Engineering Standard

SAES-J-400 31 May, 2004

Temperature

Saudi Aramco DeskTop Standards

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Previous Issue: 30 April, 2001 Next Planned Update: 1 June, 2009
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1 Scope

This Standard defines the minimum mandatory requirements governing the design and installation of temperature instrumentation systems. Temperature measurement associated with bulk storage tank automatic tank gauging (ATG) systems is covered in SAES-J-300, "Level", and is excluded from this Standard.

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 General Supervisor, Process Instrumentation Division, Process & Control Systems Department of 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 General Supervisor, Process Instrumentation Division, Process & 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, unless otherwise noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

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

Saudi Aramco Engineering Standards

SAES-A-112 — *Meterological and Seismic Design Data*

SAES-J-003 — *Basic Design Criteria*

SAES-J-601 — *Emergency Shutdown and Isolation Systems*

SAES-J-902 — *Electrical Systems for Instrumentation*

SAES-P-111 — *Grounding*

Saudi Aramco Materials System Specification

34-SAMSS-913	*Instrumentation and Thermocouple Cable*

Saudi Aramco Standard Drawing

AB-036019	*Thermowell - Assembly and Detail*

3.2 Industry Codes and Standards

American Society of Mechanical Engineers

ASME B16.5	*Pipe Flanges and Flanged Fittings*
ASME PTC 19.3	*Temperature Measurement - Instruments and Apparatus*

International Electrotechnical Commission

IEC 60751	*Industrial Platinum Resistance Thermometer Sensors*

International Society for Measurement and Control

ISA/ANSI MC96.1	*Temperature Measurement Thermocouples*

National Fire Protection Association

NFPA 70	*National Electrical Code (NEC)*

Process Industry Practice

PCFTE000	*Temperature Measurement Fabrication Details, Drawing PCFTE102*

Scientific Apparatus Makers Association

SAMA RC21-4-1966	*Temperature-Resistance Values for Resistance Thermometer Elements of Platinum, Nickel and Copper*

4 General Design Requirements

4.1 Environmental Conditions

4.1.1 Temperature instrumentation shall meet the relevant requirements of SAES-J-003 pertaining to indoor and outdoor environmental conditions. Typical dust (particulate) and gaseous concentration levels in the air are specified in SAES-A-112, Paragraph 4.6.

4.1.2 Equipment which is not enclosed or hermetically sealed, but is situated offshore or nearshore, shall be protected against corrosion and operational failure due to wind-borne sea water spray and the accumulation of wetted salt (NaCl). Nearshore is defined as any outdoor, onshore location within one kilometer from the shoreline of the Arabian Gulf; all of the Ras Tanura Refinery and Terminal; and within three kilometers from the shoreline of the Red Sea. Typical maximum pollutant concentrations found in the air that can lead to excessive corrosion can be found in SAES-A-112, Section 4.6.

4.2 Electrical Requirements

Electrical and electronic installation and wiring of temperature instrumentation shall be in compliance with SAES-J-902.

Exception:

Cast Aluminum heads may be used.

4.3 Installation Requirements

4.3.1 All temperature instruments, connections, and primary elements shall be located to provide safe access for installation and maintenance.

4.3.2 Instrumentation requiring frequent access, such as local controllers, shall be located no more than 1.5 meters above grade or permanent platform. Instruments requiring limited access, such as temperature transmitters, shall be no more than 3 meters above grade or permanent platform, and be accessible by ladder or mobile platform.

5 Thermowells

5.1 General

All temperature sensing elements shall be installed in thermowells.

Exceptions:

Sensors for bearing, motor winding, furnace, skin or surface temperature measurement, ambient air, electronic equipment cabinets. (However, a mechanical protection sleeve shall be considered for the sensors in the area where there is possibility of damage such as pump bearings.)

5.2 Design

5.2.1 When process temperatures are less than 535°C and pressure-temperature design conditions do not require an ANSI Class 900 or higher flange, threaded or flanged thermowells may be used. If process temperatures exceed 535°C or the pressure-temperature design conditions require an ANSI Class 900 or greater flange, flanged thermowells shall be used.

5.2.2 Weld-in thermowells shall only be used when ASME or Saudi Aramco standards or specifications require welded connections.

5.2.3 Thermowells shall be tapered and machined from barstock material.

5.2.4 Thermowells shall be 316 stainless steel unless alternative metallurgy is specified or dictated by process conditions. Alternative metallurgy shall be approved by the Materials Engineering Unit of CSD

5.2.5 Threaded thermowells shall be constructed and installed in accordance with Standard Drawing AB-036019.

Commentary Note:

> *Threaded thermowells with ¾-inch MNPT process connections shall be used only when required to replace existing ¾-inch thermowells.*

5.2.6 Flanged thermowells shall be furnished with ASME B16.5 flanges. Flanged thermowells shall be constructed and installed in accordance with Process Industry Practice PCFTE000 Temperature Measurement Fabrication Details, Drawing PCFTE102. Flange size shall be 1-½ inch minimum 300 # RF.

5.2.7 Standard thermowell bore selection for Threaded and Flanged thermowells is 0.260 inch. The thermowell bore may be increased to 0.385 inch where required (e.g. filled systems). For the flanged thermowell the tip diameter shall then be increased to 0.75 inch.

5.2.8 Insertion Length

5.2.8.1 Initial insertion length "U" for threaded thermowells in process piping shall be per Standard Drawing AB-036019.

5.2.8.2 Initial insertion length "U" for flanged thermowells in process piping shall be per Process Industry Practice PCFTE000 Temperature Measurement Fabrication Details, Drawing PCFTE102.

Commentary Note:

> *The final selection may be shorter based on wake frequency calculations as detailed in Paragraph 5.3.*

5.2.9 For process vessels and columns, the maximum insertion length shall be 600 mm (24 inches).

Exception:

> *For Catalyst Bed and other similar temperature profile measurements, extended thermowells are allowed. Extended thermowells shall be in a vertical orientation if feasible or supported such that vibration/gravity/ flow effects shall not cause fatigue or deformation failure of the thermowell.*

5.3 Thermowell Vibration and Stress

5.3.1 Natural frequency and wake frequency calculations shall be performed on each thermowell application, per ASME PTC 19.3.

If the calculated wake frequency is equal to or greater than 80% of the thermowell's natural frequency, the next shorter standard size well shall be specified until the calculated wake frequency falls below 80% of the natural frequency. Standard U-lengths should be chosen whenever possible.

5.3.2 For Flanged Thermowells, where the calculated U-length ends up being too short for good heat transfer, modifications to the thermowell design may be made such as:

a) A thermowell collar or special flange weldolet may be used to tightly hold the thermowell to the flange near the pipe wall, thus effectively reducing the calculation U-length, or;

b) External dimensions such as root and tip diameter may be increased to lower the wake frequency and increase the resonant frequency.

5.3.3 Maximum process pressure and static stress calculations shall be performed on each thermowell application, per ASME PTC 19.3.

Commentary Note:

> *Pressure and static stress effects may combine with wake frequency vibration to cause failure of thermowells.*

6 Thermocouple Instruments

6.1 Thermocouple Selection

6.1.1 Thermocouple construction, properties, calibration, color coding, and limits of error shall comply with ISA/ANSI MC96.1.

6.1.2 Thermocouple selection shall be determined by the temperature range to be measured. Type E, Type J, and Type K thermocouples are typically used in Saudi Aramco facilities.

Commentary Note:

Type J TCs contain iron wire which is subject to corrosion in many locations.

6.2 Thermocouple Design and Installation

6.2.1 Thermocouples shall be insulated with packed magnesium oxide and protected with a ¼-inch o.d., 316 stainless steel sheath. Alternative sheath metallurgy may be used if required by process conditions. Alternative metallurgy shall be approved by the Materials Engineering Unit of CSD

6.2.2 Thermocouples may either be grounded or ungrounded. With either type, single-point grounding of the signal loop must be observed. Ungrounded TCs shall be used to measure differential or average temperature.

Commentary Note:

Grounded thermocouples are preferred due to quicker response, and to consistently ground the signal wiring at the thermocouple end of the loop. Grounded junction TCs wll not give accurate measurements when connected together to measure differential or average temperature.

6.2.3 Thermocouples shall be installed in thermowells such that the end of the thermocouple is in contact with the bottom of the thermowell. Spring-loaded thermocouples are preferred to insure positive contact with the thermowell.

6.2.4 Dual element thermocouples are permitted when their intended function is to provide a spare thermocouple element for a single receiving instrument. A dual element thermocouple shall not be used to provide separate signals to different instruments or redundant inputs to a logic control system.

6.3 Thermocouple Extension Wire

6.3.1 Thermocouple extension wire shall be suitable for the specific type of thermocouple being connected. Thermocouple extension wire shall meet the requirements of ISA/ANSI MC96.1 and 34-SAMSS-913 and shall be installed in accordance with SAES-J-902. Each pair shall be individually twisted and shielded.

6.3.2 For grounded thermocouples, the extension wire shield drain wire shall be grounded at the thermocouple head. The continuity of the shield shall be maintained through junction boxes and transitions from single pair to multipair cables. The shield and drain wire shall be cut and secured (insulated) at the receiving instrument end of the extension wire.

6.3.3 For ungrounded thermocouples, the extension wire shield drain wire shall be grounded at the receiving instrument end to the instrument circuit ground. The continuity of the shield shall be maintained through junction boxes and transitions from single pair to multipair cables. The shield and drain wire shall be cut and secured (insulated) at the thermocouple end of the extension wire.

6.3.4 The overall shield of a multicore thermocouple extension cable shall be grounded to the instrument circuit ground at the receiving instrument end.

6.3.5 Thermocouple extension wire shall be terminated on terminal blocks. The number of intermediate terminations in a thermocouple loop should be minimized as much as practicable. As long as the terminal block is at a constant temperature along its length and is of homogeneous material, the conducting terminal needs not be constructed of like thermocouple material.

6.4 Thermocouple-Based Devices

6.4.1 General

6.4.1.1 All thermocouple instruments shall provide burnout detection. The direction of the readout or output signal on thermocouple burnout shall be selectable.

6.4.1.2 A thermocouple shall not be connected to more than one receiving instrument.

6.4.2 Transmitters

6.4.2.1 Temperature transmitters shall meet the NEC hazardous area classification of the intended installation. Transmitters certified as nonincendive are preferred in order to eliminate sealing the device in Class I, Div. 2 hazardous areas.

6.4.2.2 Thermocouple transmitters shall provide input and output signal isolation, cold junction compensation, linearization/ characterization, ambient temperature compensation, and adjustable damping.

6.4.2.3 Transmitters with smart electronics are required since they provide enhanced output accuracy and rangeability, as well as remote calibration and diagnostic capabilities.

6.4.2.4 Transmitters shall be mounted remotely from the thermocouple/thermowell assembly.

6.4.2.5 A local temperature indicator shall be provided for each transmitter. The local indicator may be an integral part of the transmitter or a separate device, but must be readable from grade, platform or permanent ladder.

6.4.3 Switches

6.4.3.1 Application

6.4.3.1.1 Thermocouple Temperature Switches may be used for Local Applications Only.

6.4.3.1.2 Temperature inputs for ESD shall follow SAES-J-601.

6.4.3.1.3 Temperature inputs for Process Automation Systems shall be implemented using Smart Temperature Transmitters.

6.4.3.2 Thermocouple switches shall meet the NEC hazardous area requirements of the intended installation.

6.4.3.3 Electric switch contacts shall be snap-acting, single-pole, double-throw (SPDT), 5 amps at 120 VAC resistive, as a minimum. The switch mechanism shall be user-selectable to activate on increasing or decreasing temperature.

6.4.3.4 The switch shall provide cold junction compensation.

6.4.4 Multipoint Indicators and Multiplexers

6.4.4.1 Multipoint temperature indicators shall consist of a panel-mounted readout and a means of selecting the desired thermocouple to display.

6.4.4.2 Multiplexers shall take the signals from a number of thermocouples as inputs and provide an output to a logic control system (DCS, PLC, etc.).

6.4.4.3 Multipoint indicators and multiplexers shall provide linearization, cold junction compensation and scaling of the thermocouple input signals.

6.4.4.4 Signals from multipoint indicators or multiplexers shall not be used for control.

6.4.4.5 A maximum of 100 thermocouple inputs (including spares) shall be permitted per multipoint indicator or multiplexer. Recommended spare capacity is 25% of the number of occupied inputs.

7 Resistance Temperature Detector (RTD) Instruments

7.1 RTD Selection

7.1.1 Resistance temperature detectors (RTDs) shall be used when greater accuracy is required than is possible through the use of thermocouples.

Commentary Note:

RTDs are preferred over thermocouples for most temperature sensing applications within Saudi Aramco. RTDs may be used for measuring temperatures up to approximately 800°C (1500°F). Above this temperature, thermocouples should be used.

7.1.2 Platinum RTDs conforming to IEC 60751, with an alpha coefficient of 0.00385 ohm/ohm/°C and tolerance class A shall be used. Resistance shall be 100 ohms at 0°C.

Commentary Note:

IEC 60751 matches DIN 43760 (Obsolete) and DIN EN 60751.

7.1.3 100-ohm platinum RTDs conforming to SAMA RC21-4-1966, with an alpha coefficient of 0.00392 ohm/ohm/°C shall only be used when replacing existing RTDs with the same alpha coefficient.

7.2 RTD Design and Installation

7.2.1 RTDs shall be insulated with packed magnesium oxide and protected with a ¼-inch o.d., 316 stainless steel sheath. Alternative sheath metallurgy may be used if required by process conditions. Alternative metallurgy shall be approved by the Materials Engineering Unit of CSD

7.2.2 Three-wire RTDs shall be used to eliminate lead wire resistance effects from the temperature measurement. For temperature measurement requiring maximum accuracy, four-wire RTDs shall be used.

7.2.3 RTDs shall be installed in thermowells such that the end of the RTD is in contact with the bottom of the thermowell. Spring-loaded RTDs are preferred to insure positive contact with the thermowell.

7.2.4 Dual element RTDs are permitted when their intended function is to provide a spare RTD element for a single receiving instrument. A dual element RTD shall not be used to provide separate signals to different instruments or redundant inputs to a logic control system.

7.2.5 Extension wire for RTD signals shall consist of shielded, twisted triad copper conductors meeting the requirements of 34-SAMSS-913. Wiring shall be installed in accordance with SAES-J-902.

Exception:

When four-wire RTDs are used in a true 4-wire configuration, two shielded, twisted pair extension wires may be used.

7.2.6 The extension wire shield drain wire shall be grounded at the receiving instrument end to the instrument circuit ground. The continuity of the shield shall be maintained through junction boxes and transitions from single pair to multipair cables. The shield and drain wire shall be cut and secured (insulated) at the RTD end of the extension wire.

7.2.7 The overall shield of a multicore RTD extension cable shall be grounded to the instrument circuit ground at the receiving instrument end.

7.2.8 Due to expected high vibration, RTDs shall not be used on the discharge flange of a gas compressor.

7.3 RTD-Based Devices

7.3.1 General

7.3.1.1 All RTD instruments shall provide open-circuit detection. The direction of the readout or output signal on RTD failure shall be selectable.

7.3.1.2 An RTD shall not be connected to more than one receiving instrument.

7.3.2 Transmitters

7.3.2.1 Temperature transmitters shall meet the NEC hazardous area classification of the intended installation. Transmitters certified as nonincendive are preferred in order to eliminate sealing the device in Class I, Div. 2 hazardous areas.

7.3.2.2 Transmitters with smart electronics are required since they provide enhanced output accuracy and rangeability, as well as remote calibration and diagnostic capabilities.

7.3.2.3 Transmitters shall be mounted remotely from the RTD/ thermowell assembly.

7.3.2.4 A local temperature indicator shall be provided for each transmitter. The local indicator may be an integral part of the transmitter or a separate device, but must be readable from grade, platform or permanent ladder.

7.3.3 Switches

7.3.3.1 Application

7.3.3.1.1 RTD Temperature Switches may be used for Local Applications Only.

7.3.3.1.2 Temperature inputs for ESD shall follow SAES-J-601.

7.3.3.1.3 Temperature inputs for Process Automation Systems shall be implemented using Smart Temperature Transmitters.

7.3.3.2 RTD switches shall meet the NEC hazardous area requirements of the intended installation.

7.3.3.3 Electric switch contacts shall be snap-acting, single-pole, double-throw (SPDT), 5 amps at 120 VAC resistive, as a minimum. The switch mechanism shall be user-selectable to energize on increasing or decreasing temperature.

7.3.3.4 The switch may be installed directly on the RTD element or mounted remotely.

7.3.4 Multipoint Indicators and Multiplexers

7.3.4.1 Multipoint temperature indicators shall consist of a panel-mounted readout and toggle switches or pushbuttons to select the desired RTD to display.

7.3.4.2 Multiplexers shall take the signals from a number of RTDs as inputs and provide an output to a logic control system (DCS, PLC, etc.).

7.3.4.3 Multipoint indicators and multiplexers shall provide linearization and scaling of the RTD input signals.

7.3.4.4 Signals from multipoint indicators or multiplexers shall not be used for control.

7.3.4.5 A maximum of 100 RTD inputs (including spares) shall be permitted per multipoint indicator or multiplexer. Recommended spare capacity is 25% of the number of occupied inputs.

8 Filled System Instruments

8.1 Filled System Selection

8.1.1 Filled system temperature sensing instruments shall be used only for noncritical, local control and/or indication, where precise temperature control is not necessary.

Commentary Note:

> *Due to the lower accuracy and repeatability associated with filled systems compared to thermocouple or RTD-based sensors, as well as the distance limits dictated by capillary length, filled systems should be limited to local control or indication.*

8.1.2 The fill fluid may be either liquid or gas, depending on the temperature range of the process being measured.

8.2 Filled System Design and Installation

8.2.1 The filled system shall consist of a sensing bulb connected via capillary to the instrument.

8.2.2 The capillary shall be protected by 300-series-stainless-steel interlocked, flexible armor.

8.2.3 Bulbs may have a bendable extension and union connection.

8.2.4 Filled system temperature instruments shall always be provided with a matching thermowell. The thermowell shall comply with Section 5 of this Standard.

Commentary Note:

Since there is no standard bulb diameter among different manufacturers, it is essential that a thermowell matched to the specific instrument be provided by the instrument manufacturer.

8.3 Filled System-Based Devices

8.3.1 Transmitters

8.3.1.1 Only pneumatic transmitters used in conjunction with local pneumatic controllers may utilize a filled temperature sensing system.

8.3.1.2 Filled systems directly operating a valve (self-acting temperature regulators) are permitted to be used only when precise temperature control is not essential.

8.3.2 Switches

8.3.2.1 Application

8.3.2.1.1 Filled System Temperature Switches may be used for Local Applications Only.

8.3.2.1.2 Temperature inputs for ESD shall follow SAES-J-601.

8.3.2.1.3 Temperature inputs for Process Automation Systems shall be implemented using Smart Temperature Transmitters.

8.3.2.2 Filled system temperature switches shall meet the NEC hazardous area requirements of the intended installation.

8.3.2.3 Electric switch contacts shall be snap-acting, single-pole, double-throw (SPDT), 5 amps at 120 VAC resistive, as a minimum. The switch setpoint shall be adjustable over the full range of measurement.

8.3.3 Thermometers

8.3.3.1 Filled system thermometers shall be used only when access, process conditions, or mechanical considerations preclude the use of bimetallic thermometers.

8.3.3.2 Thermometers shall have uniform dial graduations.

Commentary Note:

Depending on the fill fluid, dial graduations may be nonuniform, with the scale compressed at the lower end of the scale, or uniform, with equal scale graduations around the dial. For most applications, thermometers with uniform dial graduations are available.

8.3.3.3 Mercury-filled thermometers shall not be used.

9 Bimetallic Instruments

9.1 Thermometers

9.1.1 Bimetallic dial thermometers shall be used wherever local temperature indication is required.

9.1.2 Thermometers shall have a ¼-inch o.d., 316 stainless steel stem. Alternative stem metallurgy may be used if required by process conditions. Alternative metallurgy shall be approved by the Materials Engineering Unit of CSD.

9.1.3 Thermometers shall be installed in thermowells. Thermowells shall comply with Section 5 of this Standard.

9.1.4 The thermometer stem shall be in contact with the bottom of the thermowell.

9.1.5 Dial size shall be 127 mm. The angle of view and orientation of the dial shall be adjustable. The dial shall be readable from grade, platform or permanent ladder and shall face the point where any corrective action will be taken.

9.1.6 When subject to vibration, thermometers shall be sealed and filled with silicone oil.

9.2 Switches

9.2.1 Application

9.2.1.1 Temperature Switches may be used for Local Applications Only.

9.2.1.2 Temperature inputs for ESD shall follow SAES-J-601.

9.2.1.3 Temperature inputs for Process Automation Systems shall be implemented using Smart Temperature Transmitters.

9.2.2 Bimetallic temperature switches shall meet the NEC hazardous area requirements of the intended installation.

9.2.3 Electric switch contacts shall be snap-acting, single-pole, double-throw (SPDT), 5 amps at 120 VAC resistive, as a minimum. The switch setpoint shall be adjustable over the full range of measurement.

Revision Summary

31 May, 2004 Major revision.