



NUREG-0800

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

BRANCH TECHNICAL POSITION 7-13

GUIDANCE ON CROSS-CALIBRATION OF PROTECTION SYSTEM RESISTANCE TEMPERATURE DETECTORS

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of instrumentation and controls

Secondary - None

Review Note: The revision numbers of Regulatory Guides (RG) and the years of endorsed industry standards referenced in this branch technical position (BTP) are centrally maintained in Standard Review Plan (SRP) Section 7.1-T, "Regulatory Requirements, Acceptance Criteria, and Guidelines for Instrumentation and Control Systems Important to Safety," (Table 7-1). Therefore, the individual revision numbers of RGs (except RG 1.97) and years of endorsed industry standards are not shown in this BTP. References to industry standards incorporated by reference into regulation (IEEE Std 279-1971 and IEEE Std 603-1991) and industry standards that are not endorsed by the agency do include the associated year in this BTP. See Table 7-1 to ensure that the appropriate RGs and endorsed industry standards are used for the review.

Revision 6 - August 2016

USNRC STANDARD REVIEW PLAN

This Standard Review Plan (SRP), NUREG-0800, has been prepared to establish criteria that the U.S. Nuclear Regulatory Commission (NRC) staff responsible for the review of applications to construct and operate nuclear power plants intends to use in evaluating whether an applicant/licensee meets the NRC's regulations. The SRP is not a substitute for the NRC's regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide an acceptable method of complying with the NRC regulations.

The standard review plan sections are numbered in accordance with corresponding sections in Regulatory Guide (RG) 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)." Not all sections of RG 1.70 have a corresponding review plan section. The SRP sections applicable to a combined license application for a new light-water reactor (LWR) are based on RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

These documents are made available to the public as part of the NRC's policy to inform the nuclear industry and the general public of regulatory procedures and policies. Individual sections of NUREG-0800 will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience. Comments may be submitted electronically by email to NRO_SRP@nrc.gov.

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A. BACKGROUND

The purpose of this branch technical position (BTP) is to identify the information and methods acceptable to the staff for using cross-calibration techniques for surveying the performance of resistance temperature detectors (RTDs). These guidelines are based on experience in the detailed reviews of applicant or licensee submittals describing the application of in-situ cross-calibration procedures for reactor coolant RTDs, as well as U.S. Nuclear Regulatory Commission (NRC) research activities. In addition, the staff has completed reviews of applicant or licensee submittals and found that they met the requirements of the regulations identified. Other methods, such as using a diverse parameter to provide a cross-correlation reference, can be used if adequate justification is provided.

1. Regulatory Basis

Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(h), "Protection and Safety Systems," requires compliance with the Institute of Electrical and Electronics Engineers (IEEE) Standard (Std) IEEE Std 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," and the correction sheet dated January 30, 1995. For nuclear power plants with construction permits issued before January 1, 1971, the applicant or licensee may elect to comply instead with the plant-specific licensing basis. For nuclear power plants with construction permits issued between January 1, 1971, and May 13, 1999, the applicant or licensee may elect to comply instead with the requirements stated in IEEE Std 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations."

10 CFR 50.55a(h) requires in part that safety systems satisfy the requirements of IEEE Std 603-1991, including Clause 5.7 as part of the safety system criteria, Clause 6.5 for functional design requirements, and Clause 6.8 for allowances and uncertainties. 10 CFR 50.55a(h) also requires in part that protection systems satisfy the criteria of IEEE Std 279-1971, including Clause 3(9) regarding the bases for minimum performance requirements including response times and accuracies, Clause 4.9 for the capability for sensor checks, and Clause 4.10 for the capability for test and calibration.

10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix A, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," General Design Criterion (GDC) 13, "Instrumentation and Control," requires in part that instrumentation be provided to monitor variables and systems, and that controls be provided to maintain these variables and systems within prescribed operating ranges.

GDC 20, "Protection System Functions," requires in part that the protection system be designed to initiate operation of appropriate systems to ensure that specified acceptable fuel design limits are not exceeded.

GDC 21, "Protection System Reliability and Testability," requires in part that the protection system be designed for high functional reliability and in-service testability commensurate with the safety functions to be performed.

GDC 24, "Separation of Protection and Control Systems," requires in part that the protection system be separated from the control systems to the extent that failure of any single control

system component or channel, or failure or removal from service of any single protection system component or channel that is common to the protection system, leaves intact a system satisfying all reliability, redundancy, and independence requirements of the protection system.

GDC 29, "Protection against Anticipated Operational Occurrences," requires in part that protection and reactivity control systems be designed to ensure an extremely high probability of accomplishing their safety function in the event of an anticipated operational occurrence.

2. Relevant Guidance

IEEE Std 603-1991 requires in part that the safety system design basis include the following:

- The increment allotted for inaccuracies, calibration uncertainties, and errors.
- The overall response times of the safety system used in establishing the setpoint allowable value.
- The basis to demonstrate that the assumed values used for instrumentation inaccuracy, calibration uncertainties and error, and time response are acceptable and reasonable.

Performance of an RTD is characterized by its accuracy and response time. Accuracy is a measure of how well the RTD indicates a static temperature, and response time indicates how quickly the RTD can sense a temperature change. NUREG/CR-5560, "Aging of Nuclear Plant Resistance Temperature Detectors," asserts that the calibration and response time of RTDs are affected by aging even within design conditions, but that the aging is manageable by periodic tests performed at each refueling interval. Electric Power Research Institute (EPRI) TR-106453-3925, "Temperature Sensor Evaluation," provides additional information on RTD performance.

3. Purpose

The purpose of this BTP is to provide guidance for NRC reviewers to verify that the previously cited regulatory bases and standards are met by an applicant's submittal. This BTP has two objectives:

- Confirm that calibration inaccuracies, uncertainties, and errors associated with a proposed cross-calibration method are consistent with design basis and setpoint analysis assumptions, and
- Confirm that a proposed cross-calibration method is adequate to confirm that RTD response times are consistent with accident analysis assumptions.

B. BRANCH TECHNICAL POSITION

1. Introduction

To ensure adequate performance of the RTD, its accuracy and response time should be verified at appropriate intervals. For reactor coolant system (RCS) RTD sensors, practical considerations may limit the extent and methods prudent for in-situ calibration and testing. Periodic removal and re-installation of RTDs solely to support verification of calibration or response time could potentially introduce errors due to installation and increasing personnel exposure. In addition, it may not be feasible or prudent to achieve the range of isothermal conditions in the RCS for in-situ verification of the complete calibration range of the RTDs. Nevertheless, the applicant/licensee should provide assurance that the calibration and response time for each RTD has not significantly changed due to aging or degradation of the sensor and its installation.

One method acceptable to the staff is to periodically provide an installed reference RTD that has been recently calibrated and response-time tested. The remaining “similar” RTDs may be cross-correlated to the reference RTD to identify any significant degradation in performance. The “similar” RTDs are those which can be shown to be subject to sufficiently similar temperature and flow conditions in the RCS. While this method does not provide for complete calibration verification of each RTD over its range, the staff has found the method adequate for timely detection of drift or degradation of RTDs, provided that the guidance herein is applied. This guidance addresses the following topics:

- Traceability of the installed reference RTD to laboratory calibration data
- Acceptable methods for in-situ testing of RTDs
- Response time testing
- “As-found” and “as-left” surveillance data
- Control/protection interaction or common-cause failure during in-situ testing

2. Information to be Reviewed

The information to be reviewed consists of specifications, drawings, and analyses of the proposed RTD cross-calibration program.

3. Acceptance Criteria

Supporting Analysis

Analyses, and information on the instrument maintenance and calibration program should be provided to support the adequacy of the cross-calibration program. The analysis should, as a minimum, address the following topics.

- Justification that the cross-calibration program is consistent with the characteristics of the RTD sensors, including RTD specifications, range, accuracy, repeatability, dynamic response, installed configuration, environmental qualification, calibration reference, calibration history, and calibration intervals.
- The specific methods or analyses used for signal conditioning or processing (for example, averaging, biasing, failure detection, data quality determination, and error compensation).
- The planned process for cross-calibration and response time determination.
- Justification that the performance requirements and failure criteria assumed in the plant accident/event analyses are satisfied by the cross-calibration process and testing results.
- The technical basis for the acceptance criteria and values of cross-calibration points monitored in-situ throughout the RTD range, to ensure that the data are adequate for detecting degradation or systematic drift.

Traceability of the Installed Reference RTD to Laboratory Calibration Data

Laboratory calibration involves measuring the RTD's resistance at several known temperatures. The data are then used to provide a calibration curve for the device. In addition, the RTD response time can be determined under laboratory conditions using controlled temperature baths and a methodology to calculate the RTD response time over the measuring temperature range.

The installation of a calibrated RTD should include a test procedure to demonstrate the response time applicability of the laboratory test results. Loop current step response (LCSR) testing is an acceptable way to verify that the conditions of the installed RTD are adequately correlated to the laboratory test data.

Response time testing of the installed RTDs using LCSR should use an analytical technique such as the LCSR transformation identified in NUREG-0809, "Review of Resistance Temperature Detector Time Response Characteristics," to correlate the in-situ results with the results of a laboratory-type temperature test.

Acceptable Methods for In-Situ Testing

Verification of RTD calibrations should be accomplished by installing a newly calibrated reference RTD sensor and then cross-correlating with the measurements of the other RTDs subject to the same temperature and flow environment. A critical element in this approach is providing assurance that all sensor elements are subject to sufficiently similar temperature and flow environments. Other methods, such as using a diverse parameter to provide a cross-correlation reference, can be used if adequate justification is provided.

Before installing a reference or new RTD, the sensor should either be calibrated in a laboratory or, if the manufacturer's calibration data are to be used, the applicant or licensee should perform an analysis or test to verify the RTD has retained its calibration. The application temperatures should be within the manufacturer's highest calibration range.

All data should be taken at isothermal plant conditions and all loops (hot legs and cold legs) should be at similar temperatures. If this condition cannot be assured then the applicant or licensee should provide for removal of one or more of the RTDs at each representative location and for replacement with a newly calibrated RTD.

The applicant or licensee should provide an analysis which states the limits of acceptable calibration, response times, and in-situ testing of the RTDs. Test procedures, with acceptance criteria, should state the limits of the calibration, particularly the dependency of the data on uniform coolant temperature and flow.

Correction factors or bias values should be established to compensate for non-isothermal conditions. Because plant temperatures cannot be perfectly controlled, fluctuations and drift in the primary coolant temperature might occur during in-situ testing. The test data should be corrected for the fluctuations and drift in the coolant temperature. If during the testing incomplete mixing of the reactor coolant should occur, the test data should be corrected for the temperature differences. Reactor coolant temperatures should be stable and uniform. In the event this is not the case the data should be corrected to account for these effects.

Equipment used in the test should be accurate to within the necessary tolerance and have stable performance. See BTP 7-12 for guidance on determining plant instrumentation tolerances.

Response Time Testing

Even though response time testing is independent from the cross-calibration test, it should be performed for the existing and the newly installed reference sensors to account for installation effects and to identify degradation.

The resulting test data and analysis should support correlation of each of the existing sensors in the common flow path to its laboratory response time test data, and also to the laboratory response time test data for the reference sensor. Correlation between LCSR test results for the existing sensors and LCSR test results for the reference sensor may be used to establish the correlation with the reference RTD laboratory test data.

As-Found/As-Left Surveillance Data

The applicant or licensee should maintain a database of the "as-left" and "as-found" calibration and response time tests for each sensor.

To monitor systematic drift or degradation, at each refueling cycle, or as required by the plant's technical specifications, a newly calibrated RTD or a new RTD with recent calibration data should be installed at representative location(s) determined by analysis. The cross-correlation to the reference RTD(s) should be monitored using "as found" and "as left" data records.

Test data and analysis should identify and account for differences in isothermal conditions and demonstrate that the drift is random and is within an acceptable band as determined by setpoint analyses, and that systematic drift is not exhibited. If historical data reveals potential drift problems which would exceed the allowable values of temperature drift in testing for any sensor then the applicant or licensee should verify the calibration of the deviating sensor(s) and identify appropriate corrective action. Analysis to project RTD drift should be available for all RTDs within the protection system.

Control/Protection Interaction and Common-Cause Failure during In-Situ Testing

If the applicant or licensee uses test equipment common to redundant channels, qualified isolation should be provided to preclude single-failure effects on redundant channels or unacceptable protection/control interactions.

4. Review Procedures

The protection system design basis should be examined to identify the requirements for RTD accuracy and time response.

The cross-calibration method and calibration and response time data should be examined to identify calibration inaccuracies, uncertainties, and errors, and to confirm that the cross-calibration method is adequate.

The programmatic documentation of the cross-calibration process should be reviewed with respect to the acceptance criteria above. This review should confirm that the calibration process is consistent with all setpoint analysis assumptions and design basis requirements.

C. REFERENCES

1. Institute of Electrical and Electronics Engineers, IEEE Std 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations," Piscataway, NJ.
2. Institute of Electrical and Electronics Engineers, IEEE Std 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," Piscataway, NJ.
3. Electric Power Research Institute, EPRI Topical Report TR-106453-3925, "Temperature Sensor Evaluation," Electric Power Research Institute, June 1996.
4. U.S. Nuclear Regulatory Commission, "Review of Resistance Temperature Detector Time Response Characteristics," NUREG-0809, August 1981.
5. U.S. Nuclear Regulatory Commission, "Aging of Nuclear Plant Resistance Temperature Detectors," NUREG/CR-5560, June 1990.

PAPERWORK REDUCTION ACT STATEMENT

The information collections contained in the Standard Review Plan are covered by the requirements of 10 CFR Part 50, and were approved by the Office of Management and Budget, approval number 3150-0011.

PUBLIC PROTECTION NOTIFICATION

The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.

**BTP Section 7-13
Description of Changes**

**BTP 7-13 “Guidance on Cross-Calibration of Protection System
Resistance Temperature Detectors”**

This BTP section affirms the technical accuracy and adequacy of the guidance previously provided in BTP 7-13, Revision 5, dated March 2007. See the ADAMS Accession No. ML070550077.

The main purpose of this update is to incorporate the revised software Regulatory Guides and the associated endorsed standards. For organizational purposes, the revision number of each Regulatory Guide and year of each endorsed standard is now listed in one place, Table 7-1. As a result, revisions of Regulatory Guides and years of endorsed standards were removed from this section, if applicable. For standards that are incorporated by reference into regulation (IEEE Std 279-1971 and IEEE Std 603-1991) and standards that have not been endorsed by the agency, the associated revision number or year is still listed in the discussion. Additional changes were editorial.

Part of 10 CFR was reorganized due to a rulemaking in the fall of 2014. Quality requirement discussions in the former 10 CFR 50.55a(a)(1) were moved to 10 CFR 50.54(jj) and 10 CFR 50.55(i). The incorporation by reference language in the former 10 CFR 50.55a(h)(1) was moved to 10 CFR 50.55a(a)(2). There were no changes either to 10 CFR 50.55a(h)(2) or 10 CFR 50.55a(h)(3).