Branch Technical Position HICB-13

Guidance on Cross-Calibration of Protection System Resistance Temperature Detectors

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/licensee submittals describing the application of in-situ cross-calibration procedures for reactor coolant RTDs, as well as NRC research activities. In addition, the Staff has completed reviews of applicant/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

10 CFR 50.55a(h) requires in part that protection systems satisfy the criteria of ANSI/IEEE Std 279, "Criteria for Protection Systems for Nuclear Power Generating Stations," including the following:

- Section 3(9) regarding the bases for minimum performance requirements, including response times and accuracies.
- Section 4.9, "Capability for Sensor Checks."
- Section 4.10, "Capability for Test and Calibration."

10 CFR 50 Appendix A, 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.

10 CFR 50 Appendix A, 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.

10 CFR 50 Appendix A, 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.

10 CFR 50 Appendix A, 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.

10 CFR 50 Appendix A, 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

Reg. Guide 1.153, "Criteria for Power, Instrumentation, and Control Portions of Safety Systems," endorses IEEE Std. 603, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations" as an alternative to ANSI/IEEE Std. 279. IEEE Std 603 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. 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-mode 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/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 can not be assured then the applicant/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/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 HICB-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/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 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/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-Mode Failure During In-Situ Testing

If the applicant/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

ANSI/IEEE Std 279-1971. "Criteria for Protection Systems for Nuclear Power Generating Stations."

EPRI Topical Report TR-106453-3925. "Temperature Sensor Evaluation.." Electric Power Research Institute, June 1996.

IEEE Std 603-1991. "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations."

NUREG-0809. "Review of Resistance Temperature Detector Time Response Characteristics." August 1981.

NUREG/CR-5560. "Aging of Nuclear Plant Resistance Temperature Detectors." June 1990.

Regulatory Guide 1.153. "Criteria for Power, Instrumentation, and Control Portions of Safety Systems." Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, 1996.