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Performance Monitoring for Nuclear Safety-Related Instrument Channels in Nuclear Power Plants

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This standard is intended for worldwide use in all industries as applicable

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PREFACE

This preface, as well as all footnotes and annexes, is included for information and is not a normative part of ANSI/ISA-67.06.01-2023.

This document has been prepared as part of the service of ISA toward a goal of uniformity in the field of automation. To be of real value, this document should not be static but should be subject to periodic review. Toward this end, the Society welcomes all comments and criticisms and asks that they be addressed to the Secretary, ISA Standards and Practices Board; standards@isa.org.

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International System of Units (SI) are the preferred units of measurement in ISA standards.

The ISA67.04 working group (previously designated as subcommittee) has determined that the terms “sensor” and “transducer” will be interchangeable throughout this standard. The term “sensor” is preferred due to its wider application. A “sensor” is considered to be the device that transforms the monitored variable into an intelligible signal.

This standard’s purpose, when it was originally approved on 21 October 1980, was to provide guidance to the nuclear power industry in demonstrating compliance with Technical Specifications response time requirements for various Reactor Trip System and Engineered Safety Features Actuation System functions. At the time of its approval, little information was available regarding the reliability/validity of various response-time testing methods. Also, very little data existed regarding the possible degradation of the response times of the protection system sensors and modules.

Utility experience and industry research has demonstrated the adequacy of instrument response times testing methods. Utility experience, based on historic response-time test data, has also shown minimal changes in protection channel response times between tests. Industry research, based on failure modes and effects analysis (FMEAs) and component testing, has identified few degradation mechanisms that can affect some pressure sensor and rack module response times. Such research has resulted in the reduction of “periodic” response-time testing to demonstrate acceptable performance for certain pressure sensors, rack modules, logic circuits, and actuation relays. Specific instrumentation excluded from the Technical Specifications response-time testing requirements is defined in Owners Group topical reports approved by NRC Safety Evaluations. Note that similar research also confirmed that other protection system instrumentation must be response time tested periodically, e.g., RTDs.

Given the objectives of increased safety and reliability and reduced maintenance costs, the industry has developed on-line instrument performance monitoring techniques to demonstrate acceptable channel/sensor calibration. Such techniques are defined in an industry topical report approved by an NRC safety evaluation. (The general requirements for an on-line monitoring system are provided in this standard’s Annex G.)

As the emphasis on nuclear safety grew, ISA67.04 recognized the need to balance the surveillance requirements for channel calibration, channel checks, functional tests, and response-time tests by preparing a standard for performance monitoring of nuclear safety-related instrumentation. It was determined that the existing response-time testing standard would be the most suitable for inclusion of other performance monitoring techniques, i.e., surveillance test methods such as channel calibration. The working group also recognized the need to supplement other instrumentation testing requirements and methods delineated in IEEE Standard 338-1987, *IEEE*

Standard for Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems.

In 1990, ISA67.06 was reconvened with the objective of providing guidance to the nuclear power industry in demonstrating acceptable performance of nuclear safety-related instrument channels. The working group initially added other performance-monitoring techniques and attributes without curtailing the original emphasis on response-time testing. However, as the deliberations continued, the presence of the performance-related issues became more balanced, and the details of response-time monitoring found a home in the annex. The working group was careful to ensure that all performance-related issues received appropriate emphasis in revision ISA-67.06.01-2002.

ISA-67.06.01-2002 was revised to address preconditioning and provides a new annex for performing testing of instrumentation channels measuring neutron flux, including cable testing. Additionally, Annex B was revised to reflect the capability of noise analysis tests to detect problems in sensing lines that may affect the response time of pressure sensing systems. Annex E was also updated to include typical testing conditions and acceptance criteria for cross-calibration testing of narrow and wide-range resistance temperature detectors (RTDs).

This revision of ISA-67.06.01-2002 is not intended to impose new testing or monitoring requirements on the nuclear power industry; rather, in addition to providing guidance in response-time testing techniques, it is intended to describe methods that could be useful to monitor the performance of protection as well as process instrumentation systems. The standard does not intend to describe a testing program or techniques that can be implemented by themselves, but rather to provide information on methods that could be useful in developing an effective monitoring program. This standard is considered to be complementary to IEEE 338-2022.

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1 Scope

This document provides the nuclear power industry methods for assuring that nuclear safety-related instrument channels satisfy acceptable calibration, response time, and other factors affecting the performance of the instrument channel. This document applies only to those instrument channels whose primary sensors measure pressure, differential pressure, temperature, or neutron flux. Primary flow elements are addressed by other standards.

2 Purpose

The purpose of this document is to provide guidance to the nuclear power industry in demonstrating acceptable performance of nuclear safety-related instrument channels.

3 Definitions and terminology

For the purposes of this document, the following definitions apply:

3.1

accuracy

conformance of an instrument signal to an accepted value of the variable being measured; it is often expressed as inaccuracy

3.2

as-found

condition in which a channel, or portion of a channel, is found after a period of operation and before recalibration (if necessary)

3.3

as-left

condition in which a channel, or portion of a channel, is left after calibration or final setpoint device setpoint verification

3.4

calibration

process of achieving an input/output relationship for an instrument channel so it conforms within specified requirements to the desired relationship

3.5

channel check

qualitative comparison of the readings of two or more instrument channels to determine the operability of the channel that may be (1) the comparison of redundant channels that monitor the same process parameter, (2) the comparison of instruments that cover different process variable ranges at a common point on their scales, or (3) the comparison of diverse channels whose inputs have a known relationship to each other, such as steam pressure and temperature

3.6

cross calibration

procedure of intercomparison of the indications among similar channels under conditions where the process variables are expected to indicate the same value, such as temperature and/or pressure, or to have a known relationship to each other

3.7

design basis

information that identifies the specific functions to be performed by a structure, system, component, or a facility, and the specific values or ranges of values chosen for controlling parameters as reference bounds for design. These values may be either (1) restraints derived from generally accepted "state-of-the-art" practices for achieving functional goals, or (2) requirements

derived from analysis (based on calculation and/or experiments) of the effects of a postulated event for which a structure, system, or component must meet its functional goals.

3.8

direct test method

test method that substitutes a controlled parameter for the monitored process parameter and can be modulated to demonstrate the performance of the instrument channel

3.9

diverse parameter

instruments that use different measurement principles to obtain the value of a given monitored process variable as distinct from redundant instruments

3.10

drift

variation in sensor or instrument channel output that may occur between calibrations that cannot be related to changes in the process variable or environmental conditions

3.11

functional tests

tests to determine the ability of a component or system to perform its intended function, which for instrument channels may include the injection of test signals of appropriate magnitude to give the appropriate output

3.12

indirect test

test that measures a quantity other than the process parameter. The value of the desired parameter is determined, using the measured quantity and its known relationship to the process parameter of interest.

3.13

in-situ tests

tests of an instrument channel that are performed without removing the sensor or component from its normal installed position in the system. These tests may include calibration, time response, dynamic performance, dynamic range, etc. The tests may require system bypass or process maneuvers.

3.14

instrument channel (loop)

arrangement of components and modules as required to sense, interpret, act on, transmit, and display the value of a process variable

3.15

instrument channel response time

elapsed time for the monitored process variable to initiate a protective trip action for a known change of the process variable

3.16

monitoring

acquisition of data and the recording of the performance characteristics of instrument sensors, channels, or systems that may be used for trending, signal validation, or maintenance planning

3.17

noise analysis

in-situ method for measuring the response times of pressure-sensing systems (pressure, level, or flow transmitter and its associated sensing line) as installed in an operating nuclear power plant.

The noise analysis method is based on monitoring the natural fluctuations that exist at the output of pressure transmitters while the process is operating.

3.18

nuclear safety related

that which is essential to:

- a) provide emergency reactor shutdown,
- b) provide containment isolation,
- c) provide reactor core cooling,
- d) provide for containment or reactor heat removal, or
- e) prevent or mitigate a significant release of radioactive material to the environment or is otherwise essential to provide reasonable assurance that a nuclear power plant or nuclear reactor facility can be operated without undue risk to the health and safety of the public.

3.19

on-line monitoring

assessment of instrument performance and calibration while the instrumentation is in service

3.20

performance limits

limits defining the quantitative static and dynamic characteristics of the input and output subsystems measured during the operation/surveillance of the instrument channel for a given environmental condition (e.g., radiation, humidity, temperature, electromagnetic field, etc.). Instrument channel accuracy, response time, and stability are some of the attributes of performance limits.

3.21

range

span of inputs to a sensor or instrument channel over which the output indication is valid and within accuracy and response-time limits

3.22

redundant instruments

independent instruments that use the same measuring principles to provide an indication of a particular monitored process variable, which may include instruments manufactured by different sources, channels that comprise different signal-processing components, or channels that provide both analog and digital output indications (e.g., multiple thermocouples but not combinations of a thermocouple and a resistance temperature detector [RTD] to measure the same temperature). (See 3.9, diverse parameter.)

3.23

response time

time required for an output resulting from an application of a specified input under specified operating conditions

[SOURCE: ISA-51.1-1979 [R1993], referenced in Annex A]

3.24

sensing line

for the purpose of this document, a pipe or tube or both of relatively static fluid that connects the process being sensed to the sensor (transducer)

3.25**sensor**

portion of a channel that responds to changes in a process variable and converts the measured process variable into an instrument signal

[SOURCE: ISA-51.1-1979 [R1993], referenced in Annex A]

3.26**setpoint**

predetermined level at which a device changes state to indicate that the quantity under surveillance has reached the selected value

3.27**span**

algebraic difference between the *upper-* and *lower-range values*

EXAMPLE

Range 0 to 150°F, Span 150°F

Range -20 to 200°F, Span 220°F

Range 20 to 150°C, Span 130°C

Note 1 to entry: The following compound terms are used with suitable modifications to the units: *measured variable span*, *measured signal span*, etc.

Note 2 to entry: For multi-range devices, this definition applies to the particular range that the device is set to measure.

[SOURCE: ISA-51.1-1979 [R1993], referenced in Annex A]

3.28**stability**

ability of a component or device to maintain its normal operating characteristics over time after being subjected to changes in temperature, environment, or current

3.29**test interval**

elapsed time between the tests to monitor the performance of the instrument channels

3.30**time constant**

time that it takes for the output for a first-order system to reach 63.2 percent of its final steady-state output in response to a step change in input. Time constant is mathematically defined as the value T in an exponential response term $Ae^{(-t/T)}$ or in one of the transform factors $(1 + sT)$, $(1 + jwT)$, $1/(1 + sT)$, $1/(1 + jwT)$

where

s = complex variable equal to jw

t = time, seconds

T = time constant

$j = \sqrt{-1}$

w = angular velocity, radians per second

Note 1 to entry: For the output of a first-order system forced by a step or an impulse, T is the time required to complete 63.2 percent of the total rise or decay at any instant during the process. T is the quotient of the instantaneous rate-of-change divided into the change still to be completed. In higher-order systems, there is a time constant for each of the first-order components of the process. In a Bode diagram, break points occur at $w = 1/T$.

[SOURCE: ISA-51.1-1979 [R1993], referenced in Annex A]

3.31

transducer

see 3.25 sensor

3.32

trending

process of obtaining instrument data over time to form a history of the instrument channel or its components (e.g., calibration) or compared to redundant instruments (e.g., cross calibration/ comparison) to determine if the performance has been affected

4 Performance monitoring

Performance monitoring is the process of demonstrating that an installed instrument channel (within the defined environmental conditions) continues to perform its intended function(s) of monitoring the process variable with the expected accuracy, response time, and stability within its range and providing the output(s) required.

Various types of tests are typically required to provide verification of all required aspects of instrument channel performance. The objectives of the performance monitoring can be fulfilled through individual application or combinations of the following:

- a) calibration,
- b) channel checks,
- c) functional tests,
- d) response-time tests, and
- e) cable tests.

Examples of how the above processes can be used to verify required aspects of instrument channel performance or, conversely, to determine possible instrument channel degradation for pressure, differential pressure, and temperature channels are shown in Annex C, Tables C.1 and C.2.

Performance testing of instrumentation channels measuring neutron flux, including cable testing, is described in Annex L.

5 General requirements for performance monitoring

5.1 General criteria

Performance monitoring shall be conducted to verify that the nuclear safety-related instrument channels are functioning within their allowable performance limits. The tests that verify performance characteristics shall be conducted in accordance with written procedures, and the test results shall be documented as specified in Section 5.1 of IEEE 338-2022, referenced in Annex A. The instrument channel should be tested in a single test. When the total channel is not tested in a single test, separate tests on groups of components or on single components encompassing the total instrument channel shall be combined to verify total channel performance. Performance monitoring encompasses the instrument channel portion of the overall safety system. Test boundaries include cables, sensing lines, thermowells, and all other active and passive components that could affect the overall instrument channel performance. Performance test methods shall ensure other operating (not under test) instrument channels are minimally affected during the tests.

5.2 Test method considerations

Various types of tests are available to ensure instrument channels are operating within and remain within the prescribed performance limits as defined by the plant's design basis. Development of these tests requires a consideration of the following:

- a) plant design basis,
- b) regulatory requirements,
- c) instrument channel design,
- d) instrument component failure modes and detectability of each,
- e) historical data, and
- f) equipment reliability.

In addition, consideration should be given to ensure that both the interval and the extent of testing are appropriate for each component in the instrument channel without degrading the component performance and reliability.

5.3 Testing environment

“In general, abnormal environmental conditions, such as seismic events, radiation fields, extreme pressures, temperatures, and moisture conditions are covered by design qualification tests, provided unexpected degradation has not occurred. Testing of equipment for such environments is not within the scope of periodic surveillance testing and therefore need not be simulated” (see paragraph 5.2[g] of IEEE 338-2022, in Annex A). However, the performance testing should be carried out within the bounds of the instrument channel's environmental conditions (e.g., temperature, humidity, atmospheric pressure). If the test conditions vary widely, appropriate corrections should be made for comparison or trending of data to compensate for performance due to variation in the environmental conditions.

5.4 Test interval

The test intervals shall be established to detect unacceptable performance. Test intervals may vary depending on the instrument channel redundancy and availability requirements established in the design basis. The following factors shall be considered in determining the test interval:

- a) regulatory requirements,
- b) margin between measured performance characteristics and the allowable performance limits,
- c) time rate-of-change of the performance characteristics,
- d) failure modes, and
- e) reliability and qualification of as-built equipment.

(Additional guidance on establishment of test intervals can be found in paragraph 5.5 of IEEE 338-2022, referenced in Annex A.)

5.5 Preconditioning

As described in Section 3.5.2 of NUREG-1482 (referenced in Annex A), “preconditioning” refers to the “alteration, variation, manipulation, or adjustment of the physical condition of plant structures, systems, and components before Technical Specification surveillance or ASME Code testing.”

Some surveillance testing cannot be performed without disturbing or altering the equipment (e.g., attachment of test leads, pneumatic or hydraulic supply lines). Any such disturbance or alteration would be expected to be limited to the minimum necessary to perform the test and to prevent damage to the equipment. A documented evaluation of the preconditioning activity and a justification for continued confidence in the capability to assess the operational readiness of the component may be required. Annex M of this document provides a more detailed discussion of preconditioning.

5.6 Extent of testing

The extent to which instrument channels should be tested to demonstrate acceptable performance characteristics (accuracy, response, range, and reliability) shall be established. The following factors shall be considered in determining the extent of the test(s):

- a) operating status of plant; i.e., at power, shutdown, or hot standby,
- b) accessibility of the instrument channel component,
- c) whether the testing should include all channels or only some selected sample of similar or redundant channels,
- d) the number of test points needed to provide an acceptable uncertainty in the measured characteristic,
- e) whether the method(s) proposed will test both active and passive components of the instrument channel,
- f) whether the test(s) method(s) could affect the subsequent accuracy, response, and reliability of the instrument channel (e.g., change its time response by removal, testing, and reinsertion of component[s]),
- g) whether the conditions of the channel during the test are representative of the conditions experienced by the tested component during normal operation,
- h) any limitations necessary to prevent degrading the tested component during the performance test, such as the maximum permissible current that the device will tolerate, and
- i) regulatory requirements.

5.7 Test location

Testing should be performed in situ to the extent possible. Equipment removal for testing is considered acceptable if such removal does not affect test results or preclude testing any portion of the channel that has an effect on the performance characteristics.

5.8 Equipment restoration

Equipment removed from service shall be restored to the appropriate operating mode after completion of the performance monitoring test(s), and its operability shall be verified at the first practical opportunity.

6 Test methods

Performance tests can be conducted using direct or indirect methods. The assumptions and conditions required for validity of the test utilized shall be established and documented in accordance with Clause 7. Where indirect methods are used, a known quantitative relationship between the measured quantity and the performance characteristics shall be established and periodically verified.

Tests shall demonstrate the process instrumentation performs its intended function of monitoring the process variable with the expected accuracy, response time, and stability within its expected range and initiates the actions required of the instrument channel. Selection of a test method to be used for each test must consider the intent of the specific test and the limitations associated with the intended test method. The test methodology shall recognize all performance characteristics requiring verification.

6.1 Calibration

Instrument channel calibration utilizes known precision inputs to verify that a channel produces the required outputs over the required operational range within specified limits. Calibration can be accomplished/verified through individual application or combinations of the following:

- a) perturbation of the monitored variable,
- b) simulation of the monitored variable,
- c) on-line monitoring,
- d) cross calibration, and
- e) diverse parameter comparison.

On-line monitoring, cross calibration, and diverse parameter comparison techniques may be used if supported by equipment redundancy or diversity and correlation of data. Calibration shall compensate for the accuracy-related characteristics of the channel (e.g., linearity, hysteresis, drift, etc.). The specific details depend on the type of instrumentation. (For further discussion, see Annexes E, F, I, and K.)

6.2 Channel checks

Channel checks involving comparison of two or more instrument channels' indications are intended to verify the continued operability of instrument channels between calibrations. Consequently, these checks are conducted more frequently than calibrations and generally require no hardware interaction beyond observing or recording the given channel indication(s).

The performance criteria for instrument checks shall consider the following:

- a) the anticipated agreement between the channels being compared, based on the parameter monitored by each channel and the expected performance characteristics of each channel;
- b) the possibility of common mode failures when comparing redundant channels;
- c) comparison of diverse parameter channels that bear a known relationship to the channels undergoing a channel check (For further discussion, see Annex I.); and
- d) any differences in the actual process variable between sensor locations, (e.g., temperature stratification).

(For further discussion of instrument checks, see IEEE 338-2022, referenced in Annex A.)

6.3 Functional tests

Functional tests are intended to ensure that the instrument channels are capable of performing their required design functions. Functional tests are performed between calibrations. In addition, functional tests may be included in a calibration. These tests typically require injection of test signals of appropriate magnitude to give the expected output, including indication, trip, and alarm functions. Channel components not exercised through calibration or channel checks shall be tested to demonstrate operability.

Operational tests are functional tests that include calibration provisions to ensure channel components conform to specified requirements.

The performance capability of the safety system shall not be impaired. If the instrument channel is isolated for tests, the channel output shall be placed in a safe state or in a trip state, depending on the operating philosophy or regulatory requirements of the plant.

(For further discussion of functional tests, see IEEE 338-2022, referenced in Annex A.)

6.4 Response-time tests

Response-time testing can be performed by direct and indirect test methods or a combination of both. These tests can be performed with the instrumentation either in or out of service. At the time of response-time testing, the need to perform channel calibration prior to the response-time test shall be evaluated. The evaluation shall include whether or not calibration adjustments could affect response times. However, calibration of instrument channels need not be performed in conjunction with response-time testing if the instrument channel is within the required calibration interval.

The following response-time testing methods are acceptable techniques for demonstrating instrument channel and/or component response.

Direct test methods are:

- a) Substitute process perturbation:
 - 1) ramp-input signal,
 - 2) step-input signal, and
 - 3) other input signals
- b) Power interrupt (force balance pressure transmitters only)
- c) RTD plunge (laboratory testing only)

Indirect test methods are:

- a) Noise analysis
- b) Loop current step response (RTDs only, method is considered to have the validity of direct method.)
- c) Self-heating index (RTDs only, provides a value related to response time. For further discussion, see Annex B2.3.)

“Response-time testing of all safety-related equipment is not required if, in lieu of response-time testing, the response time of safety system equipment is verified by functional testing, calibration checks or other tests. This is acceptable if it can be demonstrated that changes in response time beyond acceptable limits are accompanied by changes in performance characteristics that are detectable during routine periodic tests.” (See paragraph 5.3.4[c] of IEEE 338-2022, referenced in Annex A.) For additional discussion of response-time test methods, see Annexes B and D.

7 Validation of test methods

All performance monitoring test methods used to determine quantitative data shall be validated. This validation shall be documented and shall address the following considerations:

- a) Compare the test method with a suitable direct laboratory, an in-situ test, or both to establish the validity of the test and quantify the accuracy of the method. The accuracy and validity of the test method and expected results may also be established by theoretical or experimental approaches or both. The accuracy determination shall consider all sources of error in the test method.
- b) Establish a theoretical basis for the test method.
- c) Satisfy the assumptions and conditions to ensure validity of the test method.
- d) Confirm that the essential conditions are appropriate and representative of those expected during the performance test.

The method used for data collection and data analysis needs to be validated by the four criteria mentioned here, and the results shall satisfy the system accuracy or performance criteria requirements.

8 Measuring and test equipment

The calibration of measuring and test equipment used in verifying equipment performance characteristics shall be traceable to the National Institute of Standards and Technology (NIST) standards or international standards and/or accepted values of natural physical constants.

The accuracy, response, range, and compatibility characteristics of the measuring and test equipment shall be the same as or better than the performance characteristics of the equipment

tested. These characteristics shall be known and accounted for in determining the test results. This determination may be done either by ensuring the test equipment characteristics are consistent with those assumed when determining test acceptance criteria or by appropriate correction of measured test data.

9 Test results

The test results shall be compared to the allowable performance limits. Allowances for uncertainties associated with the performance monitoring test shall be included in the test results or the establishment of performance limits. If the results are found to exceed the limit, or the rate of change in the performance characteristics are such that the allowable performance limits may be exceeded prior to the next test, appropriate action shall be taken. Test results shall be documented in accordance with ANS 3.2-2012 (referenced in Annex A).

10 Maintenance

After any repair or replacement of material, parts, or components that affect performance characteristics, the performance characteristics of that equipment shall be verified by test and the test results documented, unless it is shown and documented that the repair or replacement cannot affect the performance characteristics.

Annex A References

The following references contain provisions that, through reference in this text, constitute provisions of this document. At the time of publication, the editions indicated were valid and are included here for informational purposes. All standards are subject to revision, and parties to agreements based on this document are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of the International Electrotechnical Commission (IEC) and International Organization for Standardization (ISO) maintain registers of currently valid international standards.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI/ANS-3.2-2012 (R2017), *Managerial, Administrative, and Quality Assurance Controls for the Operational Phase of Nuclear Power Plants*

Available from: **ANSI**
25 West 43rd Street, 4th Floor
New York, NY 10036
Tel: (212) 642-4900

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E20/D30, *Standard Specification for Platinum Resistance Thermometers for Nuclear Plant or Other High-Reliability Applications*

ASTM E220-19, *Standard Test Method for Calibration of Thermocouple by Comparison Techniques*

ASTM E230/E230M-17, *Standard Specification for Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples*

ASTM E574-19, *Standard Specification for Duplex, Base-Metal Thermocouple Wire with Glass Fiber or Silica Fiber Insulation*

ASTM E608/E608M-13(2019), *Standard Specification for Mineral-Insulated, Metal-Sheathed Base-Metal Thermocouples, (for types E, J, K, N, and T)*

ASTM E780-17(2021), *Standard Test Method for Measuring the Insulation Resistance of Mineral-Insulated, Metal-Sheathed Thermocouples and Mineral-Insulated, Metal-Sheathed Cable at Room Temperature*

ASTM E839-11(2016)e1, *Standard Test Methods for Sheathed Thermocouples and Sheathed Thermocouple Cable*

ASTM E1129/E1129M-19, *Standard Specification for Thermocouple Connectors*

ASTM E1159-15(2020)e1, *Standard Specification for Thermocouple Materials, Platinum-Rhodium Alloys, and Platinum, (for types R, S, and B); or ASTM Publication MNL 12, Manual on the Use of Thermocouples, Table 10.1*

ASTM E1350-18, *Standard Guide for Testing Sheathed Thermocouples, Thermocouple Assemblies, and Connecting Wires Prior to, During, and After Installation or Service*

Available from: ASTM
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959
Tel: (610) 832-9585

ELECTRIC POWER RESEARCH INSTITUTE (EPRI)

NP-267 Project 503-1, *Sensor Response Time Verification*, October 1976 (p. 120)

NP-459 Project 503-3, *In-situ Response Time Testing of Platinum Resistance Thermometers*, 1977, (p. 121)

NP-834, *In-situ Response Time Testing of Platinum Resistance Thermometers — Noise Analysis Method, Volume 2*, 1978, (p. 122)

NP-1166 Project 503-2, *ARMA Sensor Response Time Analysis*, 1980, (p. 122)

NP-1486 Project 1161-1, *Temperature Sensor Response Characterization*, August 1980, (p. 122)

NP-7243, *Investigation of Response Time Testing Requirements*, 1991

TR-103335 R2, *Guidelines for Instrument Calibration Extension/Reduction – Revision 2*, 2014

TR-104965, *On-Line Monitoring of Instrument Channel Performance*, 2004

TR-103099, *Effects of Resistance Temperature Detector Aging on Cross-Calibration Techniques*, 1994

TR-1016725, *Requirements for On-Line Monitoring in Nuclear Power Plants*, 2008

TR-1019188, *Implementation of On-Line Monitoring to Extend the Calibration Interval of Pressure Transmitters in Nuclear Power Plants*, 2009

Available from: EPRI
3420 Hillview Avenue
Palo Alto, CA 94304
Tel: (605) 855-2000

INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)

IAEA-1147, *Management of Ageing of I&C Equipment in Nuclear Power Plants*, IAEA TECDOC-1147, 2000

INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS (IEEE)

IEEE 338-2022, *Standard for Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems*

IEEE 498-1990, *Standard Requirements for the Calibration and Control of Measuring and Test Equipment Used in Nuclear Facilities*

IEEE 603-1991, *Standard Criteria for Safety Systems for Nuclear Power Generating Stations*

Available from: **IEEE**
445 Hoes Lane
Piscataway, NJ 08855-1331
Tel: (800) 678-4333

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 62385:2007, *Nuclear power plants – Instrumentation and control important to safety – Methods for assessing the performance of safety system instrument channels*

ISA

ISA-51.1-1979 (R1993), *Process Instrumentation Terminology*

ANSI/ISA-67.02.01-2021, *Nuclear Safety-Related Instrument Sensing Line Piping and Tubing Standard for Use in Nuclear Power Plants*

ANSI/ISA-67.04.01-2018, *Setpoints for Nuclear Safety-Related Instrumentation*

ISA-RP67.04.02-2010, *Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation*

Kerlin, T. W., Miller, L. F., and Hashemian, H. M. "In-situ Response-time Testing of Platinum Resistance Thermometers," *ISA Transactions* 17, No. 4, 71–88, 1978.

Taylor, James L. *Computer-Based Data Acquisition Systems: Design Techniques*, Second edition, 1986.

Available from: **ISA**
3252 S. Miami Blvd., Suite 102
Durham, North Carolina 27703 US
Tel: (919) 549-8411

OAK RIDGE NATIONAL LABORATORY

Analytical Methods for Interpreting In-situ Measurements of Response Times in Thermocouple and Resistance Thermometers, ORNL/TM-4912, 1976.

Available from: **Oak Ridge National Laboratory**
P.O. Box 2008
Oak Ridge, TN 37831
Tel: (865) 576-7658

UNITED STATES NUCLEAR REGULATORY COMMISSION

NUREG 0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants*

NUREG 0809, *Safety Evaluation Report Review of Resistance Temperature Detector Time Response Characteristics*, 1981

NUREG 1366, *Improvements to Technical Specifications Surveillance Requirements*, 1992

NUREG 1482, *Guidelines for Inservice Testing at Nuclear Power Plants: Inservice Testing of Pumps and Valves and Inservice Examination and Testing of Dynamic Restraints (Snubbers) at Nuclear Power Plants, Revision 2*, 2013.

NUREG/CR-4256, ORNL/TM-9574, *Measurement of Response Time and Detection of Degradation and Pressure/Sensing Line Systems*, 1985

NUREG/CR-5560, *Aging of Nuclear Plant Resistance Detectors*, 1990

NUREG/CR-6343, *On-line Testing of Calibration of Process Instrumentation Channels in Nuclear Power Plants, Phase II Final Report*, 1995

NUREG/CR-6895, *Technical Review of On-Line Monitoring Techniques for Performance Assessment, Volumes I, II, III*, 2008

IN 96-24, "Preconditioning of Molded-Case Circuit Breakers Before Surveillance Testing," <https://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1996/in96024.html>

IN 97-16, "Preconditioning of Plant Structures, Systems, and Components before ASME Code Inservice Testing or Technical Specification Surveillance Testing," <https://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1997/in97016.html>

IN 2012-16, "Preconditioning of Pressure Switches before Surveillance Testing"

TIA 2009-006, "Unacceptable Preconditioning of Safety-Related Pressure Switches during Required Surveillance Testing at Monticello"

10CFR50 Appendix A General Design Criterion 21, "Protection System Reliability and Testability"

10CFR50 Appendix B General Design Criterion XI, "Test Control"

Available from: **U.S. Nuclear Regulatory Commission**
One White Flint North
1155 Rockville Pike
Rockville, MD 20852
Tel: (301) 415-7000

MISCELLANEOUS

AMS Topical Report, No. TPI8801R0, "In Situ Response-time Testing of Force-Balance Pressure Transmitters in Nuclear Power Plants," September 1988.

Burton, Dale A. "Resistance Temperature Detector Time Response Testing by the Self-Heating Method," *Instrumentation in the Power Industry* 23, 1980, 155–59. ISA.

Cain, D. G. and Foster, C. G. *A Practical Means for Pressure Transducer Response Verification*, Nuclear Technology 36, mid-December 1977, LaGrange Park, IL: American Nuclear Society.

Hashemian, H. M. Thie, J. A., and Upadhyaya, B. R. *Reactor Sensor Surveillance Using Noise Analysis*, NUREG/CP-0080, Volume 2, Proceedings of the Topical Meeting on Reactor Physics and Safety, 17–19 September 1986, Saratoga Springs, NY: American Nuclear Society.

Hashemian, H. M. "Sensor Response-time Testing Technology," ISA I&C Supervisors Meeting, October 1982, Philadelphia, PA.