Engineering Standard

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Protective and Condition Monitoring
Equipment for Rotating Machinery

Document Responsibility: Instrumentation Standards Committee

Saudi Aramco DeskTop Standards

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1 Scope

1.1 This standard defines the minimum mandatory requirements governing the design and installation of protective and condition monitoring equipment for rotating machinery.

1.2 This standard does not apply to electric motor and generator stator temperature monitoring equipment.

1.3 This entire standard may be attached to and made a part of purchase orders.

2 Conflicts and Deviations

2.1 Any conflicts between this standard and other applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Process and Control Systems Department Saudi Aramco, Dhahran.

2.2 Direct all requests to deviate from this standard in writing to the Company or Buyer Representative, who shall follow internal company procedure SAEP-302 and forward such requests to the Manager, Process and Control Systems Department of Saudi Aramco, Dhahran.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below, to the extent specified herein.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Materials System Specifications

13-SAMSS-001	*Special Purpose Gear Units*
13-SAMSS-003	*General Purpose Gear Units*
17-SAMSS-502	*Form-Wound Induction Motors 250 HP and Above*
17-SAMSS-520	*Form-Wound Brushless Synchronous Motors*

27-SAMSS-003	*Manufacture of Non-Industrial Cooling Towers*
30-SAMSS-001	*Diesel Engines*
31-SAMSS-001	*Centrifugal Compressors*
31-SAMSS-002	*Packaged Reciprocating Plant & Instrument Air Compressors*
31-SAMSS-003	*Reciprocating Compressors for Process Air or Gas Service*
31-SAMSS-004	*Centrifugal Pumps*
31-SAMSS-005	*Centrifugal Fluorocarbon Refrigeration Units for Industrial/Process Service*
31-SAMSS-006	*Packaged, Integrally Geared Centrifugal Air Compressors*
31-SAMSS-012	*Shaft Sealing Systems for Centrifugal & Rotary Pumps*
32-SAMSS-009	*General Purpose Steam Turbines*
32-SAMSS-010	*Special Purpose Steam Turbines*
32-SAMSS-011	*Manufacture of Air-Cooled Heat Exchangers*
32-SAMSS-013	*Lubrication, Shaft-Sealing and Control Oil Systems*
34-SAMSS-625	*Machinery Protection Systems*

Saudi Aramco Engineering Standard

SAES-Z-010	*Process Automation Networks Connectivity*

3.2 Industry Codes and Standards

American Petroleum Institute

API STD 670	*Vibration, Axial Position, and Bearing Temperature Monitoring Systems*

4 General Requirements

4.1 Definitions

Vibration, Axial Position and Bearing Temperature Monitoring System: The monitoring system consists of probes, accelerometers, and temperature sensors; signal conditioning devices (if required); interconnecting cables; racks; power supplies; monitors; and communication devices.

Commentary Note:

For simplicity, the remainder of the document will define the "Vibration, Axial Position and Bearing Temperature Monitoring System" as the "Vibration Monitoring System".

Rotating Machinery Protection System (RMPS): The logic system that receives the shutdown inputs, processes the machinery protection logic and automatically sends shutdown commands to the rotating equipment train. The RMPS logic solver shall be one of the following; Distributed Control System (DCS), Simplex Programmable Logic controller (PLC), or PLC based ESD system. For process critical equipment, the RMPS logic solver shall meet the requirements for Emergency Shutdown Systems.

Process Critical Equipment: Rotating equipment including turbines, electric driven pumps, compressors or generators handling combustible, flammable or toxic materials and use drivers equal to or greater than 1,000 HP. Process critical equipment also includes rotating equipment that is categorized as critical by a process hazards analysis.

Condition Monitoring System: A computer based information processing system which communicates directly to the machine protection system, to other machinery monitoring data acquisition devices, and to other plant information devices such as process measurement transmitters, DCSs, PLCs, management information systems (MIS), and plant historians to extract machinery dynamic motion signals and static machine process parameters. The CMS computer collects, stores, processes, displays and prints the machinery management data in a variety of formats. This data will be typically used for historical trending, machinery diagnostics and predictive maintenance purposes, not for machine protection.

Owner: The final recipient of the equipment (who will operate the machinery and its associated machinery protection system).

Commentary Note:

For additional machinery protection system 'definitions' please reference Section 3 in 34-SAMSS-625 (API STD 670).

4.2 Rotating Machinery to be Protected

Commentary Note:

The protective instrumentation required for each type of rotating machinery is located in the applicable Saudi Aramco Materials System Specifications (SAMSSs) or Saudi Aramco Engineering Standards (SAESs).

Rotating machinery to be protected shall include, but not be limited to:

4.2.1 Gear Units; (13-SAMSS-001 and 13-SAMSS-003)

4.2.2 Form-Wound Induction Motors 250 HP and Above; (17-SAMSS-502)

4.2.3 Form-Wound Brushless Synchronous Motors; (17-SAMSS-520)

4.2.4 Diesel Engines; (30-SAMSS-001)

4.2.5 Centrifugal and Reciprocating Compressors; (31-SAMSS-001, 31-SAMSS-002, 31-SAMSS-003, 31-SAMSS-005 and 31-SAMSS-006)

4.2.6 Centrifugal Pumps; (31-SAMSS-004)

4.2.7 Steam and Combustion Gas Turbines; (32-SAMSS-009 and 32-SAMSS-010)

4.2.8 Hydraulic Couplings (apply the requirements in 13-SAMSS-001)

4.2.9 Combustion Air Fans with a discharge pressure greater than 34 kPa (5 psi) above atmospheric pressure; (apply the requirements in 31-SAMSS-001)

4.2.10 Combustion Air Fans with a discharge pressure less than 34 kPa (5 psi) above atmospheric pressure; per Manufacturer's recommendation with Proponent approval.

4.2.11 Air-cooled heat exchangers (apply the requirements in 32-SAMSS-011).

4.2.12 Non-Industrial Cooling Towers (apply the requirements in 27-SAMSS-003)

4.3 Lubrication, Shaft-sealing and Control Oil Systems

Lubrication, shaft-sealing and control oil instrumentation shall comply with 31-SAMSS-012 and 32-SAMSS-013.

4.4 Shutdown Signals

All shutdown signals for the rotating equipment train shall be wired directly to the RMPS logic solver. Shutdown signals may originate from three sources:

1) The vibration monitoring system (based on bearing temperature, vibration, and axial position sensors),

2) Lubrication, shaft-sealing and control oil instrumentation (if applicable); and

3) Process shutdown devices.

5 Vibration Monitoring System (VMS)

5.1 Hardware (sensors and instruments) and Setpoint Requirements

5.1.1 The vibration monitoring system shall comply with 34-SAMSS-625.

5.1.2 All vibration, axial position and bearing temperature monitoring instrumentation installed for a single machinery train shall be from the same equipment manufacturer.

Exception:

Accepted practice and the intent of 34-SAMSS-625 (and API STD 670) is to bring bearing temperature sensors into the VMS. However, bearing temperature monitoring can be implemented in any RMPS logic solver upon approval by the Proponent organization. In either case, the CMS always looks at the temperatures and having them in the VMS makes this correlation cleaner.

Commentary Note:

Field sensors are not required to be from the same equipment manufacturer as the VMS.

5.1.3 The machinery vendor shall submit their recommended alarm (alert) and shutdown (danger) setpoints, for each machinery train, to the Owners representative for their review and comment.

5.1.4 The radial shaft vibration, casing vibration, shaft axial position, shaft rotational speed, piston rod drop, overspeed and critical machinery temperature limits for alarm and shutdown setpoints shall be approved, in writing, by Owner.

5.1.5 A fault in the temperature monitor or its associated transducers shall initiate the circuit-fault status alarm. The direction of the readout or output signal upon temperature sensor burnout shall be selectable. (either upscale or downscale). Downscale failure (that is, a failure in the zero direction) shall be standard unless otherwise specified by Owner.

5.2 Communication to Distributed Control System

5.2.1 The vibration monitoring equipment shall be connected to the distributed control system (DCS) using a communication port. This communication port shall be a redundant serial RS-485 link or a redundant Ethernet link (Modbus over TCP/IP). Each communication port shall be on separate module, i.e., both communication ports shall not be located in one communication module. The serial interface between the DCS and the monitoring system shall be bi-directional such

that read/write functions can be performed from both devices. If the machinery protection system vendor has a tightly integrated high speed communication link with the owner's DCS, then this communication link shall be used in lieu of serial/Ethernet links specified above.

Commentary Note:

An example of a DCS write function is to put an individual channel into 'bypass', reference Section 6.1.

5.2.2 The internal date and time clock of the vibration monitoring equipment shall be synchronized with the DCS clock. The internal clock time setting or synchronization shall be made with a maximum latency of 100 milliseconds between the master remote clock (DCS) and the VMS clock.

5.2.3 The following information shall be communicated and displayed via the DCS MMI.

1) Channel value for each variable.

2) Channel alarm status.

   The DCS channel alarm shall be initiated by a status bit from the VMS not generated internally in the DCS from the channel or measured value.

3) Armed/disarmed shutdown (bypass) status for all channels.

4) Transducer OK (Status) limit for each channel.

5) Hardware and software diagnostics.

6) Communication link status.

7) Gap Alarm for each channel, when applicable.

9) Channel bypass status (reference Section 6.1.4).

8) Setpoint multiplier invoked (reference Section 6.3).

5.2.4 The following items shall also be made available to the DCS through the serial communication link: (ref. 34-SAMSS-625).

1) Alarm storage for storing the time, date, and value for a minimum of 64 alarms.

2) Measured value as scaled engineering unit values or a percent of alarm (alert) and shutdown (danger) values to 1% resolution.

3) Alarm and Shutdown setpoints.

4) Time stamp and date for all transmitted data.

5) System entry log to include date, time, individual access code, and record of changes.

Commentary Note:

The Proponent organization shall determine which additional item listed in Section 5.2.4, if any, will be communicated and displayed in the DCS MMI.

5.3 Alarm (alert) and Shutdown (danger) Outputs

5.3.1 For fully or partially attended facilities both the alarm and shutdown outputs shall be annunciated on a visual alarm display, and with an audible alert signal. For unmanned facilities only the shutdown output shall be visually annunciated.

Commentary Note:

The audible and visual annunciation shall be in a discrete, multi-point alarm annunciator or to an alarm/annunciator display configured within a DCS system.

5.3.2 The shutdown signals for each equipment train shall be commoned, reference Section 5.4.1.8.1 in 34-SAMSS-625.

Commentary Note:

This section now mandates that the shutdown signals for each equipment train shall be commoned, e.g., a non-critical machine train that is monitoring axial position, radial vibration and bearing temperature would have a total of six contacts, three for alarms and three for shutdown. Or if the alarms are being sent to the DCS via a redundant communication link, then only three shutdown contacts would be required for the machine train.

5.3.3 The shutdown outputs from the VMS danger relay shall be hardwired to the RMPS logic solver.

5.3.4 For process critical equipment, redundant relay modules shall be used for the shutdown (danger) contacts. For redundant relay module configuration details, reference Section 5.4.1.8 in 34-SAMSS-625.

5.3.5 Dual voting logic (two-out-of-two) shall be used in the RMPS logic solver for the redundant shutdown contacts specified in Section 5.3.4.

Commentary Note:

2oo2 voting logic is being mandated to prevent the failure of one relay or one relay module from tripping the machinery train.

5.4 Module Segregation

It is permissible to install the modules to monitor more than one machine train in the same monitor system rack (chassis). However, each machine train shall have dedicated monitor modules. When multiple machine trains are monitored using a single rack, the monitoring system shall support the capability of accommodating multiple phase reference transducer inputs from each of these machine trains/cases.

5.5 Power Supply

5.5.1 Vibration monitoring systems shall be powered from branch circuits of the plant UPS.

5.5.2 The VMS shall be fitted with redundant power supplies, reference Section 5.4.1.7 in 34-SAMSS-625.

5.5.3 For each VMS cabinet, all "A" power supplies shall be on one branch circuit, and all "B" power supplies shall be on a separate branch circuit.

5.6 Junction Boxes

5.6.1 Each machinery train shall have at least one, but no more than two junction boxes installed for the termination of the temperature sensor lead wires. If two junction boxes are required, then one junction box shall be dedicated for the driver temperature sensors and the second junction box shall be dedicated for the driven equipment temperature sensors. The junction box(s) shall be located for ease of access and on the same side of the machinery train as the oscillator-demodulator junction box(s). The junction box(s) shall not be mounted on the machine but in a vibration-free environment.

Commentary Note:

A second junction box mounted separate from the motor frame is not required for vertical motors shipped with a common accessory junction box which terminates the vibration, temperature, and stator winding sensor leads.

5.6.2 For installation of all oscillator/demodulators and external accelerometer charge amplifier refer to 34-SAMSS-625.

5.6.3 All junction boxes shall be mounted vertically, i.e., the door shall open from left-to-right or from right-to-left. The terminal strip(s) shall be mounted vertically in the junction box, i.e., the DIN rail shall be mounted vertically in the junction box.

5.7 Condition Monitoring Interface

The monitor system shall be capable of interfacing to an external host computer for implementing a CMS for machine train(s) during steady state and transient operating conditions, reference Section 5.4.1.3.k in 34-SAMSS-625.

6 General Design Criteria Applied to All Rotating Machinery Protection Systems

6.1 Input Bypass Switches

6.1.1 Each RMPS shutdown signal shall be installed with a bypass switch to facilitate maintenance or testing.

6.1.2 Bypass switches in vibration monitoring equipment shall be either hardwired, or software-configured using a restrictive access mechanism such as a key-lock, a password protection scheme, or both.

6.1.3 Activation of a bypass switch, to the bypass position, shall be annunciated on a visual alarm display, and with an audible alert signal.

6.1.4 Software configured bypass switches shall meet the following:

1) Bypass individual channels
2) Shall be configured such that loss of communications between the VMS and DCS shall not deactivate any active bypasses.
3) Analog values for the bypassed channel shall not be disabled during bypass.
4) Provide bypass confirmation to the DCS console operator.
5) The total cycle time from initiation of the channel bypass to operator confirmation shall be less than 5 seconds.

6.2 Event Logging/Recording

6.2.1 First-out event logging, if required by the Proponent organization, shall be implemented in the plant event logging and archiving system.

6.2.2 Vibration monitor systems which have the ability to perform on board event logging on a per rack basis are acceptable provided that, the system is designed to accept an external synchronization signal from the plant event logger and can provide the event time discrimination required by the Proponent organization.

6.3 Setpoint Multiplier (Trip Multiply)

6.3.1 Setpoint Multiplication shall be used when both of the criteria below are encountered:

1) The machine experiences vibration amplitudes in excess of its danger or alert setpoints as it passes through a machine resonance and this results in unwanted machine shutdown or alarms.

2) The duration of this setpoint violation exceeds the preset alarm delay times.

Commentary Note:

Setpoint multiplication is the function whereby selected channels in the monitor system have their alarm (alert) and shutdown (danger) setpoints elevated by some preset amount (usually an integer multiple such as 2 or 3).

6.3.2 Bypassing or suppressing the machinery protection system alarms while it passes through a resonance in lieu of using properly established setpoint multiplication functions shall not be used.

Commentary Note:

Setpoint multiplication merely elevates the alarms, it does not suppress them. This ensures that machinery protection is provided at all rotational speeds of the machine.

7 Condition Monitoring System (CMS)

7.1 Rotating Machinery Requiring Condition Monitoring

The Project Management Team (PMT), Proponent Organization and Machinery Reliability Unit in Consulting Services Department (CSD) shall determine which rotating machinery, if any, will require condition monitoring equipment.

Commentary Note:

Careful consideration should be given before installing a transient monitoring system due to its relatively high cost and the advanced level of expertise required to interpret the data.

7.2 General Description

The Condition Monitoring System (CMS) shall be a single platform software package, capable of integrating various condition monitoring technology modules for rotating machinery and fixed asset condition management. It shall be capable of being configured as either a centralized or distributed database network installation with adequate provision for worst-case real time data

transfer requirements. The CMS shall be connected to the plant automation network to allow import and export of data including but not limited to, digital process control servers, computerized maintenance management systems (CMMS), plant historians, plant document management systems and automated reliability based maintenance programs.

7.3 Remote Monitoring

If it has been determined that CMS is required, then the CMS shall be connected to the Process Automation Network (PAN) to allow remote access through the Aramco Wide Area Network (WAN). All hardware and software required to allow secure WAN access shall be provided. Remote access shall be installed in compliance with SAES-Z-010 Process Automation Networks Connectivity.

Commentary Note:

The Proponent Organization for 'remote monitoring' of the CMS is the Dynamic Analysis Unit in Consulting Services Department (CSD).

Revision Summary

15 October 2011	Revised the "Next Planned Update." Reaffirmed the content of the document, and reissued with editorial revision to meet the deadline.
18 February 2013	Editorial revisions to Section 4 and change the primary contact person.