

Machinery Protection Systems

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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.

IEC 61508, *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61511, *Functional safety—Safety instrumented systems for the process industry sector*

IEC 62061, *Safety of machinery—Functional safety of safety-related electrical, electronic and programmable electronic control systems*

ISA S12.1 ⁶, *Definitions and Information Pertaining to Electrical Instruments in Hazardous (Classified) Locations*

ISA S12.4, *Instrument Purging for Reduction of Hazardous Area Classification*

ISA S84.00.01, *Application of Safety Instrumented Systems for the Process Industries*

ISO 13849, (all parts) *Safety of machinery—Safety-related parts of control systems*

ISO 21789, *Gas turbine applications—Safety*

Military Specification MIL-C-39012-C ⁷, *Connectors, Coaxial, Radio Frequency, General Specification for*

Military Specification MIL-C-39012/5F, *Connectors, Plug, Electrical, Coaxial, Radio Frequency [Series N (Cabled) Right Angle, Pin Contact, Class 2]*

NEMA 250 ⁸, *Enclosures for Electrical Equipment (1000 Volts Maximum)*

NEMA WC 5, *Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy*

NFPA 70 ⁹, *National Electrical Code*

NFPA 496, *Purged and Pressurized Enclosures for Electrical Equipment*

Schneider Electric PI-MBUS-300, *13 Modbus® Protocol Reference Guide*

2.2 The standards, codes, and specifications of the American Iron and Steel Institute (AISI) ¹⁰ also form part of this standard.

2.3 The purchaser and the MPS vendor shall mutually determine the measures that shall be taken to comply with any governmental codes, regulations, ordinances, or rules that are applicable to the equipment.

⁵ International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, www.iec.ch.

⁶ International Society of Automation, 67 T.W. Alexander Drive, Research Triangle Park, North Carolina, 22709, www.isa.org.

⁷ U.S. Department of Defense, Document Automation and Production Service, Building 4/D, 700 Robbins Avenue, Philadelphia, Pennsylvania 19111-5094, <https://assist.daps.dla.mil>.

⁸ National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1752, Rosslyn, Virginia 22209, www.nema.org.

⁹ National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.

¹⁰ American Iron and Steel Institute, 1540 Connecticut Avenue, NW, Suite 705, Washington, DC 20036, www.steel.org.

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1

1X

The machine running speed in cpm.

3.1.2

1X amplitude

The vibration amplitude at running speed. (See also **harmonics**.)

3.1.3

1X vectors

The vector of vibration amplitude and phase, at the machine running speed.

3.1.4

2X

Twice the machine running speed.

3.1.5

2X amplitude

The vibration amplitude at twice the running speed. (See also **harmonics**.)

3.1.6

2X vectors

The vector of vibration, amplitude, and phase, at twice the machine running speed.

3.1.7

acceleration

The time rate of change of velocity. The unit for vibration acceleration is G; 1 G = acceleration of Earth's gravity = $386.1 \text{ in./s}^2 = 32.17 \text{ ft/s}^2 = 9.81 \text{ m/s}^2$.

3.1.8

accelerometer

A sensor with an output proportional to acceleration.

3.1.9

accelerometer cable

An assembly consisting of a specified length of cable and mating connectors. Both the cable and the connectors shall be compatible with the particular accelerometer and (when used) intermediate termination.

3.1.10

acceptance region

The area around the 1X or 2X vibration vector wherein the amplitude and phase are considered normal.

3.1.11

accuracy

The degree of conformity of an indicated value to a recognized accepted standard value or ideal value.

3.1.12**active magnetic speed sensor**

A magnetic speed sensor that requires external power and provides a conditioned (i.e. square wave) output. Typical excitation is between +5 Vdc to +30 Vdc.

3.1.13**active (normal) thrust direction**

The direction of a rotor axial thrust load expected by the machinery vendor when the machinery is operating under normal running conditions.

3.1.14**A/D**

Analog to digital conversion.

3.1.15**air interface**

The technology used for a radio transmission between base station and mobile units in a wireless network.

3.1.16**alarm (alert) setpoint**

A preset value of a parameter at which an alarm is activated to warn of a condition that requires corrective action.

3.1.17**alarm levels**

API 670 provides for alert and danger levels, where the danger level is often associated with an automatic shutdown of the monitored equipment.

NOTE 1 May be called severity levels within condition monitoring and provide for additional levels of notification.

NOTE 2 By adding additional software alarm levels at amplitudes lower than alert, maintenance personnel can be notified when levels increase even though there may not be cause for immediate concern or action by operators.

3.1.18**alarm/shutdown/integrity logic**

Violations of these setpoints or circuit fault criteria result in alarm or shutdown status conditions in the monitor system.

NOTE 1 The function of a monitor system whereby the outputs of the signal processing circuitry are compared against alarm or shutdown setpoints and circuit fault criteria.

NOTE 2 These status conditions may be subjected to preset time delays or logical voting with other status conditions and are then used to drive the system output relays and status indicators and outputs.

3.1.19**aliasing**

In measurements, false indication of frequency components caused by sampling a dynamic signal at too low of a sampling frequency.

3.1.20**amplitude**

The magnitude of vibration. Displacement is measured in peak-to-peak. Velocity and acceleration are measured in zero-to-peak or root mean square (rms).

3.1.21**analog**

A signal using frequency or amplitude modulation.

3.1.22**asynchronous sampling**

The sampling of a vibration signal at time intervals not related to shaft rotation.

3.1.23**axial position**

The average position, or change in position, of a rotor in the axial direction with respect to some fixed reference (see 3.1.13).

3.1.24**balance**

(See **unbalance**.)

3.1.25**balance resonance speed**

A shaft rotational speed (or speed range) that is equal to a lateral natural frequency of the rotor system. [See also **critical speed(s)**.]

3.1.26**base station**

The central radio transmitter/receiver within a given range.

3.1.27**baseline data**

The reference data set acquired when a machine is in acceptable condition after installation or most recent overhaul that establishes a basis to which subsequent data may be compared.

3.1.28**bearing instability**

A self-excited vibration caused by interaction between the fluid in the bearing and the rotor.

3.1.29**bench test**

A test performed on system components within the testing range.

3.1.30**best fit straight line**

The line drawn through the actual calibration curve where the maximum plus or minus deviations are minimized and made equal.

3.1.31**blind monitor system**

A monitor that does not contain an integral display. The blind monitor provides certain minimal integral status indication independently of any nonintegral displays (see 7.1.6).

3.1.32**Bluetooth**

A communications protocol using the 2.4 GHz spectrum band.

3.1.33**Bode plot**

A pair of graphs in Cartesian format displaying any vibration vector (phase lag angle and amplitude) as a function of shaft rotational speed. The y-axis of the top graph represents phase lag angle, while the y-axis of the bottom graph represents amplitude. The common x-axis represents shaft rotational speed. Sometimes called an unbalance response plot.

3.1.34**broadband**

Bandwidth capacity sufficient to carry multiple voice, video, or data channels simultaneously. Per FCC: "200 kbps upstream and downstream transmission speeds."

3.1.35**buffered output**

An unaltered, analog replica of the transducer input signal that preserves amplitude, phase, frequency content, and signal polarity. It is designed to prevent a short circuit of this output to monitor system ground from affecting the operation of the MPS. The purpose of this output is to allow connection of vibration analyzers, oscilloscopes, and other test instrumentation to the transducer signals.

3.1.36**cascade plot**

A series of spectrum plots taken over a speed range, plotted against speed. The difference between a cascade plot and a waterfall plot is that the spectra within a cascade (the z-axis) are selected based upon differential speed, while a waterfall plot selects its spectra based upon differential time.

3.1.37**casing vibration**

The absolute vibration of machine housing or structure, usually measured on the bearing housing.

3.1.38**catastrophic failure**

The sudden unexpected failure of a machine or component resulting in considerable damage.

3.1.39**channel**

The monitor system components associated with a single transducer. The number of channels in a monitor system refers to the number of transducer systems it can accept as inputs.

3.1.40**channel pair**

Two associated measurement locations (such as the X and Y proximity probes at a particular radial bearing or the two axial proximity probes at a particular thrust bearing).

3.1.41**circle plot**

The data from a single waveform that is normalized to the turning speed of the shaft and then wrapped around a circle in polar format. Points outside the circle correspond to positive waveform amplitudes, while points inside the circle correspond to negative waveform amplitudes. This representation makes it possible to easily visualize events, which occur at a specific point in the shaft rotation.

3.1.42**circuit fault**

A MPS circuit failure that adversely affects the function of the system.

3.1.43**circuit switched data**

An exclusively reserved connection.

3.1.44**code division multiple access****CDMA**

A technology used to transmit wireless calls by assigning them codes.

3.1.45**colocation**

Placement of multiple antennas at a common site.

3.1.46**commercial mobile radio service provider**

FCC designation for carrier connected to public switched telephone network and/or operated for profit.

3.1.47**condition based maintenance**

(See **machinery condition based maintenance**.)

3.1.48**condition monitoring system****CMS**

(See **machinery condition monitoring system**.)

3.1.49**construction agency**

The contractor that installs the machinery train or its associated MPS.

3.1.50**contiguous**

Mechanically connected and included in the same housing or rack containing the signal processing and alarm/shutdown/integrity logic functions of the monitor system.

NOTE Installation of all monitor system components in the same panel or cabinet is not the same as contiguous.

3.1.51**continuous display**

Simultaneous, uninterrupted indication of all status conditions and measured variables in the MPS as required by this standard. It also continuously updates this indication at a rate meeting or exceeding the requirements of this standard.

3.1.52**controlled access**

A security feature of a MPS that restricts alteration of a parameter to authorized individuals. Access may be restricted by means such as the use of a key or coded password or other procedures requiring specialized knowledge.

3.1.53**critical speed(s)**

A shaft rotational speed at which the rotor-bearing-support system is in a state of resonance.

3.1.54**dBm**

Decibels relative to 1 milliwatt.

3.1.55**dedicated display**

A display that indicates only those parameters from its associated MPS(s) and is not shared with or used to indicate information from other systems such as process controllers, logic controllers, turbine controllers, and so forth.

3.1.56**defect**

An anomaly or imperfection in a machine or component.

3.1.57**diagnostics**

The examination of symptoms and syndromes to determine the nature of faults or failures (kind, situation, extent).

3.1.58**diagnostics**

The methods used to identify sources of faults from data gathered using monitoring and analytical equipment.

3.1.59**digital**

A binary communications protocol.

3.1.60**displacement**

A vibration measurement that quantifies the amplitude in engineering units of mils (1 mil = 0.001 in.) or micrometers.

3.1.61**display**

An analog meter movement, cathode ray tube, liquid crystal device, or other means for visually indicating the measured variables and status conditions from the MPS. A display may be further classified as integral or nonintegral, dedicated or shared, or continuous or noncontinuous.

3.1.62**dual path**

A configuration of the monitor system such that the same transducer system is used as an input to two separate channels in the monitor system and different signal processing (such as filtering or integration) is applied to each channel.

NOTE An example of this is a single casing vibration accelerometer that is simultaneously processed in the monitor system to both acceleration and velocity for separate filtering, display, and alarming.

3.1.63**dual-path monitor**

A device that performs more than one type of signal conditioning from a single transducer or signal interface.

3.1.64**dual voting logic**

A monitor feature whereby the signals on two channels shall both be in violation of their respective setpoints to initiate a change in status (two-out-of-two logic).

3.1.65**dynamic data**

That aspect of a signal that cannot be fully characterized by a single static or vector quantity but is instead characterized by an array of data points. Examples include orbit plots from orthogonal vibration sensors, spectrum plots, and timebase plots. Most trend plots are composed of static data values versus time and are therefore

considered static data trends. In contrast, a trend plot of dynamic data, such as a spectrum waterfall showing the entire spectrum at various intervals in time, would be considered a dynamic data trend.

3.1.66

dynamic range

The usable range of amplitude of a signal, usually expressed in decibels.

3.1.67

electrical runout

A source of error on the output signal from a noncontacting probe system resulting from nonuniform electrical conductivity properties of the observed material or from the presence of a local magnetic field at a point on the shaft surface.

3.1.68

electrically isolated accelerometer

An accelerometer in which all signal connections are electrically insulated from the accelerometer case or base.

3.1.69

emergency shutdown system

ESD

A safety instrumented system (SIS) as defined by IEC 61508/ISA S84 and IEC 61511, dedicated to stopping the machine under abnormal conditions.

NOTE 1 The ESD is separate and distinct from the machinery control system.

NOTE 2 The ESD may or may not include overspeed detection and/or surge detection.

NOTE 3 The ESD may be simple (e.g. set of relay contacts in series) or complex [e.g. programmable logic controller (PLC) type] based on the type of machine train and application (e.g. steam and gas turbines, electric drives, expanders, pumps, and compressors).

3.1.70

exception-based reporting

A monitoring strategy where the system reports back data on exception rather than adhering strictly to a specific reporting interval.

3.1.71

extension cable

The interconnection between the proximity probe's integral cable and its associated oscillator-demodulator.

3.1.72

failure

The termination of the ability of an item to perform a required function.

NOTE 1 After the failure, the item has a fault.

NOTE 2 "Failure" is an event, as distinguished from a "fault," which is a state.

NOTE 3 This concept as defined does not apply to items consisting of software only.

3.1.73

fast Fourier transform

FFT

An algorithm for transforming data from the time domain to the frequency domain. The FFT process is used to create a spectrum plot from a digitized sample of time waveform data.

3.1.74**fault**

The state of an item characterized by inability to perform a required function, excluding such inability during preventative maintenance or other planned actions or due to lack of external resources.

3.1.75**field changeable**

Refers to a design feature of a MPS that permits alteration of a function after the system has been installed.

3.1.76**filter**

An electrical device that attenuates signals outside the frequency range of interest.

3.1.77**final shutdown element**

The device(s) that accepts relay contacts and actuates the mechanism to initiate a forced shutdown.

3.1.78**flow sensor**

A device used for sensing the rate of fluid flow.

3.1.79**frequency**

The repetition rate of a periodic vibration per unit of time. Vibration frequency is typically expressed in units of cycles per second (Hertz), cycles per minute, or orders of shaft rotational speed.

3.1.80**frequency component**

The amplitude, frequency, and phase characteristics of a dynamic signal filtered to a single frequency.

3.1.81**frequency division multiplexing**

Numerous signals combined for transmission on a single communications channel.

3.1.82**g**

A unit of acceleration equal to 9.81 m/s^2 (386.4 in./s^2).

3.1.83**gap voltage**

A direct current (DC) voltage from a proximity transducer that quantifies the distance from the tip of the transducer to the observed shaft surface.

3.1.84**gauss level**

The magnetic field level of a component. It is best measured with a Hall effect probe.

3.1.85**general packet radio service**

Packet technology approach enables high-speed wireless Internet and other GSM-based data communications.

3.1.86**Hanning window**

Windows are weighting functions used in the FFT process. The FFT algorithm requires the input data to be periodic in the sampled time record. Therefore, the sampled time waveform is multiplied by a window function to force the amplitude of the input data to zero at the beginning and end of the sample. Many different window functions exist, and each type reduces the frequency resolution and introduces some amplitude error into the resulting spectrum. A Hanning window provides the best compromise between amplitude accuracy and frequency resolution for general-purpose measurements for rotating equipment.

3.1.87**harmonics**

The vibration content of a spectrum consisting of exact frequency integer multiples or submultiples of a fundamental frequency.

3.1.88**Hertz****Hz**

The unit of frequency measurement in cycles per second.

3.1.89**high-speed circuit switched data**

A permanent connection is established between the called and calling parties for the exchange of data.

3.1.90**inactive (counter) thrust direction**

The direction opposite the active thrust direction.

3.1.91**inches per second****ips**

A unit of velocity equal to 25.4 mm/s (1 in./s).

3.1.92**integral display**

A display that is contiguous with the other components comprising the monitor system.

3.1.93**integrated digital enhanced network**

Technology that combines two-way radio, telephone, text messaging, and data transmission into one digital network.

3.1.94**interconnection**

Connecting one wireless network to another.

3.1.95**interoperability**

Coordination and communication with other networks, such as two systems based on different protocols or technologies.

3.1.96**latency**

In a network, latency is an expression of how much time it takes for a packet of data to get from one designated point to another.

3.1.97**linear frequency response range**

The portion of the transducer's voltage output versus frequency curve, between lower and upper frequency limits, where the response is linear within a specified tolerance.

3.1.98**linear range**

The portion of a transducer's output where the output versus input relationship is linear within a specified tolerance.

3.1.99**local**

Refers to a device's location when mounted on or near the equipment or console.

3.1.100**machine case**

A driver (e.g. electric motor, turbine, or engine) or any one of its driven pieces of equipment (e.g. pump, compressor, gearbox, generator, fan). An individual component of a machinery train.

3.1.101**machine characteristics**

Distinguishing attributes, qualities, and properties of a machine and its subsystems that, by their presence and magnitudes, define the configuration, performance, behavior, and capabilities of the machine or process.

3.1.102**machinery condition based maintenance**

Maintenance performed based on the condition of the machine as indicated by a condition monitoring system or program.

3.1.103**machinery condition monitoring system****machinery CMS**

A system that measures and trends specified machine and process parameters. Provides alarming, presentation, and analysis tools for the detection and identification of developing faults. Allows for the continued monitoring of a detected fault to determine its propagation and severity. May also be used to manage the operating conditions of the machine to reduce stress from a developing fault. Can, in some cases, reduce the rate at which a fault propagates to minimize additional damage thus extending the time before necessary repairs. The goal of a CMS is to maximize availability while reducing operating and maintenance costs.

3.1.104**machinery protection system****MPS**

The system that senses, measures, monitors, and displays machine parameters indicative of its operating condition. When a parameter exceeds predefined limits, indicating an abnormal condition, the system will communicate the event to operators and/or a shutdown system. The goal of the system is to mitigate damage to the machine. The system consists of the transducer system, signal cables, the monitor system, all necessary housings and mounting fixtures, and documentation (see Figure 1).

3.1.105**machinery protection system vendor****MPS vendor**

The agency that designs, fabricates, configures/programs, and tests components of the MPS.

3.1.106**machinery train**

The driver(s) and all of its associated driven pieces of equipment.

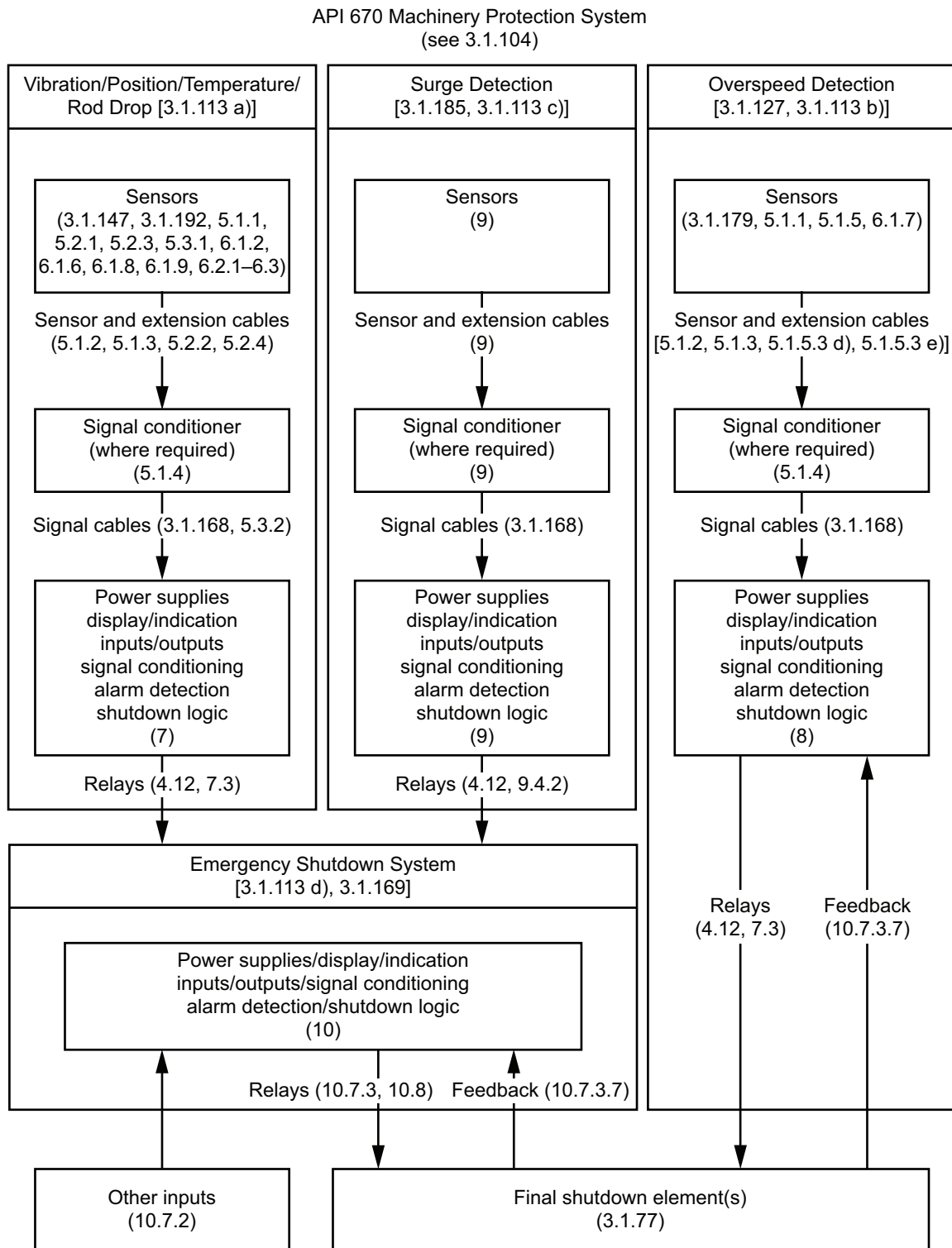


Figure 1—Machinery Protection System

3.1.107**machinery vendor**

The agency that designs, fabricates, and tests machines. The machinery vendor may purchase the monitor system or transducer system, or both, and may install the transducers or the sensors on machines.

3.1.108**magnetic speed sensor**

Responds to changes in magnetic field reluctance as the gap between the sensor and its observed ferrous target (speed sensing surface) changes. By choosing a proper speed sensing surface, the magnetic speed sensor's output will be proportional to the rotational speed of the observed surface. Magnetic speed sensors may be either passive (self-powered) or active (require external power).

3.1.109**mechanical runout**

A source of error in the output signal of a proximity probe system resulting from surface irregularities, out-of-round shafts, and such.

3.1.110**megaHertz****MHz**

Unit of frequency equal to one million Hertz or cycles per second.

3.1.111**misalignment**

The degree to which the axes of machine components are noncollinear, either in offset or angularity.

3.1.112**mode shape**

The deflection shape of a machine and support structure due to an applied dynamic force at a natural frequency; also used for the deflection shape of a forced response.

3.1.113**monitor system**

Consists of signal processing, alarm/shutdown/integrity logic processing, power supply(ies), display/indication, inputs/outputs, and protective relays (see Figure 1 and Figure 2). Monitor systems defined in this document are:

- a) vibration monitoring system (see Section 7),
- b) electronic overspeed detection system (ODS) (see Section 8),
- c) surge detection system (see Section 9),
- d) ESD (see Section 10).

Power supply(ies)	Vibration channel(s)	Thrust channel(s)	Accelerometer channel(s)	Piston rod drop channel(s)	Speed indicating channel(s)	Temperature channel(s)	Electronic overspeed detection monitor
							Redundant power supplies 3 overspeed sensing channel(s)

Figure 2—Standard Monitor System Nomenclature

3.1.114**natural frequency**

The frequency of free vibration of a mechanical system at which a specific natural mode shape of the system elements assumes its maximum amplitude.

3.1.115**negative averaging**

A technique that isolates specific vibration components by subtracting two measured signals from each other.

3.1.116**nonintegral display**

A display that is not contiguous with the other components comprising the monitor system.

3.1.117**nonsynchronous**

Any component of a vibration signal that has a frequency not equal to an integer multiple of shaft rotational speed (1X).

3.1.118**Np**

The number of electrical poles in a motor.

3.1.119***n*X amplitude**

The vibration amplitude at *n* times running speed, where *n* is an integer. (See also **harmonics**.)

3.1.120**observed**

The purchaser shall be notified of the timing of the inspection or test; however, the inspection or test shall be performed as scheduled, and if the purchaser or his/her representative is not present, the MPS vendor shall proceed to the next step. (The purchaser should expect to be in the factory longer than for a witnessed test.)

3.1.121**oil whirl**

(See **bearing instability**.)

3.1.122**OPC**

Standard that specifies communication of real-time plant data between control devices from different manufacturers (formerly an acronym).

3.1.123**orbit**

The path of the shaft centerline motion at the probe location during rotation.

3.1.124**orthogonal frequency division multiplexing**

System for transmission of digital message elements spread over multiple channels within a frequency band.

3.1.125**oscillator-demodulator**

A signal conditioning device that sends a radio frequency signal to a proximity probe, demodulates the probe output, and provides an output signal suitable for input to the monitor system.

3.1.126**overall**

A value representing the magnitude of vibration over a frequency range determined by the design of the instrument or as specified. Expressed as rms, zero-peak (0-P), or peak-to-peak (P-P).

3.1.127**overspeed detection system****ODS**

A system that consists of speed sensors, power supplies, output relays, signal processing, and alarm/shutdown/integrity logic. Its function is to continuously measure shaft rotational speed and activate its output relays when an overspeed condition is detected.

3.1.128**overspeed protection system**

An electronic ODS and all other components necessary to shut down the machine in the event of an overspeed condition. It may include (but is not limited to) items such as shutdown valves, solenoids, and interposing relays.

NOTE Only electronic ODS's are addressed in this standard. Mechanical ODS's are intentionally not addressed.

3.1.129**owner**

The final recipient of the equipment who will operate the machinery and its associated MPS and may delegate another agent as the purchaser of the equipment.

3.1.130**packet data**

Information reduced to digital pieces or "packets" so it can travel more efficiently across networks, including radio airwaves and wireless networks.

3.1.131**packet switched data**

Efficient technology used for data communication across the Internet.

3.1.132**passive magnetic speed sensor**

A magnetic speed sensor that does not require external power to provide an output.

3.1.133**path loss**

range loss

Attenuation (in dB) of a wireless signal as it travels between antennas.

3.1.134**peak-to-peak value****pp**

The difference between positive and negative extreme values of an electronic signal or dynamic motion.

3.1.135**personal communications services**

Broad family of wireless services including two-way digital voice, messaging, and data services.

3.1.136**personal digital assistant**

Portable computing device capable of transmitting data.

3.1.137**phase angle**

The timing relationship, in degrees, between two signals, such as a once-per-revolution reference probe and a vibration signal.

3.1.138**phase reference transducer**

A gap-to-voltage device that consists of a proximity probe, an extension cable, and an oscillator-demodulator and is used to sense a once-per-revolution mark.

3.1.139**piston rod drop**

A measurement of the position of the piston rod relative to the proximity probe mounting location(s) (typically oriented vertically at the pressure packing box on horizontal cylinders).

NOTE Piston rod drop is an indirect measurement of the piston rider band wear on reciprocating machinery (typically addressed by API 618).

3.1.140**point of presence**

The interconnectivity points between networks or population of transceivers.

3.1.141**polar plot**

A graphical format used to display vectors (amplitude and phase) on a polar coordinate system.

3.1.142**positive indication**

An active (i.e. requires power for annunciation and changes state upon loss of power) display under the annunciated condition. Examples include an LED that is lighted under the annunciated condition or an LCD that is darkened or colored under the annunciated condition.

3.1.143**predictive maintenance**

Maintenance performed based on the detection of faults and/or the prediction of failure.

3.1.144**preload**

A unidirectional, axial, or radial static load due to external or internal mechanisms. Also applied to the installation configuration of certain bearing types such as tilting pad bearings.

3.1.145**pressure sensor**

A device that measures the force per unit area of liquids or gasses.

3.1.146**preventive maintenance**

Maintenance performed according to a fixed schedule or according to a prescribed criterion that is intended to allow for the detection of faults, typically by inspection, and the replacement of wearable parts before faults develop or before a fault can propagate to failure.

3.1.147**primary probes**

Those proximity probes installed at preferred locations and used as the default inputs to the monitor system.

3.1.148**probe area**

The area observed by the proximity probe during measurement.

3.1.149**probe gap**

The physical distance between the face of a proximity probe tip and the observed surface. The distance can be expressed in terms of displacement (mils, micrometers) or in terms of voltage (Vdc).

3.1.150**protocol**

Standard definitions governing formatting of communications across networks and between devices.

3.1.151**proximity probe**

A noncontacting sensor that consists of a tip, a probe body, an integral coaxial or triaxial cable, and a connector and is used to translate distance (gap) to voltage when used in conjunction with an oscillator-demodulator.

3.1.152**purchaser**

The agency that issues the order and specification to the vendor.

3.1.153**radial shaft vibration**

The vibratory motion of the machine shaft in a direction perpendicular to the shaft longitudinal axis.

3.1.154**radio**

The transceiving device-part of all radio frequency systems.

3.1.155**remote**

Refers to the location of a device when located away from the equipment or console, typically in a control room.

3.1.156**repeater**

Devices that receive, amplify, and retransmit radio signals to extend range of wireless networks.

3.1.157**resistance temperature detector****RTD**

A temperature sensor that changes its resistance to electrical current as its temperature changes.

3.1.158**resolution**

The smallest increment of measure. In analog to digital conversion (A/D) systems, resolution is calculated as the full-scale value divided by 2^n where “ n ” is the number of bits of the analog to digital converter. In a spectra plot, resolution refers to the frequency change from one bin to the next, calculated as $F_{\text{max}}/\text{number of FFT lines}$.

3.1.159**root mean square****rms**

The square root of the mean of the sum of the squares of the sample values.

3.1.160**router**

A switching device in a network that directs and controls the flow of data through the network.

3.1.161**rub**

Potentially severe machine fault consisting of contact between the rotating and stationary parts of a machine.

3.1.162**self-organizing network**

A technology that dynamically manages configuration and communications, automatically making changes as needed to ensure messages reach their destinations efficiently and reliably.

3.1.163**sensor**

A device (such as a proximity probe or an accelerometer) that detects the value of a physical quantity and converts the measurement into a useful input for another device.

3.1.164**shaft bow**

A condition of deformation of a shaft that results in a curved shaft centerline.

3.1.165**shaft vibration or position transducer**

A gap-to-voltage device that consists of a proximity probe, an extension cable, and an oscillator-demodulator.

3.1.166**short messaging service**

A protocol that enables "text messaging."

3.1.167**shutdown (danger) setpoint**

A preset value of a parameter at which automatic or manual shutdown of the machine is required.

3.1.168**signal cable**

The field wiring interconnection between the transducer system and the monitor system.

NOTE Signal cable is typically supplied by the construction agency.

3.1.169**signal processing**

Transformation of the output signal from the transducer system into the desired parameter(s) for indication and alarming. Signal processing for vibration transducers may include, for example, peak-to-peak, zero-to-peak, or rms amplitude detection; pulse counting; DC bias voltage detection; and filtering and integration. The output(s) from the signal processing circuitry are used as inputs to the display/indication and alarm/shutdown/integrity logic circuitry of a monitor system.

3.1.170**signal-to-noise ratio**

The ratio of the power of the signal conveying information to the power of the signal not conveying information.

3.1.171**slow roll**

A machine state in which the shaft is rotating but too slowly for any consequential vibratory (dynamic) forces to develop.

3.1.172**spare probes**

Probes installed at alternate locations to take the place of primary probes (without requiring machine disassembly) in the event of primary probe failure.

3.1.173**spectrum allocation**

The federal government's designation of frequencies.

3.1.174**spectrum assignment**

The federal government's authorization for use of specific frequencies within a given spectrum allocation, usually in a specific geographic location.

3.1.175**spectrum averaging**

The averaging of multiple spectra to reduce random nonrecurring frequency components.

3.1.176**spectrum plot**

An x-y plot in which the x-axis represents vibration frequency and the y-axis represents amplitudes of vibration components. A full spectrum plot is an enhanced spectrum plot produced by using the timebase waveforms from XY transducers to calculate the amplitudes of the forward and reverse (backward) frequency components. A half spectrum plot displays forward or positive frequency components only.

3.1.177**speed**

The frequency at which a shaft is rotating at a given moment, usually expressed in units of revolutions per minute (rpm) or revolutions per second (rps).

3.1.178**speed sensing surface**

A gear, toothed-wheel, or other surface with uniformly-spaced discontinuities that causes a change in gap between the speed sensing surface and its associated speed sensor(s) as the shaft rotates.

3.1.179**speed sensor**

A proximity probe or magnetic speed sensor used to observe a speed sensing surface. It provides an electrical output proportional to the rotational speed of the observed surface.

3.1.180**spread spectrum**

Transmitting radio signals by using a wide range of frequencies

3.1.181**standard option**

A generally available alternative configuration that may be specified in lieu of the default configuration specified herein.

3.1.182**static data**

That aspect of a signal that can be fully characterized by a single static or vector quantity.

NOTE Examples include waveform DC bias (e.g. probe gap voltage), waveform amplitude, waveform period, or the amplitude/phase of a discrete vibration frequency such as 1X. Static data is so named because although changes in static values occur over time, the changes constitute a trend rather than a repeating waveform and are typically measured in seconds, minutes, hours, or days rather than in milliseconds.

3.1.183**steady state data**

Data acquired from a machine at constant shaft rotational speed and process conditions.

3.1.184**subsynchronous**

The component of a vibration signal that has a frequency less than 1X shaft rotational speed.

3.1.185**surge**

At a given head, the minimum volumetric flow for a specific set of gas conditions below which a centrifugal or axial compressor becomes aerodynamically unstable.

3.1.186**surge cycle**

Consists of a flow reversal accompanied by fluctuations in the compressor pressure and temperature followed by flow recovery.

3.1.187**surge detection system**

Consists of surge sensors (typically temperature, pressure, or flow), power supplies, output relays, signal processing, and alarm/shutdown/integrity logic. Its function is to continuously measure and count surge cycles.

3.1.188**surge limit line**

The line formed by theoretical or tested surge points across the head range of the compressor.

3.1.189**surge point**

(See **surge** in 3.1.185.)

3.1.190**synchronous**

The component of a vibration signal that has a frequency equal to an integer multiple of the shaft rotational speed (1X). (See also **time synchronous averaging**.)

3.1.191**synchronous sampling**

The sampling of a vibration waveform initiated by a shaft phase-reference transducer.

3.1.192**tachometer**

A device for indicating shaft rotational speed.

3.1.193**temperature sensor**

A thermocouple or RTD and its integral sensor lead.

3.1.194**thermocouple**

A temperature sensor consisting of two dissimilar metals so joined to produce different voltages when their junction is at different temperatures.

3.1.195**third generation**

Technologies that offer increased capacity and capabilities delivered over digital wireless networks.

3.1.196**time division multiple access**

Convention for transmission of information by dividing into time slots so a single channel can carry many calls at once.

3.1.197**time synchronous averaging**

The averaging of multiple synchronously sampled waveforms to reduce the nonrotational-related frequency components.

3.1.198**topology**

Arrangement of network components. Describes both physical layout of devices, routers, and gateways and the paths that data follows between them. Three common wireless topologies for in-plant wireless field network applications are star, mesh (self-organizing), and cluster tree.

3.1.199**transducer system (centrifugal machinery)**

A proximity probe, accelerometer, or sensor, an extension or accelerometer cable, and oscillator-demodulator (when required). The transducer system generates a signal that is proportional to the measured variable (see Figure 3).

3.1.200**transducer system (reciprocating compressor and surge detection)**

In reciprocating compressor and surge detection applications, other measured variables may be required. Variables include pressure, differential pressure, flow, liquid level, temperature, etc. In these applications, the system consists of a sensor, a transmitter, and associated electrical cable.

NOTE Pressure and flow transducer nomenclature can be found in API 554.

3.1.201**transient data**

The data acquired from a machine at variable shaft rotational speed and process conditions.

3.1.202**transmission control protocol/internet protocol**

Protocol permitting communications over and between networks, the basis for Internet communications.

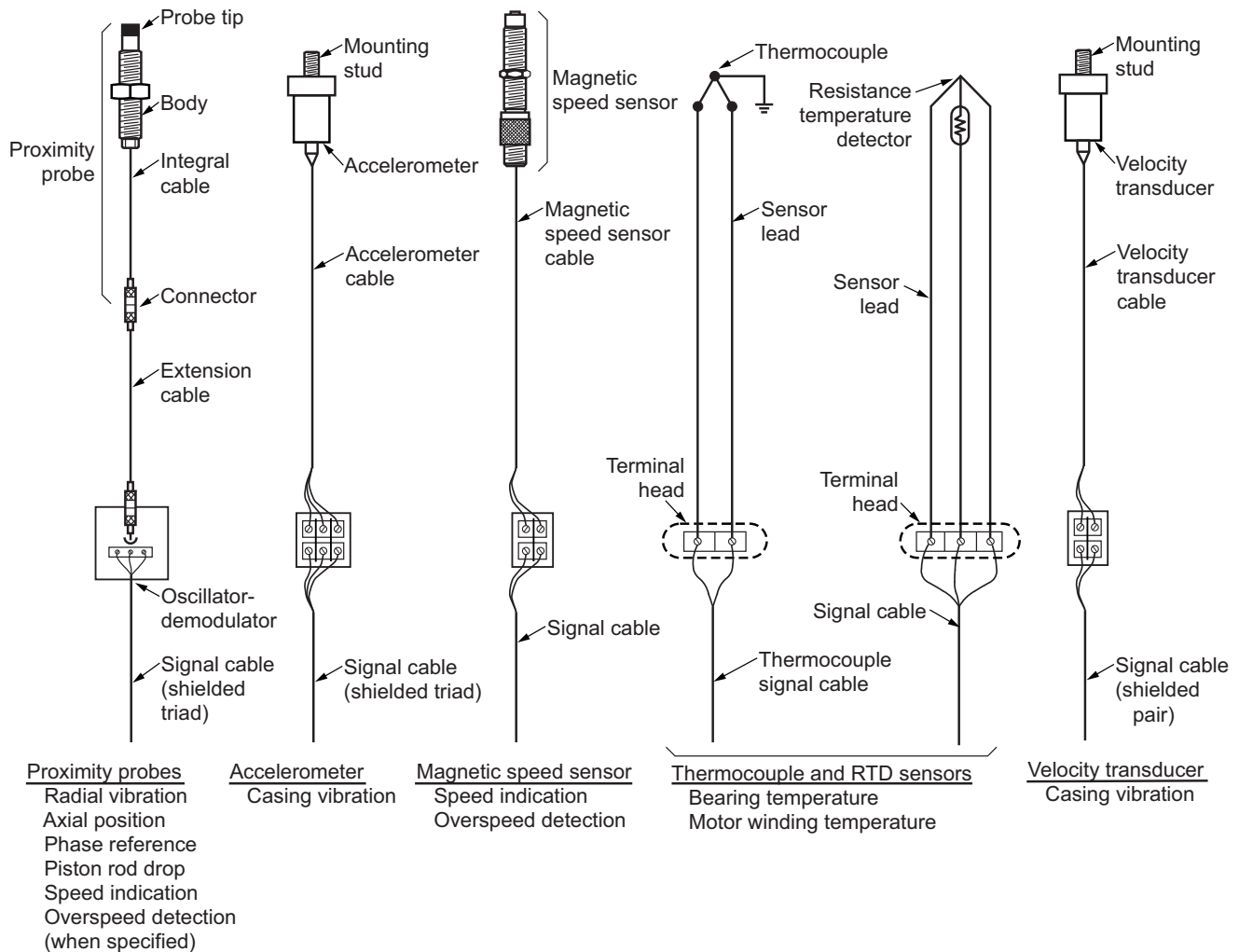


Figure 3—Transducer System Nomenclature

3.1.203

transmitter (reciprocating compressor and surge detection)

A device that consists of a sensor and a signal conditioner, usually combined into one assembly. The electrical output is proportional to the magnitude of the sensed condition and bounded by a range (lower and upper limits) (i.e. 4 mA to 20 mA). Transmitters are not used or included in the class of transducer systems defined in 3.1.199.

3.1.204

transverse sensitivity

An accelerometer's response to dynamic loads applied in a direction perpendicular to the principal axis. It is also sometimes called cross-axis sensitivity.

3.1.205

trend

Any parameter whose magnitude is displayed as a function of time.

3.1.206**trend parameter**

A characteristic extracted from a vibration spectrum or waveform. This analysis technique is often referred to as frequency band monitoring. Typical examples include the vibration within a fixed or variable frequency band or peak and phase values for a specific harmonic of shaft speed.

NOTE Any parameter associated with machinery can be displayed as a function of time.

3.1.207**tri-band handset**

Multiple frequency phones, typically in the 1900 MHz, 800 MHz, and 900 MHz frequencies used in the United States and elsewhere.

3.1.208**tri-mode handset**

Phones that operate in different modes such as the CDMA, time division multiple access, and analog standards.

3.1.209**unbalance**

A rotor condition where the mass centerline (principal axis of inertia) does not coincide with the geometric centerline, expressed in units of gram-inches, gram-centimeters, or ounce-inches.

3.1.210**unfiltered**

Data that is not filtered and represents the original transducer output signal.

3.1.211**unit responsibility**

Refers to the responsibility for coordinating the delivery and technical aspects of the equipment and all auxiliary systems included in the scope of the order. The technical aspects to be considered include, but are not limited to, such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubrication, sealing system, material test reports, instrumentation (such as the MPS), piping, conformance to specifications, and testing of components.

3.1.212**universal mobile telecommunications systems**

Third-generation technology based on wideband code division multiple access with speed between 384 kbps and up to about 2 Mbps.

3.1.213**vector**

A quantity that has both magnitude and angular orientation. For a vibration vector, magnitude is expressed as amplitude (displacement, velocity, or acceleration) and direction as phase angle (degrees).

3.1.214**velocity**

The time rate of change of displacement. Units for velocity are inches per second or millimeters per second.

3.1.215**velocity sensor—piezoelectric**

An accelerometer with integral amplification and signal integration such that its output is proportional to its vibratory velocity (5.2.3).

3.1.216**velocity sensor—moving coil**

An electromechanical type of transducer that contains a moving coil as a seismic mass suspended in a permanent magnetic field and outputs an analog signal proportional to the instantaneous velocity of the machine case (5.2.3).

3.1.217**voice recognition**

Capability for wireless phones, computers, and other devices to be activated and controlled by voice commands.

3.1.218**voted channel**

A channel requiring confirmation from one or more additional channels as a precondition for alarm (alert) and shutdown (danger) relay actuation.

3.1.219**waterfall plot**

A plot similar to cascade plot, except that the z-axis is usually time or another time-related function, such as load, instead of shaft rotational speed (rpm or rps).

3.1.220**waveform plot**

A presentation of the waveform of a signal as a function of time. A vibration time waveform can be observed on an oscilloscope in the time domain.

3.1.221**wideband code division multiple access**

One of two third-generation standards that makes use of wider spectrum than CDMA to transmit and receive information faster and more efficiently.

3.1.222**wi-max**

Technology based on IEEE 802.16 standard providing metropolitan area network connectivity for fixed wireless access at broadband speeds.

3.1.223**wireless application protocol**

Standards that enable wireless devices to browse content from specially-coded web pages.

3.1.224**wireless fidelity****WiFi**

Wireless connectivity over unlicensed spectrum (using the IEEE 802.11a or IEEE 802.11b standards), generally in the 2.4 GHz and 5 GHz radio bands. WiFi offers local area connectivity to WiFi-enabled computers.

3.1.225**wireless internet**

A general term for using wireless services to access the Internet, email, and/or the World Wide Web.

3.1.226**wireless private branch exchange**

Allows wireless communication within a building or limited area in place of traditional landlines.

3.1.227**witnessed**

A hold shall be applied to the production schedule and the inspection or test shall be carried out with the purchaser or his/her representative in attendance. For factory acceptance testing of the MPS, this requires written notification of a successful preliminary test.

3.1.228**wireless local area network**

Using radio frequency technology to transmit and receive data wirelessly in a certain area.

3.1.229**wireless local loop**

System connecting wireless users to public switched telephone network. Wireless systems can often be installed faster and cheaper than traditional wired systems.

3.2 Acronyms and Abbreviations

For the purposes of this document, the following acronyms and abbreviations apply.

AWG	American Wire Gage
CDMA	code division multiple access
CMS	condition monitoring system
cpm	cycles per minute
DC	direct current
E/E/PES	electrical/electronic/programmable electronic system
ESD	emergency shutdown system
FFT	fast Fourier transform
HFT	hardware fault tolerance
HSE	health, safety, and environment
Hz	Hertz
ips	inches per second
kHz	kiloHertz
LAN	local area network
mA	milliamp
MHz	megaHertz
MPS	machinery protection system
MTTF	mean time to failure
MTTF _d	mean time to fail to dangerous condition
MTTR	mean time to repair
mV	millivolt
N	Newton
ODS	overspeed detection system
OEM	original equipment manufacturer
PCB	printed circuit board
PES	programmable electronic system

PFD	probability of failure on low demand
PFD _{avg}	probability of failure on low demand, average
PFH	probability of failure on high demand (1/h)
PL	performance level
PLC	programmable logic controller
pp	peak-to-peak value
RBD	reliability block diagram
RFQ	request for quotation
rpm	revolutions per minute
rps	revolutions per second
rms	root mean square
RRF	risk reduction factor
RTD	resistance temperature detector
SFF	safe failure fraction
SIF	safety instrumented function
SIL	safety integrity level
SIS	safety instrumented system
SRS	safety requirement specification
SOV	solenoid operated valve
TI	proof test interval
USC	U.S. customary
Vac	volt AC
Vdc	volt DC
VFD	variable frequency drive
WiFi	wireless fidelity

4 General Design Specifications

4.1 Component Temperature Ranges

4.1.1 MPS components have two temperature ranges, testing range and operating range, over which accuracy shall be measured and in which the system components shall operate, as summarized in Table 1.

NOTE The testing range is a range of temperatures in which normal bench testing occurs. It allows verification of the accuracy and operation of transducer and monitor system components without the need for special temperature- or humidity-controlled environments. The operating range represents temperatures over which the transducer and monitor system components are expected to operate in actual service conditions.

4.1.2 For temperature ratings on other monitor system components (such as power supplies, relay, communication cards, displays), see Table 1.

4.2 Humidity

4.2.1 For transducer systems, the accuracy requirements of Table 1 shall apply at levels of relative humidity up to 100 % condensing, nonsubmerged, with protection of connectors.

4.2.2 For monitor system components, the accuracy requirements of Table 1 shall apply at levels of relative humidity up to 95 % noncondensing.

4.3 Shock

Accelerometers shall be capable of surviving a mechanical shock of 5000 g, peak, without affecting the accuracy requirements specified in Table 1.

4.4 Chemical Resistance

4.4.1 Probes, probe extension cables, and oscillator-demodulators shall be constructed of corrosion-resistant materials suitable for environments containing trace levels of chemicals such as hydrogen sulfide or ammonia.

NOTE 1 The intent of this subsection is to ensure that the standard probe system is compatible with commonly encountered bearing lube oil environments.

NOTE 2 Rod position probes may often be used in environments (such as sour gas compressors) containing elevated levels of hydrogen sulfide for which a standard probe system may not be suitable.

NOTE 3 Ammonia plants may contain atmospheres in which elevated levels of ammonia are present and for which a standard probe system may not be suitable.

- **4.4.2** If specified, probes, probe extension cables, and oscillator-demodulators shall be compatible with an environment containing other chemicals or concentrations (4.4.1).
- **4.4.3** The purchaser shall specify the list of required chemicals and concentrations.

4.5 Accuracy

4.5.1 Accuracy of the transducer system and monitor system in the testing and operating temperature ranges shall be as summarized in Table 1.

4.5.2 If monitor system components or transducer system components will be used in applications exceeding the requirements of Table 1, the MPS vendor shall supply documentation showing how the accuracy is affected or suggest alternative transducer and monitor components suitable for the intended application.

NOTE 1 Some applications may require piston rod drop and axial position measurements with measuring ranges greater than 2 mm (80 mil). Special transducer systems, such as those with 3.94 mV/ μ m (100 mV/mil) scale factors, are required for these applications and are not covered by this standard.

NOTE 2 Gas turbines may require special high-temperature seismic sensors that exceed the operating range specified in Table 1 and monitor systems with special filtering based on original equipment manufacturer (OEM) recommendations. Consult the MPS vendor.

NOTE 3 Radial vibration or position measurements using proximity probe transducers on shaft diameters as small as 76 mm (3 in.) do not introduce appreciable error compared to measurements made on a flat target area. Shaft diameters smaller than this can be accommodated but generally result in a change in transducer scale factor. Consult the MPS vendor.

NOTE 4 Proximity probe measurements on shaft diameters smaller than 50 mm (2 in.) may require close spacing of radial vibration or axial position transducers with the potential for their electromagnetic emitted fields to interact with one another (cross talk) resulting in erroneous readings. Care should be taken to maintain minimum separation of transducer tips, generally at least 40 mm (1.6 in.) for axial position measurements and 74 mm (2.9 in.) for radial vibration measurements.

4.5.3 The proximity probe transducer system accuracy shall be verified on the actual probe target area or on a target with the same electrical characteristics as those of the actual probe target area (see Figure 4).

4.5.4 When verifying the accuracy of any individual component of the proximity probe transducer system in the operating range, the components not under test shall be maintained within the testing range.

Table 1—Machinery Protection System Accuracy Requirements

Components	Temperature		Accuracy Requirements as a Function of Temperature	
	Testing Range	Operating/ Storage Range	Within Testing Range	Outside Testing Range but Within Operating Range
Proximity probes	0 °C to 45 °C (32 °F to 110 °F)	–35 °C to 120 °C (–30 °F to 250 °F)	Incremental scale factor ^a : ±5 % of 7.87 mV/μm (200 mV/mil)	Incremental scale factor ^a : an additional ±5 % of the testing range accuracy
Extension cables	0 °C to 45 °C (32 °F to 110 °F)	–35 °C to 65 °C (–30 °F to 150 °F)	Deviation from straight line ^b : within ±25.4 μm (±1 mil) of the best fit straight line at a slope of 7.87 mV/μm (200 mV/mil)	Deviation from straight line ^b : within ±76 μm (±3 mil) of the best fit straight line at a slope of 7.87 mV/μm (200 mV/mil)
Oscillator-demodulators	0 °C to 45 °C (32 °F to 110 °F)	–35 °C to 65 °C (–30 °F to 150 °F)	Minimum linear range: 2 mm (80 mil)	Minimum linear range: same as for testing range
Accelerometers and accelerometer extension cables ^c	20 °C to 30 °C (68 °F to 86 °F)	–55 °C to 120 °C (–65 °F to 250 °F)	Principal axis sensitivity ^f : 100 mV/g ± 5 % Amplitude linearity: 1 % from 0.1 g peak to 50 g peak ^d Frequency response ^e : ±3 dB from 10 Hz to 10 kHz, referenced to the actual measured principal axis sensitivity ^f	Principal axis sensitivity ^f : 100 mV/g ± 20 %
Temperature sensors and leads	0 °C to 45 °C (32 °F to 110 °F)	–35 °C to 175 °C (–30 °F to 350 °F)	±2 °C (±4 °F) over a measurement range from –20 °C to 150 °C (0 °F to 300 °F)	±3.7 °C (±7 °F) over a measurement range from –20 °C to 150 °C (0 °F to 300 °F)
Monitor system components for measuring:				
radial vibration, axial position, piston rod drop, and casing vibration	0 °C to 45 °C (32 °F to 110 °F)	–20 °C to 65 °C (0 °F to 150 °F)	±1 % of full-scale range for the channel	Same as for testing range
temperature			±1 °C (±2 °F)	Same as for testing range
speed			±1 % of alarm setpoint	Same as for testing range
overspeed			±0.1 % of shutdown setpoint or ±1 rpm, whichever is less	Same as for testing range
Other monitor system components (such as: power supplies, relay, communication cards, displays)		–20 °C to 65 °C (0 °F to 150 °F)		

^a The incremental scale factor (ISF) error is the maximum amount the scale factor varies from 7.87 mV/μm (200 mV/mil) when measured at specified increments throughout the linear range. Measurements are usually taken at 250 μm (10 mil) increments. ISF error is associated with errors in radial vibration and axial position readings.

^b The deviation from straight line (DSL) error is the maximum error (in mils) in the probe gap reading at a given voltage compared to a 7.87 mV/μm (200 mV/mil) best fit straight line. DSL errors are associated with errors in axial position or probe gap readings.

^c During the testing of the accelerometers, the parameter under test is the only parameter that is varied. All other parameters shall remain constant.

^d Conditions of test: at any one temperature within the testing range, at any single frequency that is not specified but is within the specified frequency range of the transducer.

^e Frequency response testing conditions: at any one temperature within the testing range, at an excitation amplitude that is not specified but is within the specified amplitude range of the transducer.

^f Principal axis sensitivity testing conditions: (testing range) at any one temperature within the testing range, at 100 Hz, at an excitation amplitude that is not specified but is within the specified amplitude range of the transducer. Operating range: at any one temperature within the operating range, at 100 Hz, at an excitation amplitude that is not specified but is within the specified amplitude range of the transducer.

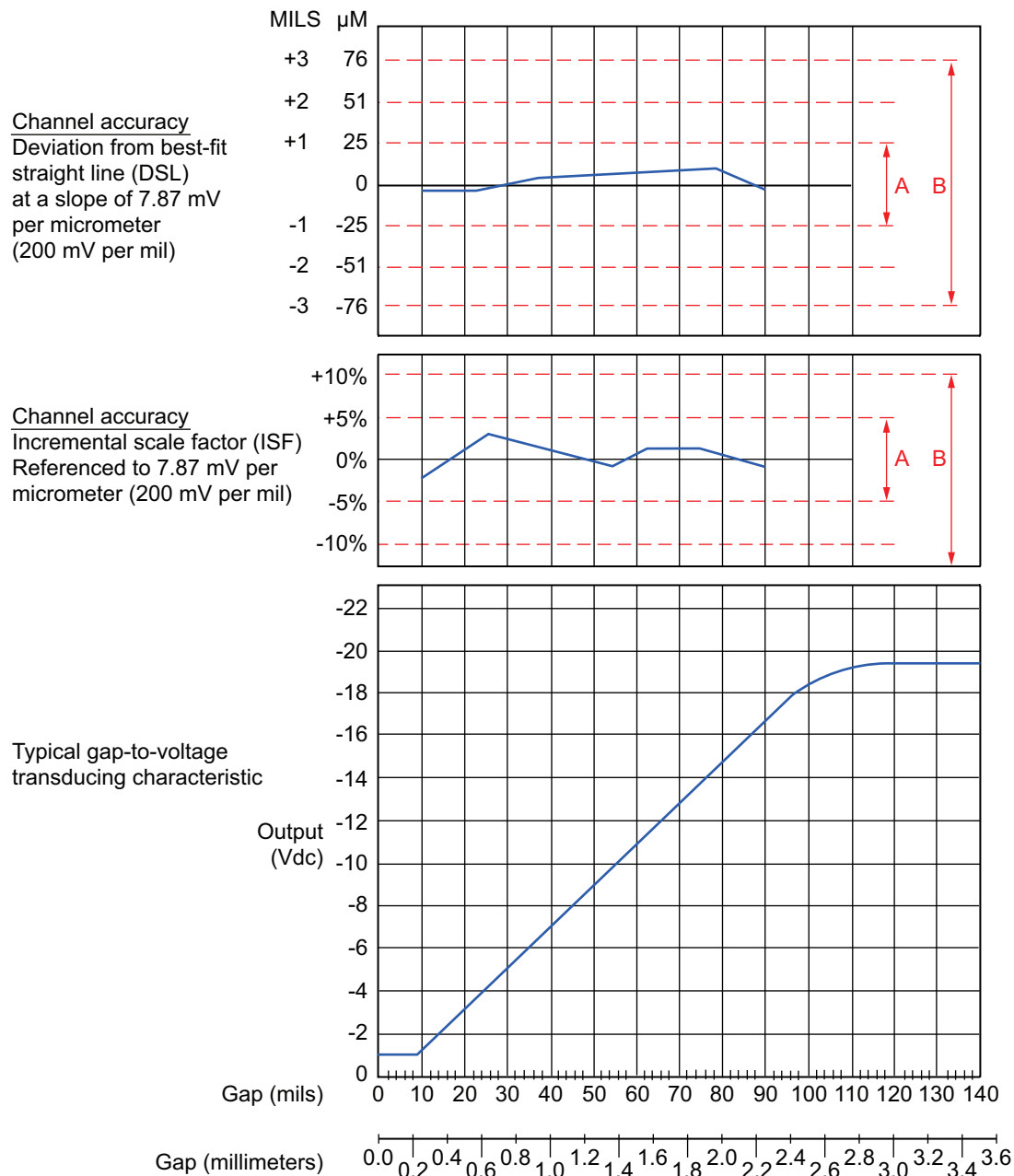


Figure 4—Typical Curves Showing Accuracy of Proximity Transducer System

4.6 Interchangeability

4.6.1 All components covered by this standard shall be physically and electrically interchangeable within the accuracy specified in Table 1. This does not imply that interchangeability of components from different MPS vendors is required or that oscillator-demodulators calibrated for different shaft materials are electrically interchangeable.

4.6.2 Unless otherwise specified, probes, cables, and oscillator-demodulators shall be supplied calibrated to the MPS vendor's standard reference target of AISI Standard Type 4140 steel.

NOTE Consult the MPS vendor for a precision factory target when verifying the accuracy of the transducer system to this standard. The MPS vendor should be consulted for applications using target materials other than AISI Standard Type 4140 steel as they may require factory recalibration of the transducer system.

4.7 Scope of Supply and Responsibility

4.7.1 For each train, the purchaser shall specify the agency or agencies responsible for each function of the design, scope of supply, installation, and performance of the monitoring system (see Annex B).

4.7.2 The details of systems or components outside the scope of this standard shall be mutually agreed upon by the purchaser and MPS vendor.

4.8 Segregation

4.8.1 The MPS shall be separate from and diverse of all other control or protective systems such that its ability to detect an alarm within the required response time on any monitored parameter and activate its system output relays (4.12) does not depend in any way upon the operation of these other systems.

NOTE The intent of this subsection is to prevent the MPS hardware from being combined with hardware from other control and automation systems, thereby eliminating common-cause failure modes and protecting the machine in the event of failure of its associated machinery control system or failure of the process control system. It is not intended to prohibit the inclusion of condition monitoring functionality within the MPS, provided failure of those functions does not impact the protective functions. See also Annex N.

4.8.2 Wireless technologies shall not be used for protective functions (see Table 2).

NOTE Annex N contains a discussion of permissible wireless condition monitoring applications, and Annex Q provides a basic tutorial on wireless technology.

4.9 System Enclosures and Environmental Requirements

4.9.1 Field-installed MPS installations shall be suitable for the area classification (zone or class, group, and division) specified by the purchaser and shall meet the requirements of the applicable sections of IEC 60079/NFPA 70 (Articles 500, 501, 502, 504, and 505) as well as any local codes specified and furnished on request by the purchaser. If instruments are located outdoors or are subject to fire sprinklers, their housings shall be watertight (IP 65/NEMA Type 4 stainless steel), as specified in IEC 60079/NEMA 250, in addition to any other enclosure requirements necessary for the area classification in which the instrument is installed. Nonincendive or intrinsically safe instruments are preferred (see Note). When air purging is specified to meet the area classification, it shall be in accordance with ISA S12.4 or with NFPA 496, Type X, Y, or Z, as required.

NOTE Explosion-proof or intrinsically safe instrumentation is acceptable for Class I, Division 1 and Division 2 hazardous (classified) locations; nonincendive instrumentation is acceptable for Class I, Division 2 hazardous (classified) locations when installed in accordance with Article 501, NFPA 70.

- **4.9.2** If specified, air purging shall be used to avoid moisture or corrosion problems, even when weatherproof or watertight housings are used (see 4.9.1). Purge air shall be clean and dry.

NOTE Circuit board and backplane connectors may require additional corrosion resistance in extreme environments (i.e. gold-plating, gas tight connector design, and so forth). Consult the MPS vendor for availability.

Table 2—Summary of Allowable Usage of Wireless Technology for Machinery Protection Systems

Input or Output	Type	Description	670 Subsection/ Paragraph	Integral Part of Machinery Protection Loop?	Wireless Media Permitted?	Notes
Input/ output	Interconnection	All interconnections between the monitor system components depicted in Figure 1, with exception of a nonintegral display	Figure 1	Y	N	If the components separated by dotted lines in Figure 1 are composed of physically separate systems interconnected by hardwiring as opposed to a contiguous system design that interconnects functions via circuit board traces or a common backplane (i.e. a traditional "rack-based" system), then such interconnections may not use wireless transmission media.
		Circuit fault indicators	4.11.4 b)	Y	N	To annunciate circuit faults within the protection system, independent of other display functionality, such as bar graphs.
		Channel alert indicator	4.11.7 e)	Y	N	
		Channel danger indicator	4.11.7 d)	Y	N	
	Display	Channel danger bypass indication	4.11.7 f)	Y	N	
		Integral display indication	7.1.9	Y	N	An integral display is the default option and when used, employs a hardwired connection. When an optional nonintegral display is specified in lieu of an integral display, it may use a wireless connection. However, the requirements of 4.11.7 still apply.
		"Blind monitor" indication	7.1.10	Y	N	Loss of a nonintegral display should not render the underlying protection system completely blind. As such, the nonintegral display may be wireless, but the minimal display requirements described in this paragraph may not be wireless.
		System danger bypass indication	4.11.5 f)	Y	N	A relay contact that allows external annunciation that the monitoring system is bypassed and machinery protection functionality is disabled. For example, to turn on an indicator in an annunciation panel in a control room or a large red warning light on the machine control cabinet.
	Alarm	Setpoint multiplier indication	7.4.1.6 a); 7.4.4.4	Y	N	The annunciation of this condition is absolutely critical so that if falsely activated, it can be rectified. It is unacceptable for the monitor to be in this condition and the operator not to know about it because a wireless transmission link has failed or updates too infrequently.
		Signal from alert detection circuitry to alert relay	4.11.5 b)	Y	N	
		Signal from danger detection circuitry to danger relay	4.11.5 c)	Y	N	
		System output relays	4.12	Y	N	These are the primary intended output mechanisms for providing machinery protection because of the integrity of relays, the speed with which they act, and the various facilities within the monitoring system to properly suppress the relays under circuit fault conditions or deliberate bypass conditions.



Table 2—Summary of Allowable Usage of Wireless Technology for Machinery Protection Systems (Continued)

Input or Output	Type	Description	670 Subsection/ Paragraph	Integral Part of Machinery Protection Loop?	Wireless Media Permitted?	Notes
Input	Transducers and Wiring	Proximity probes, extension cables, oscillator-demodulators, and field wiring from oscillator-demodulators to monitor modules	5.1.1; 5.1.2; 5.1.3; 5.1.4	Y	N	
		Magnetic speed sensors, cables, and field wiring from sensor to monitor	5.1.5	Y	N	
		Accelerometers, cables, and field wiring from accelerometers to monitors	5.2	Y	N	
		Temperature sensor wiring	5.3.2	Y	N	
		Monitor configuration ports/switches	7.1.3 c)	Y	N	
	Configuration	Gain adjustment	7.1.4 a)	Y	N	
		System danger bypass activation	4.11.7	Y	N	Typically a keylock or other controlled mechanism to bypass the monitoring system while it is being maintained. It could conceivably be activated via a wireless link, but the annunciation/indication that the monitor is in a shutdown bypass condition is too critical to entrust to a wireless link. It is unacceptable for the monitor to be in this condition and the operator to not know about it because a wireless transmission has failed or updates too infrequently.
	Condition monitoring	Setpoint multiplier activation	7.4.1.6 a); 7.4.4.4	Y	N	The purpose of this input is discussed in length in Annex I.
		Digital interface for connection to condition monitoring system/software	new	N	Y	Typically incorporates a proprietary protocol for use between a vendor's 670 protection system and that vendor's corresponding condition monitoring software.
		Buffered outputs	4.11.4 d)	N	Y	Intended for connection to portable instruments such as route-based data collectors, oscilloscopes, data acquisition instruments, and test/calibration equipment such as multimeters.
Output	Control system	Digital comm port for process control interface	4.11.4 f)	N	Y	Primarily intended for sending pertinent monitor information to a DCS, PLC, machine control system, or human machine interface, emulating status indicators and current values that are provided by the monitor's integral (or nonintegral) display.
		4 mA to 20 mA proportional analog outputs	4.11.4 e)	N	Y	Connection to strip chart recorders, or analog interfacing to process control systems to emulate display of variables measured by machinery protection system.
	Display	Link between "monitor system" and nonintegral display	Figure 1; 3.1.116	N	Y	A "blind monitor system" (3.1.31) still provides minimal integral display functionality (7.1.10), and this minimal integral display functionality may not incorporate wireless transmission media.
	Switch	Rear-panel remote alarm reset/acknowledgment	4.11.5 h)	N	Y	This does not relax the requirement for a front-panel manual switch discussed in this paragraph.

4.9.3 The satisfactory operation of electronic instrumentation in the presence of radio frequency interference requires that both the level and the form of the interference, as well as the required degree of immunity to it, be clearly defined by the owner (one company may not allow the use of radios in a control room whereas another may allow their use behind instrument panels in the control room while the enclosures are open). Once the requirement for immunity to radio frequency interference is defined, the details of electronic design and hardware installation can be established (see Note). Unless otherwise specified, MPS's shall comply with the electromagnetic radiation immunity requirements of EN 61000-6-2 and shall use metallic conduit or armored cable.

NOTE In addition to sound practices in the areas of instrument design, grounding, and shielding, the use of metallic conduit or armored cable and radio frequency interference (conductive) gasketing is critical to a successful installation. To ensure a trouble-free installation, the detailed requirements of a particular system should be discussed during the procurement phase by the MPS vendor, the construction agency, and the owner. The MPS vendor does not usually have control over all aspects of the system installation.

- **4.9.4** If specified, printed circuit boards (PCBs) shall have conformal coating to provide protection from moisture, fungus, and corrosion.

NOTE It may not be possible or desirable to conformal coat PCBs in all monitor applications. Examples include complex circuit boards containing heat sinks, DIP switches, or complex interconnections. In general, field-mounted systems in humid or corrosive environments justify conformal coating. Contact MPS vendor for specific details and capabilities.

4.10 Power Supplies

4.10.1 All machinery protection monitor systems shall be capable of meeting the accuracy requirements specified in Table 1 with input voltage to the power supply of 90 Vac rms to 132 Vac rms or 180 Vac rms to 264 Vac rms, switch selectable, with a line frequency of 48 Hz to 62 Hz.

4.10.2 If specified, the following power supply options may be used:

- a) 19 Vdc to 32 Vdc,
- b) 14 Vdc to 70 Vdc,
- c) 90 Vdc to 140 Vdc.

4.10.3 All machinery protection monitor system power supply(ies) shall be capable of supplying power to its components as defined in 3.1.113.

NOTE Nonintegral displays are exempted from this requirement and may be powered by external supplies.

4.10.4 All power supplies shall be capable of sustaining a short circuit of indefinite duration across their outputs without damage. Output voltages shall return to normal when an overload or short circuit is removed.

4.10.5 All transducer power sources shall be designed to prevent a fault condition in one transducer circuit from affecting any other channel.

4.10.6 All power supplies shall be immune to an instantaneous transient line input voltage equal to twice the normal rated peak input voltage for a period of 5 μ s.

4.10.7 Transient voltage shall not damage the power supplies or affect normal operation of the monitor system.

4.10.8 All power supplies shall continue to provide sufficient power to allow normal operation of the monitor system through the loss of AC power for a minimum duration of 50 ms.

4.10.9 As a minimum, the input power supply transformer for all instruments shall have separate windings with grounded laminations or shall be shielded to eliminate the possibility of coupling high voltage to the transformer secondary. In case of an insulation fault, the input voltage shall be shorted to ground.

- **4.10.10** If specified, the machinery protection monitor system shall be fitted with a redundant power supply. Each power supply shall:
 - a) accept the same input voltages or different input voltages as the other power supply (for input voltage options, see 4.10.1 and 4.10.2);
 - b) independently supply power for the entire machinery protection monitor system such that a failure in one supply and its associated power distribution busses shall not affect the other;
 - c) allow removal or insertion with power applied without affecting the operation or integrity of the protection system;
 - d) provide automatic switchover from one power supply to the other without affecting the operation or the integrity of the protection system.

4.10.11 The power supplies of all machinery protection monitor systems shall be energized by the purchaser's independent and uninterruptible instrument branch power circuits.

4.11 Machinery Protection System Features/Functions

- **4.11.1** If specified, the requirements of SIS's shall apply to some or all of the MPS, and the MPS supplier(s) shall provide the reliability/performance documentation to allow the SIS supplier to determine the safety integrity level (SIL) for the SIS. SIS requirements are specified by IEC 61508. The purchaser shall be responsible for the following.
 - a) Identify and ensure compliance with any applicable law that mandate the use of functional safety methods.

NOTE 1 The use of the methods of functional safety is mandatory for personnel and environmental risks.

NOTE 2 When an instrumented system is used to reduce health and safety risks to personnel or the environment, several countries now have legislation mandating the use of functional safety methods as described in IEC 61508, IEC 61511, ANSI/ISA 84.00.01, IEC 62061, or ISO 13849. The end user has to perform the risk assessment for the entire plant. Local laws may require equipment vendors to perform their own risk assessment and SIL classification additionally.

NOTE 3 See Annex L for a discussion of functional safety methodologies and typical calculations as they apply to MPS's.

- b) Perform the risk assessment for the entire process.

NOTE 1 The purchaser has the overall responsibility for the safety of the process.

NOTE 2 If the vendor has performed his/her own risk assessment with different requirements, the highest requirement governs.

- c) Determine the particular SIL required for each measurement within the MPS. A list with all safety instrumented functions (SIFs) and corresponding SIL shall be provided to the machine and MPS vendor along with the request for quotation (RFQ). Additional information such as minimum proof test interval (TI), required mean time to repair (MTTR), etc., may need to be provided with the RFQ.

NOTE 1 In some instances, different SILs will pertain to different measurements within the MPS. For example, a single MPS may have SIL 3 requirements for the overspeed detection, but SIL 1 requirements for other measurements.

NOTE 2 When determining a SIL for a particular measurement, protection of health and environment has priority over equipment protection and avoidance of economic losses.

- d) Identify with the RFQ the data and/or certification(s) that the MPS vendor shall supply to demonstrate compliance with the appropriate SIL.
- e) Identify whether the methods of functional safety apply to risks beyond health, safety, and environment (HSE), such as equipment damage, production loss, reputation loss.

NOTE 1 The use of the methods of functional safety is mandatory for personnel and environmental risks.

NOTE 2 See Annex M for a discussion of methods to reduce economic losses.

4.11.2 It is the responsibility of the vendor(s) to support the activity of 4.11.1 with the appropriate data.

4.11.3 At minimum, each machinery protection monitor system shall be provided with the following features and functions:

- a) a method of energizing all indicators for test purposes;
- b) an internal timeclock with provisions for remotely setting the time and date through the digital communication port of 4.13.1;

NOTE The internal clock time setting or synchronization should be made with the master remote clock and the monitor system internal clock for effective time correlation of events.

- c) all modules capable of removal and insertion while the system is under power without affecting the operation of, or causing damage to, other unrelated modules.

NOTE It is not the intent of this paragraph to permit module removal/replacement in hazardous areas without appropriate precautions taken by the end user, such as in purged panels, explosion-proof housings, etc.

4.11.4 A MPS shall include the following signal processing functions and outputs.

- a) Isolation to prevent a failure in one transducer from affecting any other channel.
- b) A means of indicating internal circuit faults, including transducer system failure, with externally visible circuit fault indication for each individual channel. A no-fault condition shall be positively indicated (e.g. lighted). A common circuit fault relay shall be provided for each monitor system.
- c) A circuit fault shall not initiate a shutdown or affect the shutdown logic in any way except as noted in 7.4.1.5 and 7.4.2.5.
- d) Individual unfiltered buffered output connections for all system transducers (except temperature) via front-panel bayonet nut connector (BNC) connectors and rear panel connections. If specified, the monitor system may employ connectors other than BNC or locations other than the front panel.
- e) If specified, a 4 mA to 20 mA DC analog output shall be provided for each measured variable used for machine protection in addition to the digital output of 4.13.1.

NOTE This output is designed and intended for transmitting MPS measurements to strip chart recorders and other control/automation equipment as part of their operator display and trending environments. It is not designed or intended to replace the relays of 4.12 for machinery protection purposes. Relays are the only acceptable method of interconnecting the MPS to other devices used for carrying out a shutdown command (4.12.1).

- f) If specified, a digital communications port shall be supplied for transmitting data between the MPS and compatible condition monitoring software. The protocol used shall be mutually agreed upon between vendor and purchaser.

NOTE See Annex N for additional details on the purpose of this digital interface and the types of data typically transmitted.

4.11.5 A machinery protection monitor system shall include the following alarm/shutdown functions.

- a) For each channel, alarm (alert) and shutdown (danger) setpoints that are individually adjustable over the entire monitored range. Alarm (alert) setpoints do not apply to overspeed and surge detection.
- b) An alarm (alert) output from each channel or voted channels to the corresponding alarm (alert) relay. Nonvoting (OR) logic is required.
- c) A shutdown (danger) output from each channel or voted channels to the corresponding shutdown (danger) relay, as discussed in 7.4.1.4, 7.4.2.4, 7.4.3.6, and 7.4.5.4.
- d) With exception of electronic overspeed detection (see Note), the time required to detect and initiate an alarm (alert) or a shutdown (danger) shall not exceed 100 ms. Relay actuation and the monitor system's annunciation of the condition shall be fixed by the time delay specified in 7.1.5 a).

NOTE 1 The 100 ms response time requirement applies after the system has executed any signal processing algorithms and/or filtering for disturbance rejection.

NOTE 2 Electronic ODS response is specified in 8.4.4.1.

- e) Shutdown (danger) indication for each channel that indicates channel alarm status independent of voting logic. Shutdown (danger) indication shall be positive indication (e.g. illuminated when channel violates its shutdown setpoint). If specified, shutdown (danger) indication shall conform to operation of the voting logic.
- f) If specified, a tamperproof means for disarming the shutdown (danger) function and a visible indicator (positive indication, for example, lighted when disarmed) shall be provided for each channel. Any disarmed condition shall activate a common relay located in the rack or power supply. This relay shall be in accordance with 4.12 and may be used for remote annunciation.

NOTE This requirement is intended for use to remove a failing or intermittent channel from service.

- g) Local and remote access for resetting latched alarm (alert) and shutdown (danger) conditions. For rack-based systems, front-panel switch and rear-panel connections shall be supplied.
- h) A means to identify the first-out alarm (alert) and the first-out shutdown (danger).

4.11.6 If specified, selected channels (or all channels) of the monitor system shall be available in two additional configurations utilizing redundancy or other means.

- a) A single circuit failure (power source and monitor system power supply excepted) shall only affect the offending channel and shall not affect the state of alarm relays.
- b) A single circuit failure (power source and monitor system power supply included) shall only affect the offending channel and shall not affect the state of alarm relays. This requirement is mandatory for all electronic ODS channels (8.4.2).

4.11.7 A monitoring system shall have the following indications:

- a) power status,
- b) digital communications link status,
- c) system circuit fault,

- d) system shutdown (danger),
- e) system alarm (alert),
- f) system shutdown (danger) function bypassed.

4.11.8 ODS's shall have Items a) through d) in 4.11.7.

4.12 System Output Relays

4.12.1 The output relays described in this section shall be used for interconnecting the MPS to all other devices used as part of the auto-shutdown loop.

4.12.2 The optional digital interfaces of 4.11.4 f) and 4.13 and the analog outputs of 4.11.4 d) and 4.11.4 e) shall not be used as part of the auto-shutdown loop.

4.12.3 Unless otherwise specified, output relays shall be the epoxy-sealed electromechanical type.

4.12.4 If specified, either of the following relay types may be provided in lieu of epoxy-sealed relays.

- a) hermetically-sealed electromechanical type;
- b) solid state type. If a solid state relay interface between systems is proposed, the vendor with unit responsibility shall provide a complete review of the relay capabilities and requirements to ensure reliable operation.

4.12.5 The relay control circuit shall be field changeable to be either normally de-energized or normally energized. The factory default shall be de-energize to alarm and energize to shutdown except for overspeed channels and/or functional safety requirements that preclude the use of energize-to-shutdown relays.

4.12.6 All relays shall be double-throw type with electrically isolated contacts and all contacts available for wiring.

4.12.7 Shutdown (danger), alarm (alert), and circuit-fault relays shall be field changeable to latching (manual reset) or nonlatching (automatic reset). Latching shall be standard.

4.12.8 The circuit fault relay shall be normally energized. A failure in the transducer system, monitor system, primary power supply power, or redundant power supply shall de-energize the circuit fault relay.

- **4.12.9** Contacts shall be rated at a resistive load of 2 amperes at 120 Vac, or 1 ampere at 240 Vac, or 2 amperes at 28 Vdc for a minimum of 10,000 operations. When inductive loads are connected, arc suppression shall be supplied at the load. If specified, contacts rated at a resistive load of 5 amperes at 120 Vac shall be provided.

NOTE Final element solenoid(s) power requirements may necessitate a higher power interposing relay(s). Machinery vendor should provide final element solenoid power requirements to allow proper specification of interposing relays if required.

4.12.10 For normally de-energized shutdown (danger) output relays, an interruption of power [line power or direct current (DC) output power] shall not transfer the shutdown (danger) relay contacts regardless of the mode or duration of the interruption.

4.12.11 Each monitor subsystem in the MPS (overspeed exempted) shall be provided with a means to disarm the subsystem's shutdown capability, conforming to the following.

- a) It may be internal or external to the monitor subsystem.
- b) It shall be tamperproof.

- c) A disarmed condition shall be locally annunciated at the monitor subsystem via positive indication (e.g. lighted when disarmed).
- d) Operation or maintenance of the monitor subsystem in the disarmed mode, including power supply replacements, shall not shut down the machine (see Note). Refer to IEC 61508 for governing requirements.

NOTE This feature is intended to be used during monitor system maintenance only.

- e) A disarmed condition shall be available for remote annunciation via the digital communications link of 4.13.
- f) If specified, two sets of isolated external annunciator contacts shall be provided.

4.13 Digital Communication Links

4.13.1 A digital output representative of each measured variable shall be provided at a communications port. A short circuit of this output shall not affect the MPS, and the output shall follow the measured variable and remain at full scale as long as the measured variable is at or above full scale. Unless otherwise specified, the protocol utilized for this standard digital output shall be Modbus.

NOTE This output is intended for transmitting MPS status, proportional values, and other data to process control and automation systems as part of their operator display and trending environments. It is not designed or intended to replace the relays of 4.12 for machinery protection purposes. Relays are the only acceptable method of interconnecting the MPS to other devices used for carrying out a shutdown command (4.12.1). See also Annex N.

4.13.2 If specified, any one or more of the following shall also be available from the digital communications link of 4.13.1:

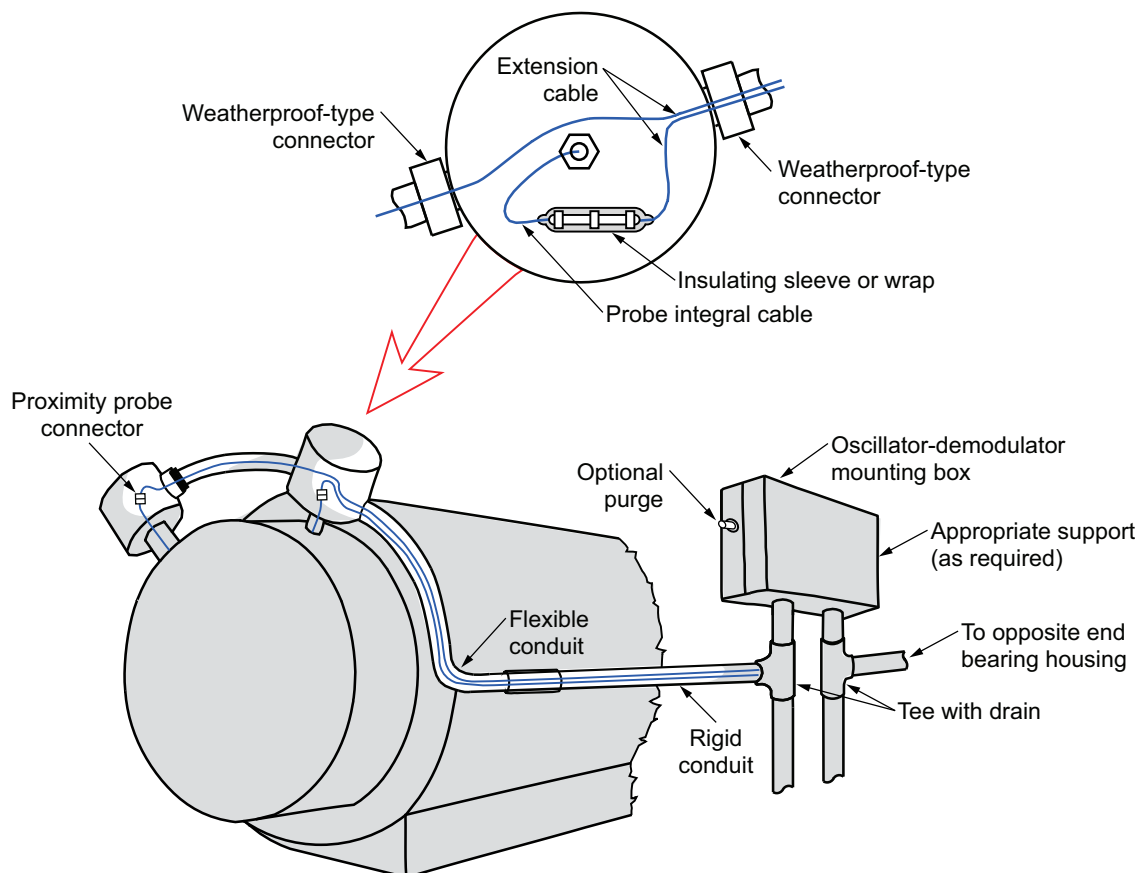
- a) channel status of alarm or no alarm;
- b) armed/disarmed (maintenance bypass) shutdown status for the monitor system (see 4.12.11);
- c) alarm storage for storing the time, date, and value for a minimum of 64 alarms;
- d) channel value ± 2 % full-scale range resolution;
- e) measured value as a percent of alarm (alert) and shutdown (danger) values to 1 % resolution;
- f) channel status: armed/disarmed [see 4.11.5 f)];
- g) transducer OK limits;
- h) hardware and software diagnostics;
- i) communication link status;
- j) alarm setpoints;
- k) gap voltage, when applicable;
- l) current system time, time stamp, and date of event for all transmitted data;
- m) system entry log to include date, time, individual access code, and record of changes;
- n) setpoint multiplier invoked (see 7.4.1.6 and 7.4.4.4).

4.14 System Wiring and Conduits

4.14.1 General

Installation shall be in accordance with the following.

- a) Wiring and conduits shall comply with the electrical practices specified in NFPA 70 (see Figure 5, Figure 6, Figure 7, Figure C.1, Figure C.2, and Figure C.3).
- b) All conduit, signal and power cable, and monitor system components shall be located in well-ventilated areas away from hot spots such as piping, machinery components, and vessels.
- c) MPS components shall not be covered by insulation or obstructed by items such as machinery covers, conduits, and piping.
- d) All conduits, armored cable, and similar components shall be located to permit disassembly and repair of equipment without causing damage to the electrical installation.
- e) Signal and power wiring shall be segregated according to good instrument installation practices (see 4.14.2.4).
- f) Signal wiring shall not be run in conduits or trays containing circuits of more than 30 V of either alternating or direct current.
- g) Signal wiring shall be shielded, twisted pair, or shielded triad to minimize susceptibility to electromagnetic or radio frequency interference.



NOTE Proximity probe extension cable connectors insulated from the ground (see 5.1.3.3).

Figure 5—Typical Conduit Cable Arrangement