PV and Rod Reversal Diagrams for 100 % Flow Without Suction Valve Unloading.....	118
B.3	PV and Rod Reversal Diagrams for Stepless Capacity Control Resulting in 40 % Flow ...	118
B.4	$\Delta T$ ...Increase Suction Temperature vs % Output .....	119
B.5	Hydraulic Stepless Capacity Control System.....	120
B.6	Electric Stepless Capacity Control System .....	120
E.1	Tolerance Band to Determine Maximum Vibration .....	124
E.2	Typical Piston Rod Loads.....	125
E.3	Typical Fourier Transform of Gas Rod Load and Cylinder Vibration .....	126
E.4	Compressor and Pipe System Model .....	127
F.1	Scope of Small-bore Piping .....	128
F.2	Typical Relief Valve Connection with Repad and Gussets .....	130

F.3	Brace Small-bore Piping to Main Pipe.....	131
F.4	Small-bore Attachment Configurations.....	131
F.5	Small-bore Remote Mounting.....	132
G.1	Measuring Flow Expressed a Change of the Vortex Frequency .....	138
H.1	Screw Compressor Pressure Versus Volume Diagram.....	140
J.1	Pump Cavitation .....	143
J.2	Pump Cavitation Field Data .....	144

## Tables

1	Design Approach Selection .....	10
2	Allowable Shaking Force Guideline.....	15
3	Analysis Selection Chart.....	23
4	Maximum Allowable Speed Table .....	24
5	Allowable Shaking Force Guideline.....	28
6	Allowable Shaking Force Guideline.....	32
A.1	Example Condition 1 .....	54
A.2	Example Condition 2 .....	55
A.3	Example Condition 3 .....	56
A.4	Example Condition 4 .....	58
A.5	Example Condition 5 .....	59
A.6	Example Condition 6 .....	60
A.7	Example Condition 7 .....	62
A.8	Example of a Maximum Span Table for 25 Hz .....	76
A.9	Effect of Pipe Support Structures on Mechanical Natural Frequencies .....	78
A.10	Compressor Geometry .....	98
A.11	Operating Conditions .....	99
A.12	Gas Composition .....	99
A.13	Lowest Mode Shape and MNF .....	102
A.14	Recommended Design Results for Cylinder Stretch Load Case.....	103
A.15	Expected Results .....	103
A.16	Compressor Data Required for Acoustic Simulation .....	112
F.1	Small-bore Piping Design MNF .....	133
G.1	Overview of Pulsation Impact on Various Flow Meters.....	136
H.1	Typical Overpressure Limit vs Line Pressure .....	141

## Introduction

Users of this standard should be aware that further or differing requirements may 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 may be particularly appropriate where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this standard and provide details.

Annex A contains informative descriptions of the work process for acoustical and mechanical analyses. It is focused on reciprocating compressors but is somewhat applicable to all positive displacement (PD) machinery.

Annex B contains information concerning stepless capacity control for reciprocating compressor cylinders.

Annex C contains the Design Approach 2 flowchart for API 618 machines.

Annex D contains the Design Approach 3 flowchart for API 618 machines.

Annex E contains information for forced mechanical response analyses of compressor systems and piping.

Annex F contains information for small-bore piping analysis and design.

Annex G contains pulsation considerations for flow metering equipment.

Annex H contains information for  $V_i$  and pressure ratio considerations for API 619 machines.

Annex I contains the design approach flowchart for PD pumps.

Annex J contains information concerning cavitation considerations for PD pump systems. In this standard, U.S. customary (USC) units are included in brackets for information.

# Pulsation and Vibration Control for Positive Displacement Machinery Systems for Petroleum, Chemical, and Natural Gas Industry Services

## 1 Scope

This standard covers the minimum requirements for pulsation and vibration control for positive displacement (PD) machinery systems used in the petroleum, chemical, and natural gas industry services. The specific machinery addressed includes:

- reciprocating compressors (ref. API 618);
- rotary-type PD compressors (ref. API 619);
- PD pumps—reciprocating (ref. API 674);
- PD pumps—controlled volume (ref. API 675);
- PD pumps—rotary (ref. API 676).

## 2 Normative References

**2.1** 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) applies.

API Standard 618, *Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services*

API Standard 619, *Rotary-type Positive-displacement Compressors for Petroleum, Chemical, and Gas Industry Services*

API Standard 674, *Positive Displacement Pumps—Reciprocating*

API Standard 675, *Positive Displacement Pumps—Controlled Volume for Petroleum, Chemical, and Gas Industry Services*

API Standard 676, *Positive Displacement Pumps—Rotary*

ASME B31.3<sup>1</sup>, *Process Piping*

ASME B31.8, *Gas Transmission and Distribution Piping Systems*

ASME *Boiler and Pressure Vessel Code (BPVC), Section III: Rules for Construction of Nuclear Power Plant Components; Division 2: Code for Concrete Reactor Vessels and Containments*

ASME *Boiler and Pressure Vessel Code (BPVC), Section III, Appendix 1, 2010 Edition*

ASME *Boiler and Pressure Vessel Code (BPVC), Section VIII: Rules for Construction of Pressure Vessels; Division 1: Rules for Construction of Pressure Vessels*

ASME *Boiler and Pressure Vessel Code (BPVC), Section VIII: Rules for Construction of Pressure Vessels; Division 2: Alternative Rules*

---

<sup>1</sup> ASME International, 2 Park Avenue, New York, NY 10016-5990, [www.asme.org](http://www.asme.org).