

Machinery Protection Systems

API STANDARD 670
FIFTH EDITION, NOVEMBER 2014



AMERICAN PETROLEUM INSTITUTE

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.

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.

Users of this standard should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

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, 1220 L Street, NW, Washington, DC 20005.

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.

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

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

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, 1220 L Street, NW, Washington, DC 20005. 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, 1220 L Street, NW, Washington, DC 20005.

Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

Currently in preview, click buy full version

Contents

	Page
1 Scope	1
1.1 General	1
1.2 Alternative Designs	1
1.3 Conflicting Requirements	1
2 Normative References	1
3 Terms, Definitions, Acronyms, and Abbreviations	3
3.1 Terms and Definitions	3
3.2 Acronyms and Abbreviations	26
4 General Design Specifications	27
4.1 Component Temperature Ranges	27
4.2 Humidity	27
4.3 Shock	28
4.4 Chemical Resistance	28
4.5 Accuracy	28
4.6 Interchangeability	31
4.7 Scope of Supply and Responsibility	31
4.8 Segregation	31
4.9 System Enclosures and Environmental Requirements	31
4.10 Power Supplies	34
4.11 Machinery Protection System Features/Functions	35
4.12 System Output Relays	38
4.13 Digital Communication Links	39
4.14 System Wiring and Conduits	40
4.15 Grounding of the Machinery Protection System	42
4.16 System Security, Safeguards, Self-tests and Diagnostics	43
4.17 Reliability	44
5 Sensors and Transducers	44
5.1 Radial Shaft Vibration, Axial Position, Phase Reference, Speed Sensing, Flow, and Piston Rod Drop Transducers	44
5.2 Seismic Transducers	48
5.3 Temperature Sensors	51
6 Sensor and Transducer Arrangements	52
6.1 Locations and Orientation	52
6.2 Mounting	60
6.3 Identification of Sensor Systems	62
7 Vibration Monitor Systems	62
7.1 General	62
7.2 Power Supplies	64
7.3 System Output Relays	64
7.4 Monitor Systems	65
7.5 Location of Monitor Systems	71
8 Electronic Overspeed Detection System	71
8.1 General	71
8.2 Accuracy	72
8.3 Segregation	72

Contents

	Page
8.4 Functions	72
9 Surge Detection Systems	75
9.1 General	75
9.2 Accuracy	75
9.3 Segregation	75
9.4 Functions	77
10 Emergency Shutdown Systems (ESDs)	79
10.1 General	79
10.2 Functional Requirements	81
10.3 ESD Security	82
10.4 ESD Arrangement	82
10.5 ESD Interface	83
10.6 Display, Indications	86
10.7 System Inputs	86
10.8 System Outputs	88
11 Inspection, Testing, and Preparation for Shipment	88
11.1 General	88
11.2 Inspection	88
11.3 Testing	88
11.4 Preparation for Shipment	89
11.5 Mechanical Running Test	89
11.6 Field Testing	89
12 Vendor's Data	93
12.1 General	93
12.2 Proposals	95
12.3 Contract Data	96
Annex A (informative) Machinery Protection System Datasheets	98
Annex B (informative) Typical Responsibility Matrix Worksheet	107
Annex C (normative) Accelerometer Application Considerations	108
Annex D (normative) Signal Cable	113
Annex E (normative) Gearbox Casing Vibration Considerations	116
Annex F (normative) Field Testing and Documentation Requirements	118
Annex G (informative) Contract Drawing and Data Requirements	121
Annex H (informative) Typical System Arrangement Plans	126
Annex I (informative) Setpoint Multiplier Considerations	133
Annex J (normative) Electronic Overspeed Detection System Considerations	137
Annex K (informative) Surge Detection and Antisurge Control	141
Annex L (informative) Safety Integrity Level	145
Annex M (informative) Considerations Regarding Spurious Shutdowns and the Use of Functional Safety Methodology to Reduce Economic Losses	165

Contents

	Page
Annex N (informative) Condition Monitoring	169
Annex O (normative) Overspeed	209
Annex P (informative) Reciprocating Compressor Monitoring	226
Annex Q (informative) Considerations when Using Wireless Connectivity Technologies	236
Bibliography	244
Figures	
1 Machinery Protection System	13
2 Standard Monitor System Nomenclature	14
3 Transducer System Nomenclature	23
4 Typical Curves Showing Accuracy of Proximity Transducer System	30
5 Typical Conduit Cable Arrangement	40
6 Typical Armored Cable Arrangement	41
7 Inverted Gooseneck Trap Conduit Arrangement	41
8 Typical Instrument Grounding	43
9 Standard Proximity Probe and Extension Cable	44
10 Standard Options for Proximity Probes	45
11 Standard Magnetic Speed Sensor with Removable (Non-integral) Cable and Connector	47
12 Standard Axial Position Probe Arrangement	53
13 Typical Piston Rod Position Probe Arrangement	54
14 Typical Installations of Radial Bearing Temperature Sensors	58
15 Standard Installation of Radial Bearing Temperature Sensors	59
16 Typical Installation of Thrust Bearing Temperature Sensors	59
17 Piston Rod Drop Calculations	67
18 Piston Rod Position Measurement Using Phase Reference Transducer for Triggered Mode	68
19 Surge Detection and Antisurge Control Systems	76
20 Surge Detection with Compressor Inlet Temperature	78
21 Typical System Arrangement Using Distributed Architecture	84
22 Typical System Arrangement Using Integrated Architecture	85
23 Calibration of Radial Monitor and Setpoint for Alarm and Shutdown	90
24 Calibration of Axial Position (Thrust) Monitor	91
25 Typical Field Calibration Graph for Radial and Axial Position (Gap)	92
C.1 Typical Flush-mounted Accelerometer Details	109
C.2 Typical Nonflush-mounted Arrangement Details for Integral Stud Accelerometer	110
C.3 Typical Nonflush-mounted Arrangement for Integral Stud Accelerometer with Protection Housing ..	111
H.1 Typical System Arrangement for a Turbine with Hydrodynamic Bearings	127
H.2 Typical System Arrangement for Double-helical Gear	128
H.3 Typical System Arrangement for a Centrifugal Compressor or a Pump with Hydrodynamic Bearings	129
H.4 Typical System Arrangement for an Electric Motor with Sleeve Bearings	130
H.5 Typical System Arrangement for a Pump or Motor with Rolling Element Bearings	131
H.6 Typical System Arrangement for a Reciprocating Compressor	132
I.1 Setpoint Multiplication Example	134
J.1 Overspeed Protection System	137
J.2 Relevant Dimensions for Overspeed Sensor and Multitooth Speed Sensing Surface Application Considerations	138
J.3 Precision-machined Overspeed Sensing Surface	139

Contents

	Page
K.1 Compressor Performance Limitations	142
K.2 Pressure and Flow Variations During a Typical Surge Cycle	145
L.1 Risk Graph as per VDMA 4315L	147
L.2 Risk Graph as per ISO 13849	154
L.3 Relationship Between Categories, DC_{avg} , $MTTF_d$ of Each Channel, and PL	156
L.4 Functional Block Diagram of Typical Protection Loop with a Single Solenoid Valve	158
L.5 Functional Block Diagram of Typical Protection Loop with a Dual Solenoid Valve	158
M.1 Process Block Diagram	168
N.1 Orbit Plot and Order Spectrum	175
N.2 Case Plot with x-axis Configured for Frequency	176
N.3 Waterfall Plot with Half Spectrum and x-axis Configured for Frequency	176
N.4 Waterfall Plot with x-axis Configured for Frequency	177
N.5 Waterfall Plot with Full Spectrum and x-axis Configured for Orders	177
N.6 Example of Broken Fan Blade Causing Unbalance Condition. Diagram Shows the Heavy Spot. The Spectrum Indicates High 1X Peak and the Waveform Resembles a Sine Wave.	178
N.7 Offset Misalignment	178
N.8 Angular Misalignment	178
N.9 Offset Misalignment Spectrum Shows 1X with Larger 2X Peak. Offset Misalignment Waveform Shows Two Peaks per Revolution.	179
N.10 Looseness Can Be Caused by Excessive Clearance on a Bearing. The Looseness Spectrum Shows Many Harmonics of 1X. Looseness Waveform Shows Random Peaks—No Pattern.	179
N.11 Orbit and Time Waveform Plot of a Rub on a Motor	180
N.12 Full Spectrum Plot of a Rub on a Motor	180
N.13 Antifriction Bearings	181
N.14 Spectrum (left) Shows Cage Defect Frequency. The Waveform (right) Has a Clear Impacting Pattern.	182
N.15 Spectrum (left) Plot of Outer Race Defect Generates Spiked Peaks at Harmonics of BPFO. The Waveform (right) Shows a high number of Impacts Closely Spaced Together.	183
N.16 The Spectrum (top) Shows High Frequency Peaks Typically Surrounded by Sidebands. The Waveform (bottom) Shows Repeating Peaks with a Modulated Amplitude.	184
N.17 The First Waveform (upper left) is of Early Stage Defect. The Second Waveform (upper right) is of an Advanced Stage Defect. The Third Plot (bottom) is the Trend of Waveform Amplitude.	185
N.18 Typical Multistage Gearbox	186
N.19 Spectrum Showing 1X and 2X of Gear Mesh Frequency	186
N.20 Early Stage Gear Wear Showing 1X, 2X, and 3X of Gear Mesh Frequency.	187
N.21 Late Stage Gear Wear Showing Sidebands Around Gear Mesh	187
N.22 Waveform Showing Amplitude Modulation of Impacts	188
N.23 Circle Plot of the Waveform Reveals the Number and Location of Broken Teeth	188
N.24 Fluid Wedge illustration	189
N.25 Waterfall Representation of Whirl and Whip Phenomenon	190
N.26 Orbit and Time Waveform Representation of Whirl and Whip Phenomenon	191
N.27 Examples of Oil Whirl Frequency Spectrums.	192
N.28 Examples of Oil Whirl Orbit and Frequency Spectrum	192
N.29 Waterfall Plot with Orbits Displaying Oil Whirl and Oil Whip	193
N.30 Bode Plot showing Resonant Frequency	194
N.31 Cascade Plot of a Start-up. A Structural Resonance is Present in the Data as Well as the Normal 1X Vibration. When Machine Speed Becomes Equal to the Resonant Frequency, a Large Increase in Amplitude Occurs.	194
N.32 Frequency Spectrum of Cavitation Fault	196

Contents

	Page
N.33 Time Waveform of Cavitation Fault	197
N.34 Probe Mount Frequency Ranges	206
N.35 Condition Monitoring Configurations with Wireless Connectivity	207
O.1 The Peak Kinetic Energy of the Rotor	119
Q.1 Unidirectional Wireless Communication	240
Q.2 Omnidirectional Wireless Communication	240
Q.3 Star Topology Network	241
Q.4 Mesh Topology Network	242
Q.5 Cluster Tree Topology Network	243
Tables	
1 Machinery Protection System Accuracy Requirements	29
2 Summary of Allowable Usage of Wireless Technology for Machinery Protection Systems	32
3 Minimum Separation Between Installed Signal and Power Cables	42
4 Accelerometer Test Points (SI)	93
5 Accelerometer Test Points (USC Units)	94
D.1 Color Coding for Single-circuit Thermocouple Signal Cable	115
F.1 Tools and Instruments Needed to Calibrate and Test Machinery Protection Systems	118
F.2 Data, Drawing, and Test Worksheet	119
G.1 Typical Milestone Timeline	121
G.2 Sample Distribution Record (Schedule)	122
J.1 Recommended Dimensions for Speed Sensing Surface when Magnetic Speed Sensors Are Used ..	140
J.2 Recommended Dimensions for Nonprecision Speed Sensing Surface when Proximity Probe Speed Sensors Are Used	140
J.3 Recommended Dimensions for Precision-machined Speed Sensing Surface when Proximity Probe Speed Sensors Are Used	140
L.1 Safety Integrity Levels and Probability of Failure	149
L.2 Performance Level as per ISO 13049 and Safety Integrity Level as per IEC 61508/61511	151
L.3 Definition of the Range of the Parameter Severity, S	152
L.4 Definition of the Range of the Parameter Probability of Presence in the Hazardous Zone— <i>F</i>	153
L.5 Definition of Vulnerability <i>V</i> and Unavoidability <i>A</i>	154
L.6 Definition of the Range of the Parameter AV (Unavoidability Considering the Vulnerability)	154
L.7 Definition of the Range of the Parameter W (Probability of the Occurrence of the Unwanted Event) .	154
L.8 Table of Calculated PF_{avg} for Example of L.7.2.2	161
L.9 Mean Time to Dangerous Failure of Each Channel ($MTTF_d$)	163
L.10 Diagnostic Coverage (DC)	163
L.11 Table of Calculated PF_{avg} for Example in L.8.4	164
N.1 MPS and CMS Objectives and Goals	170
N.2 MPS and CMS Content Comparison	171
N.3 Probe Mount Frequency Ranges	206
P.1 Typical Protective Signals	233
P.2 Typical Condition Signals	234

Currently in preview, click buy full version

Machinery Protection Systems

1 Scope

1.1 General

This standard covers the minimum requirements for a machinery protection system (MPS) measuring radial shaft vibration, casing vibration, shaft axial position, shaft rotational speed, piston rod drop, phase reference, overspeed, surge detection, and critical machinery temperatures (such as bearing metal and motor windings). It covers requirements for hardware (transducer and monitor systems), installation, documentation, and testing.

NOTE A bullet (●) at the beginning of a subsection or paragraph indicates that either a decision is required or further information is to be provided by the purchaser. This information should be indicated on the datasheets (see Annex A); otherwise, it should be stated in the quotation request or in the order.

1.2 Alternative Designs

The MPS vendor may offer alternative designs. Equivalent metric dimensions and fasteners may be substituted as mutually agreed upon by the purchaser and the vendor.

1.3 Conflicting Requirements

In case of conflict between this standard and the inquiry or order, the information included in the order shall govern.

2 Normative References

2.1 The editions of the following standards, codes, and specifications that are in effect at the time of publication of this standard shall, to the extent specified herein, form a part of this standard. The applicability of changes in standards, codes, and specifications that occur after the inquiry shall be mutually agreed upon by the purchaser and the MPS vendor.

API Recommended Practice 552, *Transmission Systems*

API Standard 610, *Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries*

API Standard 611, *General Purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Systems*

API Standard 612, *Petroleum Petrochemical and Natural Gas Industries—Steam Turbines—Special-Purpose Applications*

ANSI MC96.1¹, *Temperature Measurement Thermocouples*

ASME Y14.2M², *Line Conventions and Lettering*

EN 61000-6-2:2005³, *Electromagnetic Compatibility Generic Immunity Standard; Part 2: Industrial Environment*

ICEA S-61-402⁴, *Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy*

IEC 60079⁵, (all parts) *Explosive atmospheres*

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

² ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org.

³ European Committee for Standardization, Rue de Stassart 36, B-1050 Brussels, Belgium, www.cenorm.be.

⁴ Insulated Cable Engineers Association, P.O. Box 1568, Carrollton, Georgia 30112, www.icea.net.