Licensing Technical Report

NuScale Instrument Setpoint Methodology Technical Report

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Abstract

This technical report describes the instrument setpoint determination methodology applied to the safety-related instrumentation and control functions. The methodology is established to ensure the reactor trip system and engineered safety features actuation system setpoints are consistent with the assumptions made in the safety analysis and conform to the setpoint-related requirements of industry standard, ANSI/ISA-S67.04.01-2018, and Nuclear Regulatory Commission Regulatory Guide 1.105, Revision 4.

The detailed setpoint calculation processes for the module protection system are described in this report and may change according to plant-specific data. The methodology determines calibration uncertainty allowances, including as-found and as-left tolerances, used in plant surveillance tests to verify setpoints for safety-related protective functions are within technical specification limits. The methodology also establishes performance and test acceptance criteria to evaluate setpoints during surveillance testing and calibration for setpoint drift.

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Executive Summary

This technical report describes the instrument setpoint determination methodology applied to the safety-related instrumentation and control functions. The methodology described in this report ensures the reactor trip system (RTS) and the engineered safety features actuation system (ESFAS) setpoints are consistent with the assumptions made in the safety analysis and industry standards.

Setpoints for the RTS and ESFAS must be selected to provide sufficient allowance between the trip setpoint and the safety limit to account for instrument channel uncertainties. The methodology for establishing safety-related trip setpoints and their associated uncertainties ensures the analytical limit applied to the module protection system (MPS) protective actions are satisfied in accordance with the plant safety analysis. The instrument setpoint methodology is used to establish MPS setpoints for safety-related instrumentation and calibration uncertainty allowances. The methodology also establishes performance and test acceptance criteria to evaluate setpoints during surveillance testing and calibration for setpoint drift.

The assumptions applicable to the NuScale Instrument Setpoint Methodology are described in Section 2.0 of this report.

The sources of error and uncertainty associated with instrumentation channels (i.e., process measurement and miscellaneous effects errors, sensor errors, and digital system processing errors) are described in Section 3.0.

The relationships among trip setpoints, analytical limits, and the plant safety limits that are used to properly account for the total instrument channel uncertainty in establishing the setpoints are described in Section 4.0.

Sample uncertainty and setpoint calculations based on the methodology described in this document are provided in Section 5.0 to demonstrate the application of the methodologies and are not to be used in plant calibration procedures or for development of technical specifications. The detailed setpoint calculation processes for the MPS are described in this report and may change according to plant specific data. This methodology does not include provisions for using a graded approach for less important instrumentation.

The analytical limits, uncertainties, and setpoints for each RTS and ESFAS function are summarized in Section 6.0.

1.0 Introduction

1.1 Purpose

This document describes the methodology for determining setpoints for NuScale safety-related instrumentation and control (I&C) functions. Setpoints for the reactor trip system (RTS) and the engineered safety features system (ESFAS) must be selected to provide sufficient allowance between the trip setpoint and the safety limit to account for instrument channel uncertainties. The methodology for determining NuScale safety-related instrument channel uncertainties described in this document is based on Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.105, Revision 4 (Reference 8.4). The RG 1.105 endorses conformance with ANSI/ISA-S67.04.01-2018 as an acceptable method for satisfying the NRC regulations for ensuring setpoints for safety-related instrumentation are established and maintained within technical specification limits. The NuScale Instrument Setpoint Methodology is based on ANSI/ISA-67.04.01-2018 (Reference 8.8), and ANSI/ISA-RP67.04.02- 2010 (Reference 8.9).

Channel uncertainty calculations include instrument setpoint drift allowances. Periodic surveillance testing is required by the technical specifications in accordance with 10 CFR 50.36 (Reference 8.3) to measure setpoint drift. This document describes the methodology for determining calibration uncertainty allowances, including as-found and as-left tolerances, used in plant surveillance tests to verify setpoints for safety-related protective functions are within technical specification limits. The methodology for establishing performance and test acceptance criteria to evaluate setpoints during surveillance testing and calibration for setpoint drift is also described.

1.2 Scope

The NuScale Setpoint Methodology is used to establish module protection system (MPS) setpoints for safety-related instrumentation. This report documents the methodology for establishing safety-related trip setpoints and estimates the associated setpoint uncertainties to ensure analytical limits associated with safety-related MPS protective actions is satisfied in accordance with the plant safety analysis. This methodology is only applicable to instrumentation that supports the RTS and ESFAS. Sample uncertainty and setpoint calculations based on the methodology described in this document are provided in Section 5.0 to demonstrate the application of the methodologies and are not to be used in plant calibration procedures or for development of technical specifications. This methodology does not include provisions for using a graded approach for less important instrumentation.

1.3 Abbreviations

A list of acronyms and abbreviations used in this report are provided in Table 1-1. A list of defined terms used in this report is provided in Table 1-2.

Table 1-1 Abbreviations

Term	Definition
AFT	as-found tolerance
ALT	as-left tolerance
CS	calibrated span
DDR	digital system drifting
DMTE	digital system measurement and testing equipment error
DPM	decades per minute
DRA	digital system reference accuracy
DTE	digital system temperature error
ELVS	low voltage alternating current electrical distribution system
ESFAS	engineered safety features actuation system
HFE	human factors engineering
I&C	instrumentation and controls
IRE	insulation resistance effect
ISA	International Society of Automation
LSSS	limiting safety system setting
LTSP	limiting trip setpoint
M&TE	measurement and test equipment
MPS	module protection system
NDE	neutron monitoring system drift error
NDR	neutron monitoring system drift
NMS	neutron monitoring system
NMTE	neutron monitoring system M&TE error
NRA	neutron monitoring system reference accuracy
NRC	United States Nuclear Regulatory Commission
NTE	neutron monitoring system temperature error
NTSP	nominal trip setpoint
PEA	primary element accuracy
PME	process measurement error
psia	pounds per square inch absolute
psig	pounds per square inch gauge
PT	potential transformer
RG	regulatory guide
RCS	reactor coolant system
RTD	resistance temperature detector
RTP	rated thermal power
RTS	reactor trip system
SCA	sensor calibration accuracy
SDR	sensor drift
SEA	sensor accident effect
SME	sensor M&TE
SPE	sensor pressure effects
SRA	sensor reference accuracy
SRSS	square-root-sum-of-squares
SSE	sensor seismic effect
STE	sensor temperature effect

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Table 1-1 Abbreviations (Continued)

Term	Definition
TSTF	Technical Specifications Task Force
URL	upper range limit

Table 1-2 Definitions

Term	Definition
Analytical limit	Limit of a measured or calculated variable established by the safety analysis to ensure that a safety limit is not exceeded. Source: Reference 8.8
As-found	The condition that a channel, or portion of a channel, is found after a period of operation and before calibration. Source: Reference 8.8
As-left	The condition that a channel, or portion of a channel, is left after calibration or final setpoint device setpoint verification. Source: Reference 8.8
As-found tolerance	The maximum amount above and below the desired output by which the measure setpoint or desired calibration point is expected to change over the course of a calibration interval and still be considered to be performing normally. Source: Reference 8.8
Bias	An uncertainty component that consistently has the same arithmetic sign and is expressed as an estimated limit of error. Source: Reference 8.9
Dependent uncertainty	Uncertainty components are dependent on each other if they possess a significant correlation, for whatever cause, known or unknown. Typically, dependencies form when effects share a common cause. Source: Reference 8.9
Drift	A 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. Source: Reference 8.8
Error	The arithmetic difference between the indicated and the ideal value of the measured signal. Source: Reference 8.8
Independent uncertainty	Uncertainty components are independent of each other if their magnitudes or arithmetic signs are not significantly correlated. Source: Reference 8.9

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Table 1-2 Definitions (Continued)

Term	Definition
Instrument channel	An arrangement of components and modules as required to generate a single protective action signal when required by a plant condition. A channel loses its identity where single protective action signals are combined. Source: Reference 8.8
Instrument span	The region between the limits within which a quantity is measured, received, or transmitted, expressed by stating the lower- and upper-range values. Source: Reference 8.9
Limiting safety system setting	Limiting safety system settings (LSSS) are settings for automatic protective devices related to those variables having significant safety functions. Where an LSSS is specified for a variable that a safety limit is placed, the setting must be chosen so that automatic protective action corrects the abnormal situation before a safety limit is exceeded. Source: Reference 8.8
Limiting trip setpoint	The limiting value for the nominal trip setpoint so that the trip or actuation occurs at or before the analytical limit is reached. The setpoint considers credible instrument errors associated with the instrument channel, not including additional margin for conservativism. Source: Reference 8.8
Margin	In setpoint determination, an allowance added to the instrument channel uncertainty. Margin moves the setpoint farther away from the analytical limit. Source: Reference 8.9
Nominal trip setpoint	A predetermined value for actuation of a final setpoint device to initiate a protective action. The nominal trip setpoint (NTSP) is the trip setpoint value used for plant operations and must be equal to or more conservative than the LTSP. Source: Reference 8.8
Performance test	A test that evaluates the performance of equipment against a set of criteria. The results of the test are used to support an operability determination. Source: Reference 8.8
Random	Describing a variable whose value at a particular future instant cannot be predicted exactly but can be estimated by a probability distribution function Source: Reference 8.9
Reference accuracy	A number of quantity that defines a limit that errors will not exceed when a device is used under specified operating conditions. Source: Reference 8.8

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Table 1-2 Definitions (Continued)

Term	Definition
Safety limit	A limit on an important process variable necessary to reasonably protect the integrity of physical barriers that guard against the uncontrolled release of radioactivity. Source: Reference 8.8
Sensor	The portion of a channel that responds to changes in a process variable and converts the measured process variable into an instrument signal. Source: Reference 8.8
Signal conditioning	One or more modules that perform signal conversion, buffering, isolation, or mathematical operations on the signal as needed. Source: Reference 8.9
Total loop uncertainty	Represents an allowance between the LTSP and the analytical limit to accommodate the expected performance of the instrumentation under applicable process and environmental conditions. The trip or actuation is only required to mitigate certain postulated events; only the process and environmental conditions that occur during those postulated events need be considered. Source: Reference 8.8
Uncertainty	The amount that an instrument channel's output is in doubt (or the allowance made for such doubt) due to possible errors, either random or systematic. The uncertainty is identified within a probability and confidence level. Source: Reference 8.8

1.4 Background

The I&C safety systems control plant parameters to ensure safety limits are not exceeded under the design basis events. Instrument setpoints and acceptable as-left and acceptable as-found bands for these I&C safety system functions are chosen so that potentially unsafe or damaging process excursions (transients) can be avoided or terminated before plant conditions exceed safety limits. Safety analyses establish the limits for credited protective actions. These analytical limits established by safety analyses, do not normally include considerations for the accuracy (uncertainty) of installed instrumentation. Additional analyses and procedures are necessary to ensure the limiting trip setpoint (LTSP) of each safety control function is appropriate.

Instrument channel uncertainties in these analyses are based on the characteristics of installed instrumentation, the environmental conditions present at the instrumentation installed locations, and process conditions. A properly established setpoint initiates a plant protective action before the process parameter exceeds its analytical limit. This, in turn, ensures that transients are avoided or terminated before the process parameters exceed the established safety limits.

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Early versions of the RTS and ESFAS technical specifications for existing plants contained only trip setpoint requirements with no allowance for setpoint drift. The setpoint values were specified as limits with inequality signs to indicate the direction of allowable drift. In order to maximize operating margin, instrument channels were sometimes calibrated without sufficient allowance for setpoint drift leading to numerous reportable events when technical specification limits were exceeded.

The International Society of Automation (ISA) sponsored a review of the setpoint drift problem in April 1975. Revision 1 to RG 1.105,"Instrument Setpoints," was published in November 1976 in response to the large number of reported instances in which instrument setpoints in safety-related systems drifted outside the limits specified in the technical specifications. Using the method described in to the RG and additional criteria on establishing and maintaining setpoints, Subcommittee SP67.04, Setpoints for Safety-Related Instruments in Nuclear Power Plants, under the Nuclear Power Plant Standards Committee of the ISA, developed a standard containing minimum requirements for establishing and maintaining setpoints of individual instrument channels in safety-related systems. This standard was issued as ISA-S67.04-1982, "Setpoints for Nuclear Safety Related Instrumentation Used in Nuclear Power Plants."

ISA-S67.04 was revised in 1987 to provide clarification and to reflect industry practice. The standard was revised further in 1994 and reflects the Improved Technical Specification Program (a cooperative between the industry and NRC staff) and current industry practice established in the Standard Technical Specifications, which included a nominal trip setpoint and an allowable value to establish limits of instrument channel operability during periodic surveillance testing.

Conformance with Part I of ISA-S67.04-1994, "Setpoints for Nuclear Safety-Related Instrumentation," with the exceptions and clarifications specified in RG 1.105, Revision 3, provided a method acceptable to the NRC for ensuring setpoints for safety-related instrumentation are established and maintained within the technical specification limits. Revision 3 did not address or endorse Part II of ISA-S67.04-1994, "Methodologies for the Determination of Setpoints for the Nuclear Safety-Related Instrumentation." Part II provided recommended practices and guidance for implementing Part I.

In September 2002, during review of a plant-specific license amendment request, the NRC expressed a concern that the allowable values calculated using some methods in ISA-S67.04-1994 Part II could be non-conservative depending upon the evaluation of instrument performance history and the as-left requirements of the calibration procedures. To resolve this concern, the industry and the NRC worked together to develop requirements to ensure instrument channels actuate safety systems to perform their preventive or mitigation functions as assumed in the safety analysis. As a result of this joint effort, the industry Technical Specifications Task Force (TSTF) issued TSTF-493, Rev. 0, "Clarify Application of Setpoint Methodology for LSSS Functions," on January 27, 2006.

The NRC responded to TSTF-493, Rev. 0 and their comments were incorporated in TSTF-493, Rev. 4, issued on July 31, 2009 (Reference 8.6).

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The NuScale Design Specific Review Standard for Chapter 7 provides the NRC staff guidance in the review of the NuScale licensing submittals describing instrumentation setpoints. Section 7.2.7 of the standard provides review and acceptance criteria for acceptable as-found and as-left tolerances used in the setpoint methodology.

ANSI/ISA 67.04.01-2018 (Reference 8.8) incorporated a standard method for addressing the analytical limit avoidance probability, incorporated improved guidance establishing statistical confidence and maintaining setpoints, provided the definition of tolerance interval and a recommended method of combination of uncertainties, and incorporated standards for performance monitoring and is endorsed by RG 1.105, Revision 4 (Reference 8.4). ANSI/ISA 67.04.02-2010 (Reference 8.9) is not endorsed, but NRC staff believe it contains useful information as it provides recommended practices and guidance for implementing 67.04.01.

In accordance with the regulatory and industry standard guidance cited above, the methodology described in this document establishes the relationship between the safety limit, analytical limit, limiting trip setpoint, the performance and acceptance test criteria, the setpoint, the acceptable as-found band, the acceptable as-left band, and the setting tolerance. The instrumentation setpoint methodology in this document adopts updated guidance provided in Reference 8.8 and Reference 8.9. These industry standards provide updated guidance based on best-industry practices that have not been included in previous regulatory guidance.

1.5 Regulatory Requirements

10 CFR 50.55a(h), "Protection and Safety Systems," requires compliance with IEEE Std. 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," and the correction sheet dated January 30, 1995 (Reference 8.5). Clause 4.4 of IEEE Std. 603-1991 requires identification of the analytical limit associated with each variable. Clause 6.8.1 requires allowances for uncertainties between the analytical limit and device setpoint be determined using a documented methodology.

10 CFR 50, Appendix B, Criterion XI, “Test Control,” and Criterion XII, "Control of Measuring and Test Equipment," provide requirements for tests and test equipment used in maintaining instrument setpoints.

10 CFR 50 Appendix A, General Design Criterion 13, “Instrumentation and Control,” requires instrumentation be provided to monitor variables and systems, and controls be provided to maintain these variables and systems within prescribed operating ranges.

General Design Criterion 20, “Protection System Functions,” requires the protection system be designed to initiate automatically the operation of appropriate systems including the reactivity control systems, to ensure specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences.

10 CFR 50.36(c)(1)(ii)(A), “Technical Specifications,” requires where an LSSS is specified for a variable on which a safety limit is placed, the setting be chosen so automatic protective action corrects the abnormal situation before a safety level is

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exceeded. The LSSSs are settings for automatic protective devices related to variables with significant safety functions. Setpoints found to exceed technical specification limits are considered as malfunctions of an automatic safety system. Such an occurrence could challenge the integrity of the reactor core, reactor coolant pressure boundary, containment, and associated systems.

10 CFR 50.36(c)(3), “Technical Specifications,” states that surveillance requirements are requirements relating to test, calibration, or inspection to ensure the necessary quality of systems and components is maintained, facility operation will be within safety limits, and the limiting conditions for operation will be met.

1.5.1 Regulatory Guidance

The following regulatory guidance is applicable to the NuScale setpoint methodology described in this document.

RG 1.105, Revision 4, “Setpoints for Safety-Related Instrumentation,” provided guidance for ensuring that instrument setpoints are initially - and remain - within the technical specification limits. The RG endorses ISA-67.04.01-2018, Reference 8.8.

Generic Letter 91-04, “Guidance on Preparation of a Licensee Amendment Request for Changes in Surveillance Intervals to Accommodate a 24-Month Fuel Cycle,” provides guidance on issues that should be addressed by the setpoint analysis when calibration intervals are extended from 12 or 18 to 24 months.

NuScale Design Specific Review Standard for Chapter 7, Section 7.2.7, provides NRC staff review guidance of safety-related setpoint determination for the NuScale reactor protection systems.

1.5.2 Industry Standards

IEEE-603-1991, “IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations.”

ISA-67.04.01-2018, “Setpoints for Nuclear Safety-Related Instrumentation.”

ISA-RP67.04.02-2010, “Methodology for the Determination of Setpoints for Nuclear Safety-Related Instrumentation,” provides additional guidance. Regulatory Guide 1.105, Revision 4, does not endorse this practice, but believes it contains useful information.

2.0 Assumptions

The NuScale Instrument Setpoint Methodology is based on the following assumptions.

2.1 Generic Assumptions

The following assumptions apply generically to the NuScale methodology.

2.1.1 Statistically Neglected Variables

Random independent terms whose values are less than {{ }}$^{2(a),(c)}$ of any of the other associated device random uncertainties can be statistically neglected.

2.1.2 Calculation of Uncertainty Terms

Uncertainty terms of devices are calculated in terms of percent calibrated span (CS) unless otherwise noted.

2.1.3 Random Term Probability Distribution

Random terms are assumed to have an approximately normal probability distribution function for the purposes of this document. Common industry practice is to assume published vendor specifications conform to 95/95 confidence level unless specific information is available to indicate otherwise (Section 3.2 and Section 3.4.2.1).

2.1.4 Sensor Temperature Error

For the purposes of setpoint analyses, the instrumentation is assumed to be calibrated at the reference ambient conditions, specified in plant calibration procedures. The sensor temperature effect (STE) for the instrumentation is an allowance based on the maximum expected ambient temperature deviation from the reference calibration conditions. A value of {{

}}$^{2(a),(c)}$ (in units of ± X percent CS for Y degrees Fahrenheit).

{{

}}$^{2(a),(c)}$

2.1.5 Seismic Effect Error

The sensor seismic effect error is {{ }}$^{2(a),(c)}$ (Section 3.4.2.9).

2.2 Example Setpoint Calculation Assumptions

The following assumptions are made to demonstrate the application of the NuScale Instrument Setpoint Methodology. These assumptions are validated and updated if necessary in the application of this methodology based on final sensor selection and known instrumentation loop parameters.

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2.2.1 Insulation Resistance Effect

The insulation resistance effect is a bias error {{ }}$^{2(a),(c)}$

2.2.2 Sensor Drift Error

For sensors except neutron detectors, the sensor drift (SDR) error is conservatively assumed to be {{

}}$^{2(a),(c)}$

2.2.3 Measurement and Test Equipment Error

For sensors except neutron detectors, the sensor measurement and test equipment (M&TE) error (SME) is conservatively assumed to be {{ }}$^{2(a),(c)}$ The M&TE readability error is assumed to be zero as it is assumed that M&TE have digital readouts.

2.2.4 Sensor Process Measurement Errors

The sensor process measurement errors (PMEs) and sensor reference accuracies (SRAs) are shown for the sensors listed in Table 2-1. Instrument Sensor Uncertainties below, because actual process measurement errors are unknown at this time, the PME terms are {{

}}$^{2(a),(c)}$

Table 2-1 Instrument Sensor Uncertainties

Pressure Sensor Applications	**Process Measurement Error, (PME)**	**Sensor Reference Accuracy, (SRA)**
Narrow Range Pressurizer Pressure	{{	}}$^{2(a),(c)}$
Narrow Range Containment Pressure	{{	}}$^{2(a),(c)}$
Main Steam Pressure	{{	}}$^{2(a),(c)}$
Water Level Applications	**Process Measurement Error, (PME)**	**SRA**
Pressurizer Level	{{	}}$^{2(a),(c)}$
RPV Water Level	{{	}}$^{2(a),(c)}$

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Table 2-1 Instrument Sensor Uncertainties (Continued)

Flow Rate Sensor Applications	Process Measurement Error, (PME)	SRA
RCS Flow Rate	{{	}}2(a),(c)
Temperature Sensor Applications	**Process Measurement Error, (PME)**	**SRA**
RCS Hot	{{	}}2(a),(c)
Main Steam Temperature	{{	}}2(a),(c)
Under the Bioshield Temperature	{{	}}2(a),(c)

2.2.5 Neutron Monitoring System Assumptions

2.2.5.1 Power Range Error

There are {{ }}2(a),(c) associated with the neutron detectors used in the power range detector instrument channel functions. {{

}}2(a),(c)

2.2.5.2 Intermediate Range Error

The intermediate range neutron detector sensor reference accuracy and drift is assumed to be {{ }}2(a),(c) respectively. This value is based on data provided by {{

}}2(a),(c) The indicated value is in units of counts per second, which is directly proportional to percent RTP. Therefore, the accuracy values specified are applied to the indicated value for percent rated thermal power on a logarithmic scale spanning six decades (1.00x10-4 percent RTP to 200 percent RTP).

2.2.5.3 Intermediate Range Process Measurement Error

The intermediate range neutron monitoring detector process measurement uncertainty is {{

}}2(a),(c)

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2.2.5.4 Neutron Monitoring System Measurement and Test Equipment Error

The NMS uncertainties NMS measurement and test equipment error (NME) is {{

}}2(a),(c)

2.2.5.5 Source Range Log Power

{{

}}2(a),(c)

2.2.5.6 Primary Element Accuracy and Process Measurement Error

Primary Element Accuracy (PEA) and Process Measurement Error (PME) are assumed to be accounted for in the NMS reference and stability accuracies.

2.2.5.7 Aggregate Uncertainties

Uncertainties are assumed to be the {{ }}2(a),(c) To accommodate this assumption in the setpoint methodology, sensor uncertainties assign a value of {{

}}2(a),(c)

2.2.5.8 Neutron Monitoring System Drift Error

Neutron monitoring system drift error (NDE) is assumed to be {{

}}2(a),(c)

2.2.5.9 Analytical Limit Value

The analytical limit value is used as input for percent of indicated value.

2.2.5.10 Subcritical Multiplication Protective Function

The subcritical multiplication protective function is a ratio of source range count rates. The errors are {{

}}2(a),(c)

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{{ }}2(a),(c)

2.2.6 Digital System Uncertainties

2.2.6.1 Digital System Uncertainties for Reference Accuracy

The digital system uncertainties for digital system reference accuracy (DRA) are {{ }}2(a),(c) These values are {{ }}2(a),(c)

2.2.6.2 Module Protection System Digital System Inaccuracies

The MPS digital system uncertainties for temperature error, digital system temperature error (DTE), drift, digital system drifting (DDR), and measuring and test equipment, digital system measurement and testing equipment error (DMTE), are {{ }}2(a),(c)

2.2.7 Process Parameter Operating Points

The values for the process parameter operating points are obtained from plant design information.

2.2.8 Analytical Limits

The values for the analytical limits are obtained from the plant safety analysis.

2.2.9 Sensor Static Pressure

Sensor static pressure effect applies to differential pressure sensors. {{ }}2(a),(c)

2.2.10 Source Range and Intermediate Range Power Rate Trip

The analytical limit source and intermediate range log power rate is {{ }}2(a),(c) The log power rate trip is implemented on both the source range and the intermediate range signals of NMS. {{ }}2(a),(c)

The source range doubling time output accuracy is specified as {{ }}2(a),(c)

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{{ }}$^{2(a),(c)}$

The source range doubling time output is {{ }}$^{2(a),(c)}$

2.2.11 Power Range High Power Rate Trip

The Power Rate Trip is enabled at the 15 percent RTP startup power hold point and is used to detect rapid increases or decrease in core power. The Power Rate Trip is expressed in percent RTP/ 30 sec. with an analytical limit of 7.5 percent RTP/ 30 sec. It is assumed therefore that Process & Miscellaneous Effects Error, Sensor Errors, Neutron Monitoring System Errors and Digital Processing Errors do {{ }}$^{2(a),(c)}$ Based upon engineering judgment {{ }}$^{2(a),(c)}$ in the determination of the Nominal Trip Setpoint.

2.2.12 Primary Element Accuracy for ELVS Bus Voltage

{{ }}$^{2(a),(c)}$ A potential transformer has a fixed ratio of primary to secondary windings. Process and Sensor Errors do not apply to when a potential transformer is the primary element. {{ }}$^{2(a),(c)}$ where analog to digital conversion occurs. {{ }}$^{2(a),(c)}$

3.0 Methodology

3.1 Uncertainties and Instrument Error

The measurement signal is a combination of multiple errors including, but not limited to, instrument reference accuracy, process effects, changes in ambient conditions, and calibration methods. Because the actual value of the error is unknown, the accuracy of the instrument measurement can only be expressed in terms of statistical probabilities. Therefore, the term uncertainty is used to reflect the distribution of possible errors (Reference 8.9).

This methodology for combining instrument uncertainties is a combination of statistical and algebraic methods. The statistical square-root-sum-of-squares (SRSS) method is used to combine uncertainties that are random, normally distributed, and independent. The algebraic method is used to combine uncertainties that are not randomly distributed or are dependent.

3.2 The Square-Root-Sum-of-Squares Method

The SRSS methodology for combining uncertainty terms that are random and independent is an established and accepted analytical technique as endorsed by RG 1.105. The SRSS methodology is a direct application of the central limit theorem, providing a method for determining the limits of a combination of independent and random terms. The probability that all the independent processes under consideration would simultaneously be at their maximum value in the same direction (i.e., + or -) is very small. The SRSS methodology provides a means to combine individual random uncertainty terms to establish a resultant net uncertainty term with the same level of probability as the individual terms. If an individual uncertainty term is known to consist of both random and bias components, the components should be separated to allow subsequent combination of like components.

Bias components are treated separately from random components during SRSS addition. (Reference 8.9, Appendix J, Section J.1)

Resultant net uncertainty terms should be determined from individual uncertainty terms based on a common probability level. The methodology in this document uses the 95/95 tolerance limits as an acceptance criterion. Thus, there is a 95 percent probability that the specified limits contain 95 percent of the population of interest for the surveillance interval in question. In some cases, individual uncertainty terms may need to be adjusted to the common probability level. Typically, a probability level that corresponds to two standard deviations (2-sigma) is equal to a 95.6 percent probability on a normal (Gaussian) distribution curve. However, RG 1.105 (Reference 8.4) describes using a 95/95 tolerance limit, which has an actual confidence level of 1.96-sigma. The methodology described in this document used a 95/95 tolerance interval for consistency with regulatory guidance.

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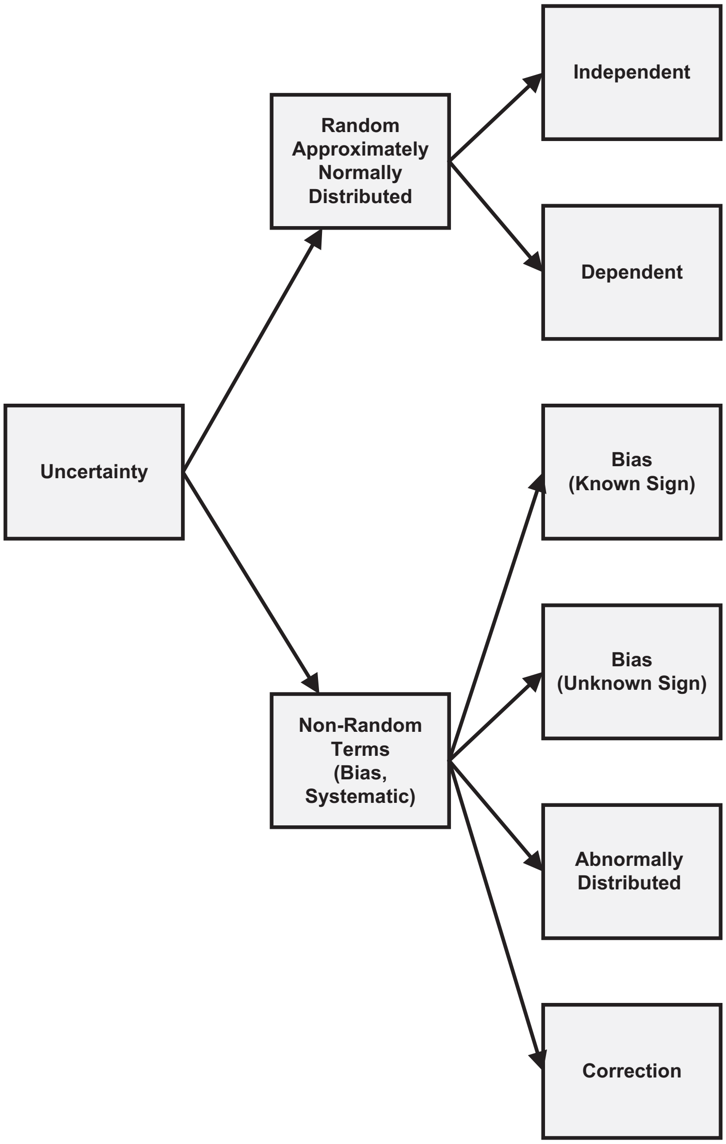
3.3 Uncertainty Categories

Instrument uncertainties must be categorized to determine how they are combined in the overall instrument channel uncertainty calculation. The two basic categories, random and non-random are discussed below.

Figure 3-1 Statistical Uncertainty



3.3.1 Random Uncertainties

Random uncertainties are referred to as a quantitative statement of the reliability of a single measurement or of a parameter, such as the arithmetic mean value, determined from a number of random trial measurements, often called the statistical uncertainty and is one of the so-called precision indices. The most commonly used

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indices, usually in reference to the reliability of the mean, are the standard deviation, the standard error (also called the standard deviation of the mean), and the probable error.

After uncertainties are categorized as random, dependencies between the random uncertainties are identified. The uncertainty must be mean-centered and approximately normally distributed to be considered random and it is expected that the instrument uncertainties that a manufacturer specifies as having a ± magnitude are random uncertainties.

3.3.1.1 Independent Uncertainties

Independent uncertainties are those uncertainties where no common root cause exists.

Sensor temperature effects and pressure effects are examples of uncertainties with no root cause. Ambient temperature and pressure are assumed to be constant during the sensor calibration process. These uncertainties are independent and are combined as separate terms using the SRSS methodology.

3.3.1.2 Dependent Uncertainties

Dependent uncertainties are those uncertainties where a a common root cause exists that influences two or more of the uncertainties with a known relationship.

Calibration methodology is a common influence for uncertainties such as reference accuracy and drift. For example, if the calibration methodology does not verify repeatability, one of the four attributes of reference accuracy, then drift and repeatability errors are interactive and cannot be independently determined. If two or more uncertainties are determined to be dependent, then they are combined algebraically to create a larger independent uncertainty.

3.3.2 Non-Random Uncertainties

3.3.2.1 Bias (known sign)

A bias is a systematic instrument uncertainty that is predictable for a given set of conditions due to the existence of a known direction (positive or negative).

Differential pressure level measurements are subject to bias errors caused by reference leg heat up or flashing if transmitters are used with reference leg. Fluid density changes due to process temperature changes can also be a source of bias errors in flow or level measurements. Process density errors are minimized by calibrating the transmitter for a normal operating condition.

3.3.2.2 Abnormally Distributed Uncertainties

Some uncertainties are not normally distributed. Such uncertainties are not eligible for SRSS combinations and are categorized as abnormally distributed uncertainties. Such uncertainties may be random (equally likely to be positive or negative with respect to some value) but extremely non-normal. This type of uncertainty is treated as a bias against both the positive and negative components of a module's uncertainty.

3.3.2.3 Bias (unknown sign)

Some bias effects may not have a known sign. Their unpredictable sign should be conservatively treated by algebraically adding the bias in the worst (i.e., conservative) direction.

3.3.2.4 Correction

Errors or offsets that are of a known direction and magnitude are corrected for in the calibration of the instrument module and are not included in the setpoint calculation. The fact that these corrections are made during calibration should be identified in the setpoint uncertainty calculation.

3.3.3 Combining Uncertainties

The TLU for an instrument or instrument loop/channel is typically a combination of several categories using the SRSS and algebraic methodologies described above. A simplified example illustrates how these uncertainties are combined.

An instrument channel has eight uncertainties: A, B, C, D, E, F, L and M as categorized below. Values are scaled to units of percent CS to ensure they are combined consistently with other values in the total channel uncertainty calculation. Direction signs are included to illustrate the combined effect.

A (random / independent) = ± 1.0% CS

B (random / independent) = ± 1.0% CS

C (random / independent) = ± 1.0% CS

D (random / dependent) = ± 1.5% CS (D interacts with E)

E (random / dependent) = ± 2.0% CS (E interacts with D)

F (abnormally distributed) = ± 2.5% CS (Treated as ± Bias value)

L (Bias: known direction)= + 3.0% CS

M (Bias: known direction)= - 4.0% CS

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The setpoint calculation ensures protective actions occur before the analytical limits are reached. The SRSS technique applies only to those uncertainties characterized as independent, random, and approximately normally distributed (or otherwise allowed by versions of the central-limit theorem). Other uncertainty components are combined using the maximum possible uncertainty treatment, i.e., algebraic summation of absolute values.

The total loop uncertainty is calculated, as follows, using the SRSS method for random terms and algebraic summation of like signs for bias terms:

$$TLU = [(A)^2 + (B)^2 + (C)^2 + (D + E)^2]^{1/2} \pm |F| + L - M$$

$$TLU = [(1)^2 + (1)^2 + (1)^2 + (1.5 + 2)^2]^{1/2} \pm |2.5| + 3 - 4$$

$$TLU = \pm 3.9\%\ CS + 5.5\%\ CS - 6.5\%\ CS$$

$$TLU^+ = (+)3.9\%\ CS + 5.5\%\ CS = +\ 9.4\%\ CS$$

$$TLU^- = (-)3.9\%\ CS - 6.5\%\ CS = -\ 10.4\%\ CS$$

This general example indicates how uncertainty calculations can be dominated by dependent and bias errors. The larger negative error can be significant if it is in the non-conservative direction with respect to the analytical limit for this instrument channel.

3.3.4 Sign Convention

The sign convention used in this setpoint methodology is consistent with the ISA definition of error (Table 1-2). In this definition, error is equal to the difference between the indication and the ideal value of the measured signal. Therefore, a positive error indicates that the measured value is greater than the actual process value. The error direction is referenced to the ideal, or true value, and is expressed mathematically in one or two ways:

Error = Indicated Value - Actual Value; or

Indicated Value = Actual Value + Error

3.4 Sources of Uncertainty

3.4.1 Uncertainty Categories

There are three main categories of error and uncertainty associated with instrumentation channels: process measurement and miscellaneous effects errors, sensor errors, and digital system processing errors. A unique set of reactor protection functions are associated with the NMS such that for these reactor protection functions, an additional set of error and uncertainties associated with the error introduced by the NMS signal processing function is considered.

The most sources of uncertainty are encountered by the measurement process and instrumentation. A typical reactor protection actuation normally requires signal transformation from process parameters to voltage or current values. The typical instrument channel elements are:

- Process
- Process interface
- Process measurement and reading
- Signal interface and transmission
- Signal conditioning
- Actuation

Furthermore, the instrument channel environment should be considered in uncertainty calculations because a safety-related instrument channel actuation setpoint could vary under changing environmental conditions. After the environmental conditions are determined, the potential uncertainty sources of the instrument channel are provided below.

3.4.1.1 Primary Element Uncertainties

Sensor PEA uncertainties are included when a process variable depends on a measuring device in addition to the process sensor. Examples include the use of a venturi, elbow, or orifice plate as the primary element for flow measurements. These uncertainties are independent of sensor uncertainties.

3.4.1.2 Process Measurement Uncertainties

The PME uncertainties account for errors in the process variable. These uncertainties are independent of sensor uncertainties. Examples include the effect of fluid stratification on temperature measurement, the effect of fluid density changes on differential pressure, level and flow measurements, and the effect of borated water on neutron flux measurements.

3.4.2 Instrument and Sensor Uncertainties

Sensor uncertainty includes a set of parameters combined as a group to account for sensor errors. In general, these uncertainties include reference accuracy, calibration error, drift, and other parameters, as appropriate, such as pressure effects and normal ambient temperature effects. Additionally, the environmental effects of sensors required to operate during accident conditions must also be considered.

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3.4.2.1 Sensor Reference Accuracy

The SRA is provided by the manufacturer as a limit for measurement errors when the sensor is in operation under specified conditions. The SRA includes linearity, hysteresis, dead band, and repeatability. The sensor reference accuracy provided by instrument vendors must be verified to conform to the 95/95 criterion to support the use of SRA in the calculation of the total loop uncertainty described in this document. If the SRA does not meet the 95/95 criterion, then it must be treated as a separate bias term (with the appropriate sign) in the determination of total loop uncertainty.

3.4.2.2 Sensor Drift

An SDR is an undesired change in sensor output over a period of time. An SDR allowance is included in the calculation of sensor uncertainties to establish a limit for setpoint drift between surveillance intervals. The calibration procedures must be established to properly account for the as-left data during the previous calibration and the as-found data from the current calibration so changes in the conditions between the calibrations are analyzed and accounted for. For example, if the previous and current calibrations are performed at different ambient temperatures, the calibration temperatures must be recorded and accounted for because it would be impossible to distinguish between sensor drift and changes due to ambient temperature conditions.

The source of SDR allowance may be the manufacturer specifications or an analysis of calibration data. The sensor calibration interval is used to establish the drift allowance. Periodic sensor calibration is performed during the refueling outage. Therefore, the drift allowance is based on a 24-month fuel cycle with 25 percent added margin, or 30 months.

3.4.2.3 Measurement and Test Equipment Uncertainties

The SME, M&TE calibration uncertainties, and readability of the M&TE must be considered to determine the overall magnitude of M&TE uncertainties. Uncertainties associated with input and output M&TE used in the calibration process must be considered. Typically, a bounding M&TE allowance is used in the setpoint methodology to account for M&TE uncertainties. The M&TE calibration and use is controlled by plant procedures to ensure errors are limited to the value assumed in the setpoint methodology. The methodology for establishing M&TE uncertainty should include the M&TE reference accuracy (typically provided by the M&TE vendor), the M&TE calibration standard, uncertainties associated with readability errors with the M&TE (for M&TE with digital readouts, this would be zero), and any additional uncertainties associated with the M&TE used during the calibration process.

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3.4.2.4 Sensor Calibration Accuracy

Sensor calibration accuracy (SCA) refers to uncertainties introduced into the sensor during the calibration process, and sometimes referred to as the “setting tolerance” or the “as-left tolerance”. Sensor calibration errors are the result of M&TE uncertainties and human errors introduced during the calibration process. Time constraints, indicator readability, calibration procedures, and individual skills limit the precision of calibration data in the field.

Calibration or performance verification involves the application of known values of the measured variable at the sensor input and recording corresponding output values over the entire sensor range in ascending and descending directions. If the method of calibration verifies all four attributes of reference accuracy and the calibration tolerance is less than or equal to the reference accuracy, then the calibration tolerance does not need to be included in the total sensor error allowance.

Verification of all four attributes of reference accuracy requires multiple cycles of ascending and descending calibration data; however, this is not practicable for field calibration and plant procedures typically require only a single up-down cycle. Because this method of calibration does not verify all attributes of the reference accuracy such as repeatability, the potential exists to introduce an offset in the sensor output that is not identified in the calibration data. This offset is usually very small, but could be as large as the calibration tolerance limit allowed in the test procedure. In this case, an additional calibration tolerance is needed to account for the potential repeatability error. If adequate margin exists, the additional calibration tolerance is acceptable. Otherwise, verifying repeatability during the calibration process may be justified to reduce the calibration error allowance.

Reference 8.9 provides several methods to account for the potential calibration error. For the instrument setpoint methodology, it is conservatively assumed that the calibration process does not verify all attributes of the reference accuracy, and therefore, a separate allowance for the calibration tolerance is included in the overall total loop uncertainty calculations. It is impossible to calibrate an instrument loop with a tolerance that is less than the reference accuracy - calibration of a component to a tolerance less than its reference accuracy cannot increase its accuracy. Therefore, the minimum requirement for the calibration tolerance should normally be equal to the reference accuracy.

For the purpose of determining the calibration error allowance. Per Assumption 2.1.4, the calibration is performed at essentially the same ambient temperature. Ambient temperature data is recorded in the calibration procedure to verify this assumption (Section 3.4.2.2). If the calibration is performed at a different temperature, then the uncertainty calculation must consider this for inclusion of a temperature error term.

This data can also be used to analyze calibration results.

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The sensor calibration accuracy is conservatively set to be equal to the sensor reference accuracy as shown in (Equation 3-1). The SCA term is included in the TLU equation to provide additional conservative allowances for uncertainties due to the instrument calibration procedures and methods.

Sensor Calibration Accuracy Assumption

$$\text{Sensor Calibration Accuracy (SCA)} = \text{Sensor Reference Accuracy (SRA)} \qquad \text{Equation 3-1}$$

3.4.2.5 Sensor Temperature Effects

The STE account for ambient temperature variations that may cause undesired changes in sensor output. The STE allowance is based on the maximum expected ambient temperature deviation from reference calibration conditions. This allowance refers to ambient temperature variations within the manufacturer's specified normal operating limits only. Harsh environment temperature errors are treated separately as discussed below.

Sensor temperature effects are considered statistically independent with random errors in the ± direction. It is assumed that temperature effects are minimal at the time of calibration because surveillance testing is performed at essentially the same ambient temperature. The temperature effect allowance accounts for ambient temperature variations during plant operation.

For example, {{

}}2(a),(c)

3.4.2.6 Sensor Pressure Effects

The SPE account for differences between operating pressure and calibration pressure for differential pressure transmitters. Manufacturer specifications typically include this uncertainty as static pressure effect and treat it as a random uncertainty. The differential pressure transmitters are used for process parameters such as flow and level, and are typically calibrated by injecting a known differential pressure across the transmitter high and low inputs. The transmitter is isolated from the process connections at this time and test pressures are injected at a low static pressure, usually at or near ambient pressure. When the transmitter is placed back into service at process pressure conditions, some transmitters exhibit a change in output due to the high static pressure operating conditions.

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This effect can typically be corrected using a factor provided by the manufacturer so the transmitter provides the desired output at high pressure operating conditions. To calculate the SPE at the operating pressure, the maximum pressure variation above and below the operating pressure should be determined. The manufacturer's static pressure effect is then applied to the operating pressure variation to determine the sensor pressure effects. Normally the manufacturer specifies separate span and zero effects. Any of these effects that cannot be zeroed out during calibration must be accounted for in the calibration. Typically the error is treated as a bias term for a sensor whose SPE is in a predictable magnitude and direction.

As an example, a differential pressure level transmitter is designed to operate at 1850 psig with a process pressure variation (PV) of 1600 to 2100 psig, or ± 250 psig. The static pressure effect specified by the manufacturer for the transmitter in this example is ±0.5 percent CS per 1000 psig. It should be noted that static pressure effects are typically specified in percent upper range limit (URL). In this case, the URL-based value must be scaled to percent CS using the ratio of URL to CS.

Assuming the static pressure effect is linear over the pressure range, SPE is calculated as follows:

$$SPE = (\pm 0.5\%\ CS)\ PV\ psig\ /\ 100\ psig$$

$$SPE = (\pm 0.5\%\ CS)(2100 - 1600)\ psig\ /\ 1000\ psig$$

$$SPE = (\pm 0.5\%\ CS)(500\ psig\ /\ 1000\ psig)$$

$$SPE = (\pm 0.25\%\ CS)$$

3.4.2.7 Insulation Resistance Effects

The instrument channel uncertainty is dependent on insulation resistance effects (IRE) that quantify changes in the insulation resistance of the sensor and instrument cabling in harsh environments. Under high humidity and temperature events, the instrument channels may experience a reduction in insulation resistance such as during a high energy line break or loss-of-coolant-accident. During normal conditions, the leakage current is relatively small and typically is calibrated out during instrument channel calibrations. However, during conditions of high temperature and humidity, the leakage current may increase to a level that causes significant uncertainty in measurement. The effect is particularly a concern for sensitive, low signal level circuits such as neutron detector measurements, current transmitters, RTDs, and thermocouples. The IRE is a known sign bias term.

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3.4.2.8 Accident Environmental Effects

Instruments that can be exposed to severe ambient conditions as a result of an accident, and that are required to remain functional during or after an accident, may have additional accident-related error terms that must be considered in a loop accuracy analysis. These additional terms account for the effects of extreme temperature, radiation, pressure, and seismic/vibration conditions. For this methodology, due to the limited availability of sensor qualification data, the accident temperature effect, accident pressure effect and accident radiation effect described below, are combined into a single sensor accident environmental effect term, SAE, and is conservatively treated as a bias term in the calculation of total loop uncertainty. Each contributing effect is described below.

3.4.2.8.1 Accident Temperature Effect

Frequently, the effect of abnormal temperature during accident conditions is the largest contributor to instrument inaccuracy during an accident. While a field-mounted device, such as a transmitter, may be able to perform well under design temperatures of up to 200 degrees Fahrenheit, an accident temperature of near 300 degrees Fahrenheit can cause severe changes in performance. Typical inaccuracies of 5 to 10 percent due to harsh temperature conditions are not uncommon.

The temperature profile used by the vendor should be compared with the plant-specific accident temperature profiles. The plant-specific profiles should be fully enveloped by the actual acceptability for the specification to be valid.

3.4.2.8.2 Accident Pressure Effect

Accident pressure effects can occur for some instrumentation due to the large increase in ambient/atmospheric pressure associated with an accident. While most instrumentation is not affected by changes in atmospheric pressure, devices are used that use local pressure as a reference of measurement can be greatly affected. Of primary concern are pressure transmitters that use containment pressure as the reference atmospheric pressure.

Loop error analysis must consider containment pressure over time following an accident for the transmitter. If the transmitter uses a sealed reference, the additional error is minimized and may be ignored. Accident pressure effects are generally not included in an error analysis except for the reason cited above.

3.4.2.8.3 Accident Radiation Effect

Accident radiation effects are considered in cases where high radiation levels caused by an accident are another effect that can greatly influence instrument accuracy. Electronic instrumentation may be affected by both the rate of radiation and the total radiation dose to which it is exposed. In normal

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operation, radiation effects are small and can be calibrated out during periodic calibrations. Accident radiation effects are also determined as part of a manufacturer environmental qualification testing.

Generally, the effect is stated as a maximum error effect for a given integrated radiation dose, typically 10^7 or 10^8 rads. The accident radiation levels used for testing are chosen to envelope maximum dose levels expected at a large sampling of plants.

3.4.2.9 Seismic Effect

Some instruments experience a change in accuracy performance when exposed to equipment or seismic vibration. The vibration can cause minor changes in instrument calibration settings, component connections or sensor response. The sensor seismic effect (SSE) may have different values for seismic and post-seismic events. To account for uncertainties in instruments due to seismic events, the instruments are required to be calibrated following a seismic event to calibrate out abnormal effects. {{

}}2(a),(c)

3.5 Digital System Processing Error

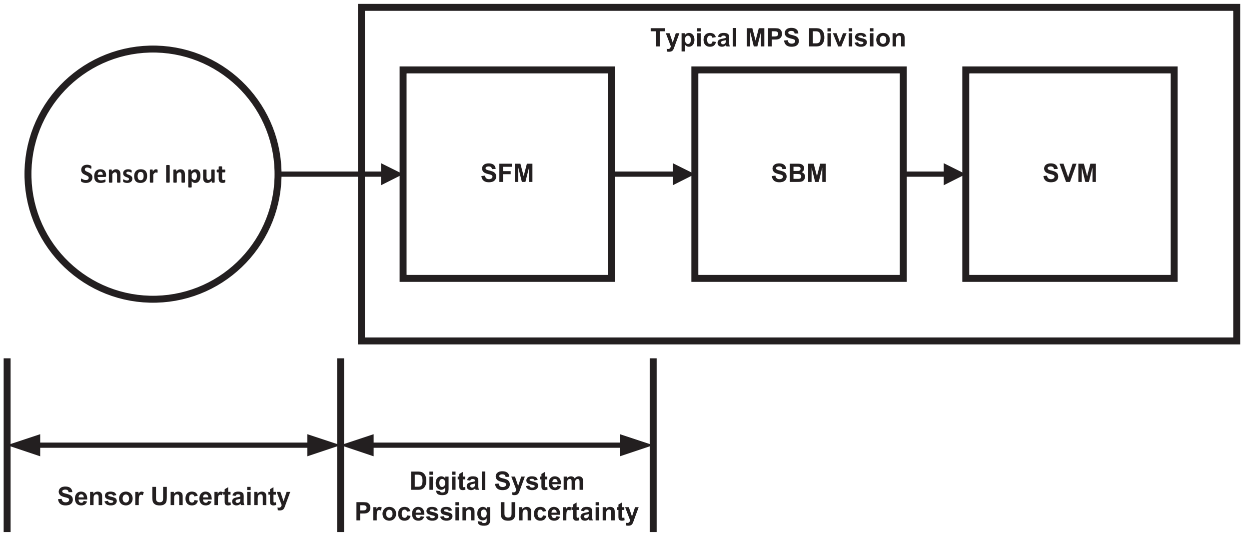
Digital system processing error, sometimes commonly referred to as “rack error” or “rack uncertainty,” includes a set of parameters combined as a group to account for errors typically associated with the analog-to-digital conversion by the digital I&C system. These uncertainties include reference accuracy, calibration error, drift, and other parameters, such as normal ambient temperature effects. The DRA is typically provided by the manufacturer as a limit for measurement errors when the digital I&C system is in operation under specified conditions. The DRA includes linearity, hysteresis, dead band, and repeatability.

This methodology specifically considers the error associated with the safety-related digital I&C system. The NuScale MPS is the safety-related I&C system that performs the RTS and ESFAS functions.

The MPS consists of a safety function module (SFM) that filters analog signals, analog-to-digital conversion, and trip determination. Once the instrument loop signal is converted to a digital signal for input into the trip determination circuit, further signal transmission to the scheduling and bypass module (SBM) and the scheduling and voting module (SVM) are purely digital signal transmissions, so no more instrument errors need to be considered, (Figure 3-2).

Therefore, the error associated with the safety function module in the MPS is a function of the digital processing error of the MPS associated with the analog signal conditioning channel and analog-to-digital conversion components performed by the input sub-module of the MPS as described in Sections 2.5.1.1 and 8.2.1.1 of Reference 8.11.

Figure 3-2 Simplified Loop Schematic for the NuScale Module Protection System



3.5.1 Digital System Reference Accuracy

The DRA term is a function of the vendor-supplied hardware of the MPS and is certified by the vendor (similar to the reference accuracy specified by a sensor manufacturer). The digital system reference accuracy includes the digital calibration tolerances, and hysteresis associated with the signal conditioning, conversion, and digital processing performed by the safety function module within the MPS.

3.5.2 Digital System Drift

Per Assumption 2.2.6.2, the DDR is considered negligible due to self-calibration functions of MPS hardware; however, it will be verified with the system manufacturer.

3.5.3 Digital System Temperature Error

The DTE is an error term typically supplied by the MPS hardware vendor and is a representative term that is a function of errors associated with temperature variations experienced by the MPS hardware.

Per Assumption 2.2.6.2, DTE is considered negligible due to the self-calibration functions of MPS hardware; however, it will be verified with the system manufacturer.

3.5.4 Digital System Measurement and Test Equipment Error

The module protection system M&TE error (DMTE) is the error associated with the M&TE used to calibrate the MPS.

Per Assumption 2.2.6.2, DMTE is considered negligible due to the self-calibration functions of MPS hardware, however, it will be verified with the system manufacturer.

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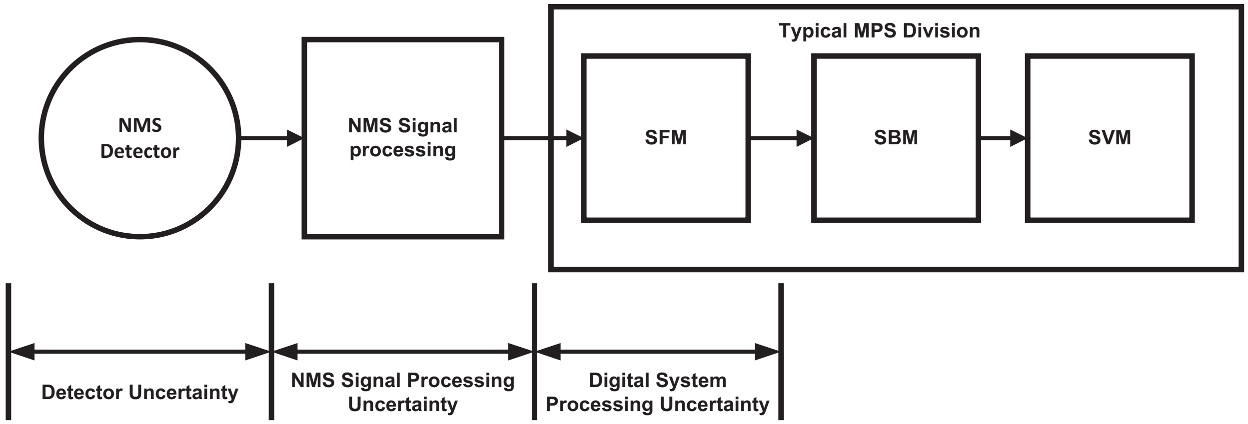
3.6 Neutron Monitoring System Error

The NMS contains signal conditioning and processing electronics that takes the raw detector signal as input (typically current or voltage measurement proportional to core neutron flux and reactor power level) and processes that signal for input into MPS as an analog. Therefore, for the specific nuclear instrumentation reactor protection functions listed in Table 6-1 the uncertainties of the NMS signal processing components must be included in the overall total loop uncertainty. Figure 3-3 is a schematic of the NMS hardware. The following sections describe the uncertainties associated with NMS protective functions.

Figure 3-3 Simplified Loop Schematic for Neutron Monitoring System Functions



3.6.1 Neutron Monitoring System Reference Accuracy

The NMS reference accuracy (NRA) term is a function of the vendor-supplied hardware of the NMS signal processing equipment and is certified by the vendor (similar to the reference accuracy specified by a sensor manufacturer). The NRA includes the NMS calibration accuracy and hysteresis associated with the signal conditioning, amplification, analog to digital (A/D) or digital to analog (D/A) conversion and processing performed by the NMS hardware. Due to the uncertainty in the design of the NMS signal processing equipment, the NRA is treated as a separate, independent uncertainty term from other sources of uncertainty in the NMS hardware and signal processing function.

3.6.2 Neutron Monitoring System Drift

The NMS signal processing equipment drift (NDR) is the change in NMS signal output over time. The NMS signal processing equipment design is unknown at this time and the NMS drift will be verified with the system manufacturer.

3.6.3 Neutron Monitoring System Temperature Error

The NMS temperature error (NTE) is an error term typically supplied by the NMS hardware vendor and is a representative term that is a function errors associated with temperature variations experienced by the NMS hardware.

3.6.4 Neutron Monitoring System Measurement and Test Equipment Error

The NME is the error associated with the M&TE equipment used to calibrate the NMS signal processing equipment. The accuracy of the test equipment used to calibrate the NMS equipment will be verified with the system manufacturer and included in the overall uncertainty calculation.

3.7 Calculation of Total Loop Uncertainty

The general TLU can now be calculated by combining independent random uncertainties using the SRSS method and then accounting for like-signed loop bias terms algebraically considering whether process conditions are increasing or decreasing with respect to the analytical limit (Figure 4-1).

The bias terms in (Equation 3-2) may have a positive or negative sign. For conservatism, bias terms of unknown signs are applied in the worst-case direction (i.e., biases are subtracted for an increasing process and added for a decreasing process.) When the signs of the biases are known and predictable, they are applied algebraically based on their magnitude and sign in the conservative direction. For conservatism, in cases where the magnitude and sign of the bias is known, only the biases that affect total loop uncertainty in a conservative manner are considered. For example, only negative biases are applied for an increasing process and only positive biases are applied for a decreasing process. In this case, the bias terms are not allowed to cancel each other out.

Total Loop Uncertainty

$$\begin{aligned}\mathrm{TLU} = \ & \{[(\mathrm{PEA})^2 + (\mathrm{PME})^2 + (\mathrm{SRA})^2 + (\mathrm{SDA})^2 + (\mathrm{SME})^2 + (\mathrm{SCA})^2 + \\ & (\mathrm{STE})^2 + (\mathrm{SPE})^2 + (\mathrm{NRA})^2 + (\mathrm{NTE})^2 + (\mathrm{NME})^2 + (\mathrm{DRA})^2 + \\ & (\mathrm{DTE})^2 + (\mathrm{DDR})^2 + (\mathrm{DMTE})^2]^{1/2} + [\mathrm{IRE} + \mathrm{SAE} + \mathrm{Bias}]\}\end{aligned} \qquad \text{Equation 3-2}$$

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Table 3-1 Total Loop Uncertainty Category Summary

Uncertainty Parameter	Section
Process and Miscellaneous Effects Error	
Primary element eccuracy (PEA)	Section 3.4.1.1
Process measurement error (PME)	Section 3.4.1.2
Sensor Error	
Sensor reference accuracy (SRA)	Section 3.4.2.1
Sensor drift (SDR)	Section 3.4.2.2
Sensor measurement and test equipment (SME)	Section 3.4.2.3
Sensor calibration accuracy (SCA)	Section 3.4.2.4
Sensor temperature effect (STE)	Section 3.4.2.5
Sensor static pressure effect (SPE)	Section 3.4.2.6
Insulation resistance effect (IRE)	Section 3.4.2.7
Sensor accidenteEnvironment effect (SAE)	Section 3.4.2.8
Sensor seismic effect (SSE)	Section 3.4.2.9
Digital Processing Error	
Digital system reference accuracy (DRA)	Section 3.5.1
Digital system drift error (DDR)	Section 3.5.2
Digital system temperature error (DTE)	Section 3.5.3
Digital system M&TE error ([[DMTE]])	Section 3.5.4
Neutron Monitoring System Error	
NMS reference accuracy (NRA)	Section 3.6.1
NMS drift (NDR)	Section 3.6.2
NMS temperature error (NTE)	Section 3.6.3
NMS measurement and test equipment error (NME)	Section 3.6.4

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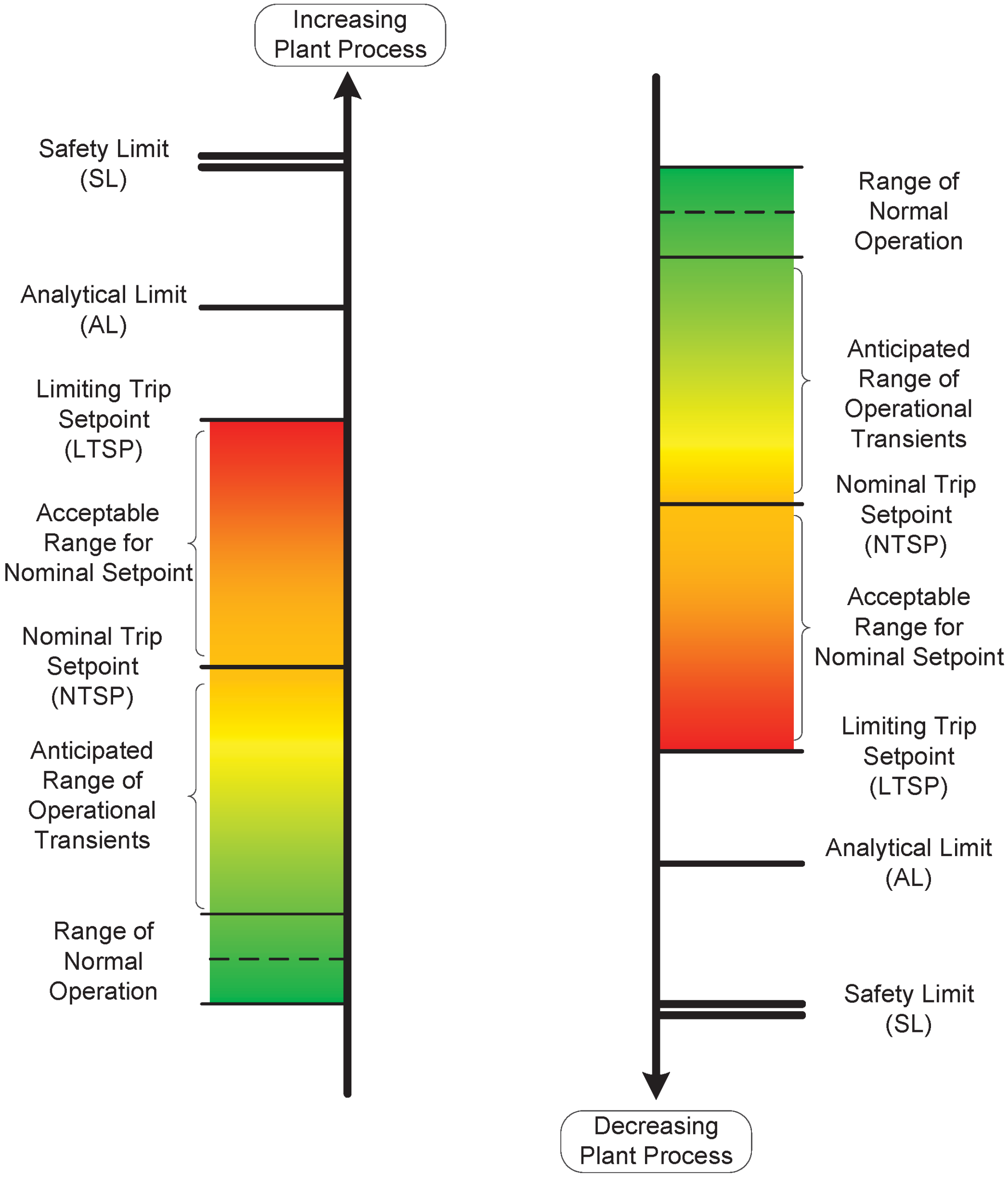
4.0 Setpoint Determination

4.1 Setpoint Relationships

It is important to understand the relationships between trip setpoints, analytical limits, and the plant safety limits in order to properly account for the total instrument channel uncertainty in the establishment of the setpoints Figure 4-1 presents the relative position of these items with respect to both an increasing process and a decreasing process.

Figure 4-1 Nuclear Safety-Related Setpoint Relationships



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The safety limits are imposed on plant process variables, such as pressure, level, temperature, or these combinations. Some safety limits may also be defined in terms of indirectly calculated process conditions such as the critical heat flux ratio or linear heat generation rate. This section discusses the concepts used to determine limiting trip setpoint and nominal trip setpoints.

4.1.1 Safety Limits

Nuclear power plants include barriers to limit release of radioactive material. Safety limits are the most critical aspects of the safety-related design of a nuclear power plant to prevent unacceptable hazards to the environment or population. They are critical design values to protect the integrity of key fission product barriers to guard against the release of radioactive materials. Safety limits must be established to protect the integrity of these barriers. The safety limits can be defined in terms of measured process variables such as pressure, temperature, and their combinations (e.g., departure from nuclear boiling ratio).

4.1.2 Analytical Limits

Analytical limits are based on the results of plant safety analyses and ensure plant safety limits are not exceeded. The safety analyses should account for interaction activities between plant safety equipment during normal operation, anticipated operational occurrences, and postulated accidents. Based on the results of the plant safety analyses, analytical limits are established for various plant safety parameters, processes, and variables. The analytical limits are applied in the determination of plant setpoints, which are designed to initiate protective functions.

4.1.3 Limiting Trip Setpoint

Trip setpoints are the predetermined values at which protective actuation devices perform a protective function (e.g., trip a breaker, de-energize a solenoid). The limiting trip setpoint is the least conservative value the trip setpoint can be accounting for uncertainties and still ensure analytical limits are not exceeded and safety limits are protected. For the NuScale Instrument Setpoint Methodology, the LTSP is the LSSS as required by 10 CFR 50.36(c)(1)(ii)(A).

4.1.4 Nominal Trip Setpoint

The NTSP is the LTSP with margin added. The NTSP is always equal to or more conservative than the LTSP. The NTSP is the value of the trip setpoint chosen for plant operation to account for the total as-found tolerance (AFT) (Equation 4-15) and generally contains added margin based on engineering judgement to add a level of conservatism to ensure the limiting trip setpoint is not exceeded. In all cases, the margin must be greater than or equal to the AFT. For the purposes of this document, the total AFT is not applied to the NTSP; rather the NTSP value is rounded, where appropriate, to the nearest whole number in the conservative direction for simplification and to add margin. For an increasing process, the NTSP is rounded down; for a decreasing process the NTSP is rounded up.

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4.2 Calculation of Limiting Trip Setpoint

The NuScale setpoint methodology uses a procedure based on evaluating the as-found setpoint conditions in comparison to the NTSP for the instrument loop in question. This method is based on conditions established in ISA 67.04.01 (Reference 8.8) as described below.

- The as-left value (setting or calibration tolerance) is less than the SRSS of the reference accuracy, M&TE, and readability errors. (Equation 3-1) defines the sensor calibration accuracy is equal to the sensor reference accuracy.
- The setting (or calibration) tolerance is included in the overall TLU; Section 3.4.2.4 (Equation 3-2).
- The predefined performance and test acceptance criteria band for evaluating the AFT setpoint value includes either the setting or calibration tolerance (Section 3.4.2.4) or the uncertainties associated with the calibration or setting tolerance band, but not both.
- The NuScale methodology specifies acceptance criteria for the loop AFT based on the NTSP that include the SRSS of the reference accuracy, M&TE errors, and drift.

As shown in Figure 4-1, evaluating setpoints should ensure there are no overlapping, redundant, or inconsistent values. A trip setpoint is established such that an instrument channel trip signal occurs before the analytical limit is reached while at the same time minimizing the potential for spurious trips. In considering the interrelationship of instrument performance, overly conservative setpoints can reduce the operating margin with respect to normal plant operation and may reduce overall plant safety by increasing the frequency of safety system protective actuations.

The established NTSP places margin in the LTSP for conservatism (Section 4.1.4). The calculation of the LTSP and NTSP are shown below:

Limiting Trip Setpoint

$$\mathrm{LTSP} = \mathrm{AL} \pm |\mathrm{TLU}| \qquad \text{Equation 4-1}$$

Nominal Trip Setpoint

$$\mathrm{NTSP} = \mathrm{AL} \pm (|\mathrm{TLU}| + \mathrm{Margin}) \qquad \text{Equation 4-2}$$

The signs of channel uncertainty and margin are dependent on the direction of the processes. For an increasing process from normal operating point toward the analytical limit, the channel uncertainty is subtracted from the analytical limit. For a decreasing process from the normal operating point toward the analytical limit, the channel uncertainty is added to the analytical limit.

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Nominal Trip Setpoint (Increasing Process)

$$\text{NTSP (Increasing Process)} = \text{AL} - (|\text{TLU}| + \text{Margin}) \qquad \text{Equation 4-3}$$

Nominal Trip Setpoint (Decreasing Process)

$$\text{NTSP (Decreasing Process)} = \text{AL} + (|\text{TLU}| + \text{Margin}) \qquad \text{Equation 4-4}$$

4.3 Determination of As-Found and As-Left Tolerance Bands

The acceptable range of instrument channel values during as-found conditions takes into consideration those errors expected to be found during testing, which includes: the calibration or setting tolerance from the last instrument calibration (as-left value), the error associated with the M&TE used during the surveillance testing, and the instrument drift. For NuScale safety-related instrument loops, these components are comprised of the ALT values for the sensor, NMS, and digital protection system. For each instrument channel component, the reference accuracy and M&TE uncertainties are combined using the SRSS method to obtain the ALTs as shown below. Because loop calibration is typically performed as a series of overlapping tests in individual components, or modules, the ALTs are determined for each instrument channel component. The determination of the total loop AFT and ALT values are provided for information if a loop calibration is performed; however, calibration is typically performed for each loop component, as stated above.

Sensor As-Left Tolerance

$$\text{ALT}_{\text{Sensor}} = \pm\, [(\text{SRA})2 + (\text{SME})2]^{1/2} \qquad \text{Equation 4-5}$$

Neutron Monitoring System As-Left Tolerance

$$\text{ALT}_{\text{NMS}} = \pm\, [(\text{NRA})^{2} + (\text{NME})^{2}]^{1/2} \qquad \text{Equation 4-6}$$

Digital System As-Left Tolerance

$$\text{ALT}_{\text{Digital}} = \pm\, [(\text{DRA})^{2} + (\text{DMTE})^{2}]^{1/2} \qquad \text{Equation 4-7}$$

Total As-Left Tolerance

$$\text{ALT}_{\text{Total}} = \pm\, [(\text{ALT}_{\text{Sensor}})^{2} + (\text{ALT}_{\text{NMS}})^{2} + (\text{ALT}_{\text{Digital}})^{2}]^{1/2} \qquad \text{Equation 4-8}$$

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Alternatively, the total loop ALT can be shown as the SRSS of the reference accuracy and M&TE error for the total instrument loop as shown below:

Total Loop Reference Accuracy

$$RA_{Total} = \pm [(SRA)^2 + (NRA)^2 + (DRA)^2]^{1/2} \qquad \text{Equation 4-9}$$

Total Loop M&TE Error

$$MTE_{Total} = \pm [(SME)^2 + (NME)^2 + (DMTE)^2]^{1/2} \qquad \text{Equation 4-10}$$

Total As-Left Tolerance

$$ALT_{Total} = \pm [(RA_{Total})^2 + (MTE_{Total})^2]^{1/2} \qquad \text{Equation 4-11}$$

The AFT accounts for the uncertainty at the time of the previous calibration and the instrumentation channel drift, and is mathematically shown below for each instrument loop module:

Sensor As-Found Tolerance

$$AFT_{Sensor} = \pm [(ALT_{Sensor})^2 + (SDR)^2]^{1/2} \qquad \text{Equation 4-12}$$

Neutron Monitoring System As-Found Tolerance

$$AFT_{NMS} = \pm [(ALT_{NMS})^2 + (NDR)^2]^{1/2} \qquad \text{Equation 4-13}$$

System As-Found Tolerance

$$AFT_{Digital} = \pm [(ALT_{Digital})^2 + (DDR)^2]^{1/2} \qquad \text{Equation 4-14}$$

Total Loop As-Found Tolerance

$$AFT_{Total} = \pm [(AFT_{Sensor})^2 + (AFT_{NMS})^2 + (AFT_{Digital})^2]^{1/2} \qquad \text{Equation 4-15}$$

Alternatively, the total loop drift can be determined by calculating the SRSS of the individual loop module drift uncertainties in (Equation 4-16):

Total Loop Drift

$$DR_{Total} = [(SDR)^2 + (NDR)^2 + (DDR)^2]^{1/2} \qquad \text{Equation 4-16}$$

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Then substituting the relationship for total loop ALT from (Equation 4-8), the total loop AFT can be simplified and shown as:

Total Loop AFT

$$AFT_{Total} = [(ALT_{Total})^2 + (DR_{Total})^2]^{1/2} \qquad \text{Equation 4-17}$$

4.4 Performance Test and Acceptance Criteria

Periodic surveillance of instrument loops is required to ensure the loops are operating as expected. The instruments are tested to verify they perform their required safety function (i.e., initiate a protective action when a setpoint is exceeded) within their prescribed limits within the time interval required. Channel operability using performance test acceptance criteria is based on determining the as-found values for the instrument loop components under test and comparing them using a double-sided band around the nominal trip setpoint.

The performance and test acceptance criteria band (PTAC) is equivalent to the value of the nominal trip setpoint plus or minus the AFT and evaluated as a double-sided band for evaluation of channel operability:

Performance and Test Acceptance Criteria

$$\pm PTAC_{Total} = NTSP \pm AFT_{Total} \qquad \text{Equation 4-18}$$

Building upon relationships of the various parameters shown in Figure 4-1, the surveillance test and calibration relationships are presented in Figure 4-2.

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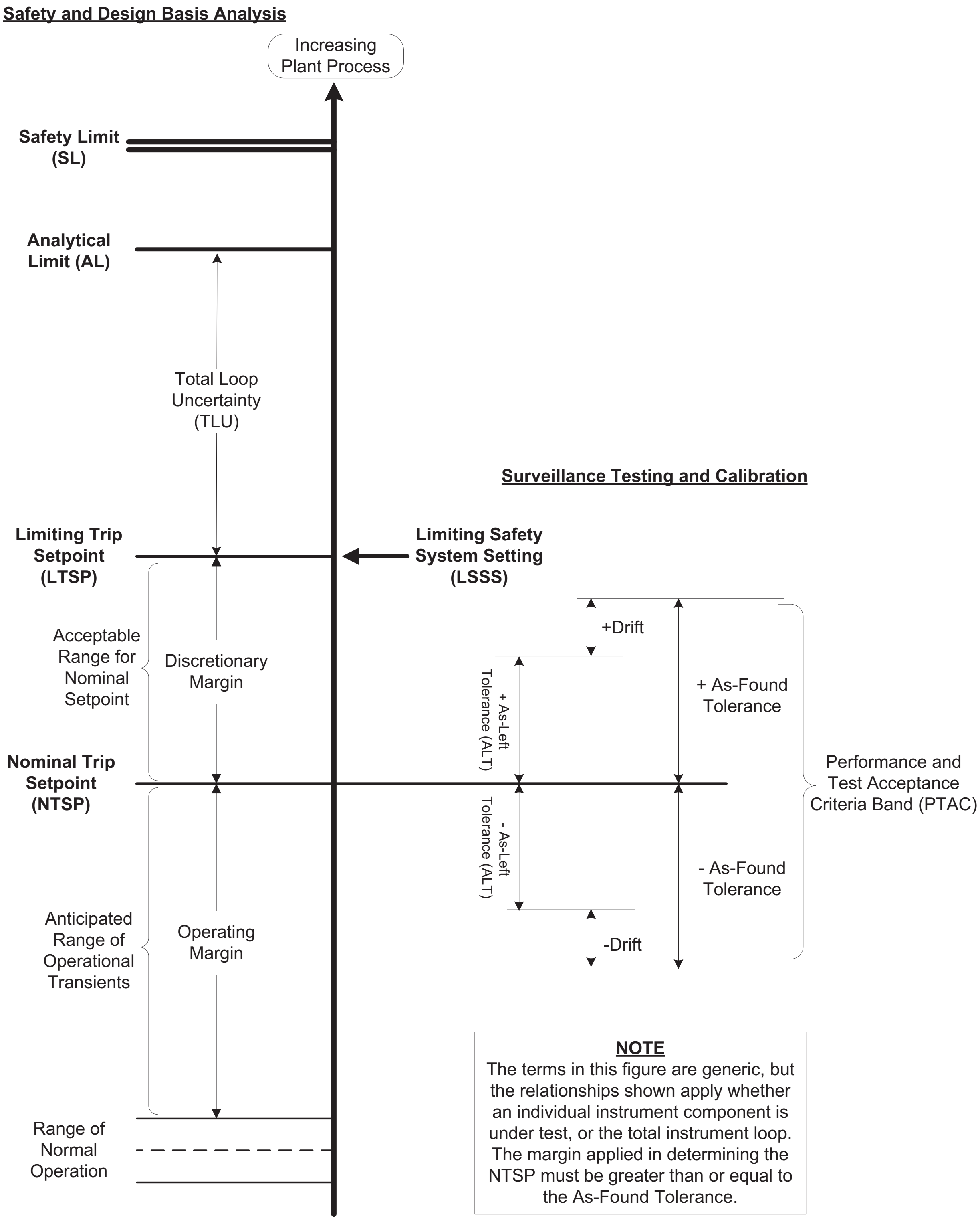
Figure 4-2 Setpoint Relationships during Surveillance Testing and Calibration



NOTE
The terms in this figure are generic, but the relationships shown apply whether an individual instrument component is under test, or the total instrument loop. The margin applied in determining the NTSP must be greater than or equal to the As-Found Tolerance.

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4.4.1 Operability Determination and Evaluation

The operability of the instrument channel under test is evaluated by performing channel operability tests or channel calibrations. The performance and test acceptance criteria described in Section 4.4 is used to determine degradation, thus avoiding the use of excessive tolerances. Plant procedures will reflect this approach. Using Figure 4-2 as a reference, the following criteria are used to evaluate the measured as-found trip setpoint for channel operability.

<u>As-Found Trip Setpoint within As-Left Tolerance Band:</u>

If the as-found measured trip setpoint values during calibration and surveillance testing are inside the two-sided limits of (NTSP ± PTAC), then the channel is fully operable and no additional actions are required.

<u>As-Found Trip Setpoint outside As-Left Band but within As-Found Band:</u>

During channel operability or calibration testing, if the measured trip setpoint values are within the AFT band (Equation 4-17) but outside the ALT band (Equation 4-17), then the instrumentation channel is fully operable; however, calibration is required to restore the channel within the ALT band.

<u>As-Found Trip Setpoint outside of As-Found Tolerance Band:</u>

If any as-found calibration setting value is outside the AFT band, then the channel is inoperable, and corrective action is required, including those actions required by 10 CFR 50.36 when automatic protective devices do not function as required.

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5.0 Calculation of Reactor Protection and Engineered Safety Features Actuation System Setpoints

This section demonstrates the setpoint methodology described in this document and contains preliminary calculations of instrument uncertainties associated with analytical limits for credited protective actuation functions contained in the I&C Parameters and Analytical Limits report. The protective actuation functions consist of RTS functions listed in FSAR Table 7.1-3 and ESFAS functions listed in FSAR Table 7.1-4. This methodology is not applicable to other process instrumentation setpoints. The uncertainty calculations and resultant NTSP and LTSP values in this section are based on preliminary estimates of device behavior using engineering judgement and vendor estimates. They are provided to show the application of the instrument setpoint methodology described in this document and are not intended to be the final NTSP and LTSP values for use in plant calibration procedures or technical specifications. Final calculations of instrument channel uncertainties and trip setpoints will be provided in a separate document using actual, verified instrument sensor uncertainty data.

The tables in this section contain detailed individual total loop uncertainty calculations (Section 3.7) and LTSPs (Section 4.1.3) for the following reactor trip functions and input signals based on their respective analytical limits. The tables contain parameter ranges, CSs and normal operating points for parameters of interest, and list values in both the engineering units and CSs for the instrument loop.

The general process for calculating instrument loop uncertainties and setpoints is shown in Figure 5-1 below. The general representation of an instrument channel is presented in Figure 3-2 and Figure 3-3.

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Figure 5-1 Setpoint Calculation Flow Chart

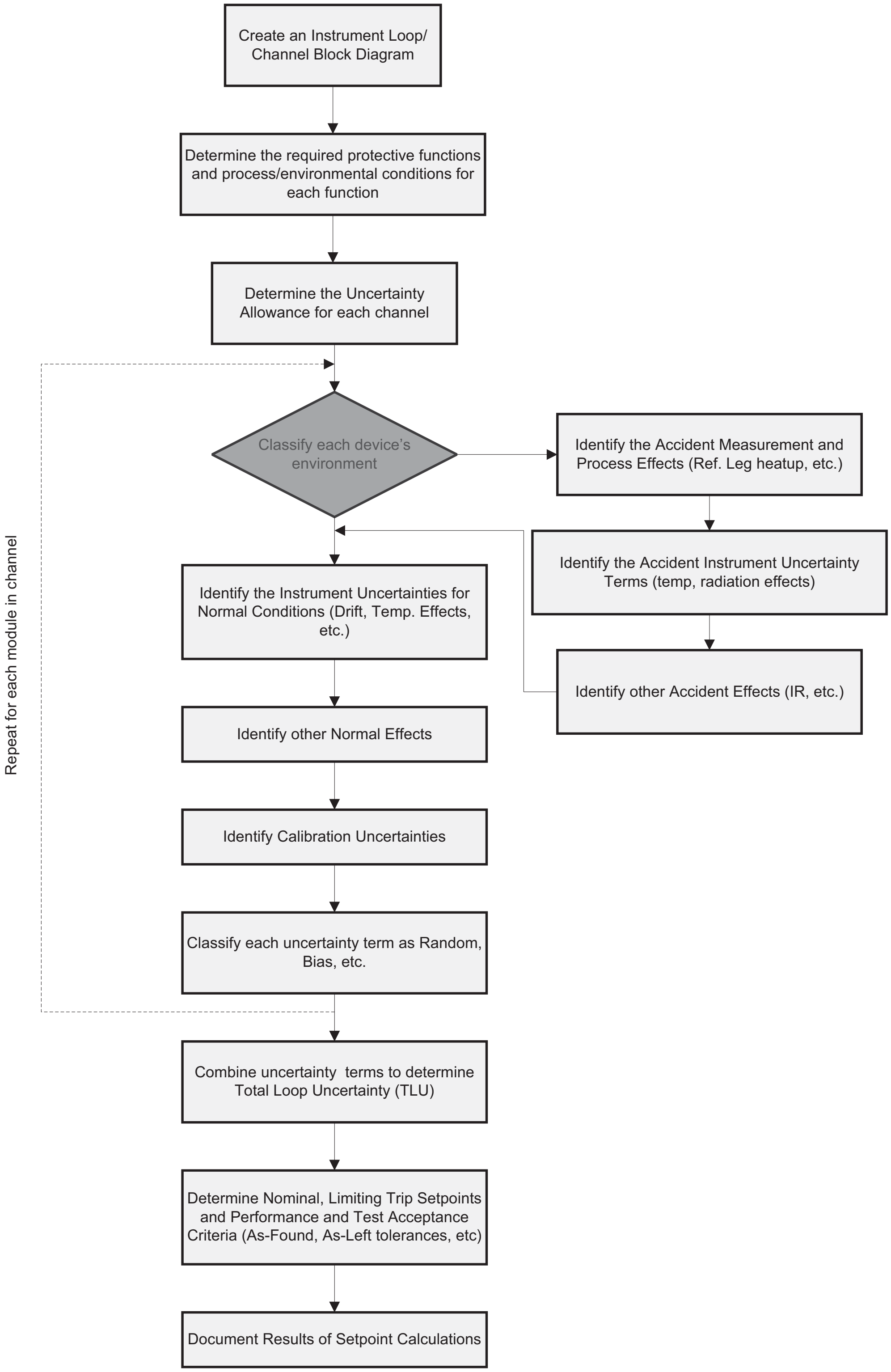

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Table 5-1 Setpoint Calculation for High Power Range Protective Functions

Actuation Function	High Power Range Linear Power
Sensor	PR Neutron Flux Detector
Engineering Units of Measure	% RTP
Upper Limit	200.00
Lower Limit	0.00
Calibrated Span (CS)	200.00

Process and Miscellaneous Effects Error	**% RTP**	**% CS**	**Source / Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	3.4.1.1
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.5.1
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.5.1
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.5.1
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.5.1
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	Assumption 2.2.5.1
STE	{{	}}$^{2(a),(c)}$	Assumption 2.2.5.1
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.5.1
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.5.1
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.5.1
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.2.5.1
Neutron Monitoring System Error			
Neutron Monitoring System Reference Accuracy (NRA)	{{	}}$^{2(a),(c)}$	Assumption 2.2.5.4
Neutron Monitoring System Drift Error (NDE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.5.4
Neutron Monitoring System Temperature Error (NTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.5.4
Neutron Monitoring System M&TE Error (NMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.5.4
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1

Total Loop uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**% RTP**	**% CS**

Analytical Limit	115.0	**% RTP**
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$	**% RTP**
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$	**% RTP**

Analytical Limit	25.0	**% RTP**
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$	**% RTP**
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$	**% RTP**

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Table 5-2 Setpoint Calculation for SR & IR High Log Power Rate Protective Functions

Actuation Function	**High SR & IR Log Power Rate**	
Sensor	**Source & Intermediate Range Detectors**	
Engineering Units of Measure	**Decades per minute (dpm)**	**Source/Reference**
Upper Limit	5.00	Assumption 2.2.10
Lower Limit	0.00	Assumption 2.2.10
Calibrated Span (CS)	5.00	N/A
Process and Miscellaneous Effects Error	{{ }}$^{2(a),(c)}$	Assumption 2.2.10
Neutron Monitoring System Error	{{ }}$^{2(a),(c)}$	Assumption 2.2.10
Digital Processing Error	{{ }}$^{2(a),(c)}$	Assumption 2.2.10

Total Loop uncertainty (TLU)	{{ }}$^{2(a),(c)}$

Analytical Limit	3.00 dpm
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$

1. The SR log power rate trip and IR log power rate trip are separate trips developed by their respective NMS channels. A trip in either channel initiates the trip logic in MPS for that channel.

Table 5-3 Setpoint Calculation for High Power Range Rate Protective Function

Actuation Function	**High Power Range Rate**	
Sensor	**Power Range Detectors**	
Engineering Units of Measure	**% RTP/30 seconds**	**Source/Reference**
Upper Limit	N/A	Assumption 2.2.11
Lower Limit	N/A	Assumption 2.2.11
Calibrated Span (CS)	N/A	N/A
Process and Miscellaneous Effects Error	{{ }}$^{2(a),(c)}$	Assumption 2.2.11
Sensor Error	{{ }}$^{2(a),(c)}$	Assumption 2.2.11
Neutron Monitoring System Error	{{ }}$^{2(a),(c)}$	Assumption 2.2.11
Digital Processing Error	{{ }}$^{2(a),(c)}$	Assumption 2.2.11
Margin	{{ }}$^{2(a),(c)}$	Assumption 2.2.11

Total Loop Uncertainty (TLU)	{{ }}$^{2(a),(c)}$
Units	**% RTP/ 30 sec**

Analytical Limit	7.5 % RTP/ 30 sec
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ % RTP/ 30 sec
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ % RTP/ 30 sec

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Table 5-4 Setpoint Calculation for High Source Range Count Rate Protective Function

Actuation Function	**High SR Count Rate**
Sensor	**SR Detector**
Engineering Units of Measure	**Counts per second**
Upper Limit	1.00E+06
Lower Limit	5.00E+00
Calibrated Span (CS)	1.00E+06

Process and Miscellaneous Effects Error	**counts per second**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00E+00	Assumption 2.2.5.6
Process Measurement Error (PME)	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.6
Sensor Error		
Sensor Reference Accuracy (SRA)	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.7
SDR	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.7
Sensor Measurement and Test Equipment (SMTE)	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.7
Sensor Calibration Accuracy (SCA)	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.7
STE	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.7
SPE	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.7
IRE [Bias]	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.7
Sensor Accident Effect (SEA) [Bias]	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.7
SSE	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.7
Neutron Monitoring System Error		
Neutron Monitoring System Reference Accuracy (NRA)	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.5
Neutron Monitoring System Drift Error (NDE)	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.8
Neutron Monitoring System Temperature Error (NTE)	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.5
Neutron Monitoring System M&TE Error (NMTE)	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.4
Digital Processing Error		
DRA	{{ }}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{ }}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{ }}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{ }}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{ }}$^{2(a),(c)}$
Units	**CPS**

Analytical Limit	5.00E+05 CPS
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ CPS
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ CPS

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Table 5-5 Setpoint Calculation for High Subcritical Multiplication Protective Function

Actuation Function	**High Subcritical Multiplication**	
Sensor	**SR Detector**	
Engineering Units of Measure	**Note 1**	**Source/Reference**
Upper Limit	5.00	Note 2
Lower Limit	0.00	Note 2
Calibrated Span (CS)	5.00	Note 2
Process & Misc. Effects Error	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.10
Neutron Monitoring System Error	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.10
Digital Processing Error	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.10
Margin	{{ }}$^{2(a),(c)}$	Assumption 2.2.5.10

Total Loop uncertainty (TLU)	{{ }}$^{2(a),(c)}$
Units	Note 1

Analytical Limit	3.20
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$

1. The subcritical multiplication factor (M) is calculated by the MPS and is defined as the ratio of the current count rate (CR), defined as a rolling 30s average, and the long-term average count rate (CR_0), defined as the 12 hour average CR:

$$M = \frac{CR}{CR_0}$$

2, For this protective function, a calibrated span for the subcritical multiplication factor is assumed to be 0 to 5.00

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Table 5-6 Setpoint Calculation for High Reactor Coolant System Hot Temperature Protective Function

Actuation Function	High RCS Hot Temperature
Sensor	RCS Hot Temperature
Engineering Units of Measure	°F
Upper Limit	700
Lower Limit	300
Calibrated Span (CS)	400

Process and Miscellaneous Effects Error	**°F**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	3.4.1.1
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.2
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	(Equation 3-1)
STE	{{	}}$^{2(a),(c)}$	Assumption 2.1.4
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.9
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.1
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.1.5
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**°F**	**% CS**

Analytical Limit	620.00°F
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ °F
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ °F

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Table 5-7 Setpoint Calculation for High Reactor Coolant System Average Temperature

Actuation Function	**High RCS Average Temperature**
Sensor	**RCS Hot and RCS Cold Temperature**
Engineering Units of Measure	**ºF**
Upper Limit	700
Lower Limit	300
Calibrated Span (CS)	400

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**°F**	**% CS**

High RCS Average Temperature

Analytical Limit	555.00	°F
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$	°F
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$	°F

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Table 5-8 Setpoint Calculation for High Containment Pressure Protective Function

Actuation Function	**High Containment Pressure**
Sensor	**Narrow Range Containment Pressure**
Engineering Units of Measure	**psia**
Upper Limit	20
Lower Limit	0
Calibrated Span (CS)	20

Process and Miscellaneous Effects Error	**psia**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	3.4.1.1
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.2
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	(Equation 3-1)
STE	{{	}}$^{2(a),(c)}$	Assumption 2.1.4
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.9
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.1
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.1.5
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**psia**	**% CS**

Analytical Limit	9.50 psia
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ psia
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ psia

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Table 5-9 Setpoint Calculation for High Pressurizer Pressure Protective Function

Actuation Function	**High Pressurizer Pressure**
Sensor	**Pressurizer Pressure**
Engineering Units of Measure	**psia**
Upper Limit	2200
Lower Limit	1200
Calibrated Span (CS)	1000

Process and Miscellaneous Effects Error	**psia**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	3.4.1.1
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.2
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	(Equation 3-1)
STE	{{	}}$^{2(a),(c)}$	Assumption 2.1.4
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.9
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.1
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.1.5
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**psia**	**% CS**

Analytical Limit	2200.00 psia
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ psia
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ psia

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Table 5-10 Setpoint Calculation for High Pressurizer Level Protective Function

Actuation Function	**High Pressurizer Level**
Sensor	**Pressurizer Level**
Engineering Units of Measure	**% Level**
Upper Limit	100
Lower Limit	0
Calibrated Span (CS)	100

Process and Miscellaneous Effects Error	**% Level**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	3.4.1.1
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.2
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	(Equation 3-1)
STE	{{	}}$^{2(a),(c)}$	Assumption 2.1.4
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.9
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.1
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.1.5
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**% Level**	**% CS**

Analytical Limit	80.00 % Level
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ % Level
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ % Level

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Table 5-11 Setpoint Calculation for Low & Low-Low Pressurizer Pressure Protective Function

Actuation Function	**Low and Low-Low Pressurizer Pressure**
Sensor	**Pressurizer Pressure**
Engineering Units of Measure	**psia**
Upper Limit	2200
Lower Limit	1200
Calibrated Span (CS)	1000

Process and Miscellaneous Effects Error	**psia**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	3.4.1.1
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.2
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	(Equation 3-1)
STE	{{	}}$^{2(a),(c)}$	Assumption 2.1.4
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.9
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.1
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.1.5
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**psia**	**% CS**

Low Pressurizer Pressure

Analytical Limit	1850.00 psia
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ psia
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ psia

Low-Low Pressurizer Pressure

Analytical Limit	1200.00 psia
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ psia
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ psia

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Table 5-12 Setpoint Calculation for Low & Low-Low Pressurizer Level Protective Functions

Actuation Function	**Low & Low-Low Pressurizer Level**
Sensor	**Pressurizer Level**
Engineering Units of Measure	**% Level**
Upper Limit	100
Lower Limit	0
Calibrated Span (CS)	100

Process and Miscellaneous Effects Error	**Inches**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	3.4.1.1
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.2
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	(Equation 3-1)
STE	{{	}}$^{2(a),(c)}$	Assumption 2.1.4
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.9
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.1
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.1.5
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**% Level**	**% CS**

Low Pressurizer Level

Analytical Limit	35.00 % Level
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ % Level
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ % Level

Low-Low Pressurizer Level

Analytical Limit	15.00 % Level
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ % Level
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ % Level

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Table 5-13 Setpoint Calculation for Low & Low-Low Main Steam Pressure Protective Function

Actuation Function	**Low & Low-Low Main Steam Pressure**
Sensor	**Main Steam Pressure**
Engineering Units of Measure	**psia**
Upper Limit	1200
Lower Limit	0
Calibrated Span (CS)	1200

Process and Miscellaneous Effects Error	**psia**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	3.4.1.1
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.2
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	(Equation 3-1)
STE	{{	}}$^{2(a),(c)}$	Assumption 2.1.4
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.9
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.1
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.1.5
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**psia**	**% CS**

Low Main Steam Pressure

Analytical Limit	300.00 psia
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ psia
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ psia

Low-Low Main Steam Pressure

Analytical Limit	20.00 psia
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ psia
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ psia

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Table 5-14 Setpoint Calculation for High Main Steam Pressure Protective Function

Actuation Function	**High Main Steam Pressure**		
Sensor	**Main Steam Pressure**		
Engineering Units of Measure	**ºF**		
Upper Limit	1200		
Lower Limit	0		
Calibrated Span (CS)	1200		
Process and Miscellaneous Effects Error	**psia**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	3.4.1.1
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.2
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	(Equation 3-1)
STE	{{	}}$^{2(a),(c)}$	Assumption 2.1.4
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.9
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.1
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.1.5
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**psia**	**% CS**

Analytical Limit	1200.00 psia
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ psia
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ psia

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Table 5-15 Calculation for High Main Steam Temperature Loop Uncertainty

Actuation Function	**Main Steam Temperature**		
Sensor	**Main Steam Temperature**		
Engineering Units of Measure	**ºF**		
Upper Limit	700		
Lower Limit	100		
Calibrated Span (CS)	600		
Process and Miscellaneous Effects Error	**°F**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	3.4.1.1
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.2
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	(Equation 3-1)
STE	{{	}}$^{2(a),(c)}$	Assumption 2.1.4
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.9
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.1
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.1.5
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
Total Loop uncertainty (TLU)	{{	}}$^{2(a),(c)}$	
Units	**ºF**	**% CS**	

To calculate the uncertainty associated with the Superheat protective function, a simple equation for determining the steam superheat temperature (TSH) for main steam is used, this is represented in Figure 5-2. The degree of superheat is found by determining the saturation temperature (T_{SAT}) at the measured main steam pressure (P_{STM}), and subtracting this value from the measured in steam saturation temperature is found via a simple steam table lookup function using the measured steam pressure value.

Degree of Superheat

$$T_{SH} = T_{STM} - T_{SAT}(P_{STM}) \qquad \text{Equation 5-1}$$

The equation for error propagation for a simple mathematical subtraction function is determined by the SRSS of the individual module uncertainty values. In this case, the

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Superheat error (E_{TSH}) is calculated using the SRSS of the steam temperature error (E_{TSTM}) and steam pressure error (E_{PSTM}) from Table 5-8 TLU. As the steam temperature loop uncertainty contains a bias term for IRE, it is necessary to subtract it from the E_{STM} term before it can be combined by the SRSS method. To account for the IRE bias term, it is added to the resultant SRSS result

Superheat Error

$$E_{TSH} = [(E_{TSTM} - E_{TSTM(IRE)})^2 + (E_{PSTM})^2]^{1/2} + E_{TSTM(IRE)} \qquad \text{Equation 5-2}$$

Therefore, to calculate the Total Loop Uncertainty of the Steam Superheat protective function, the uncertainty associated with the steam temperature measurement must first be determined, then using the equations above, the steam superheat TLU can be calculated as shown in Figure 5-2 below.

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Figure 5-2 Function Block Diagram for Steam Superheat Calculation

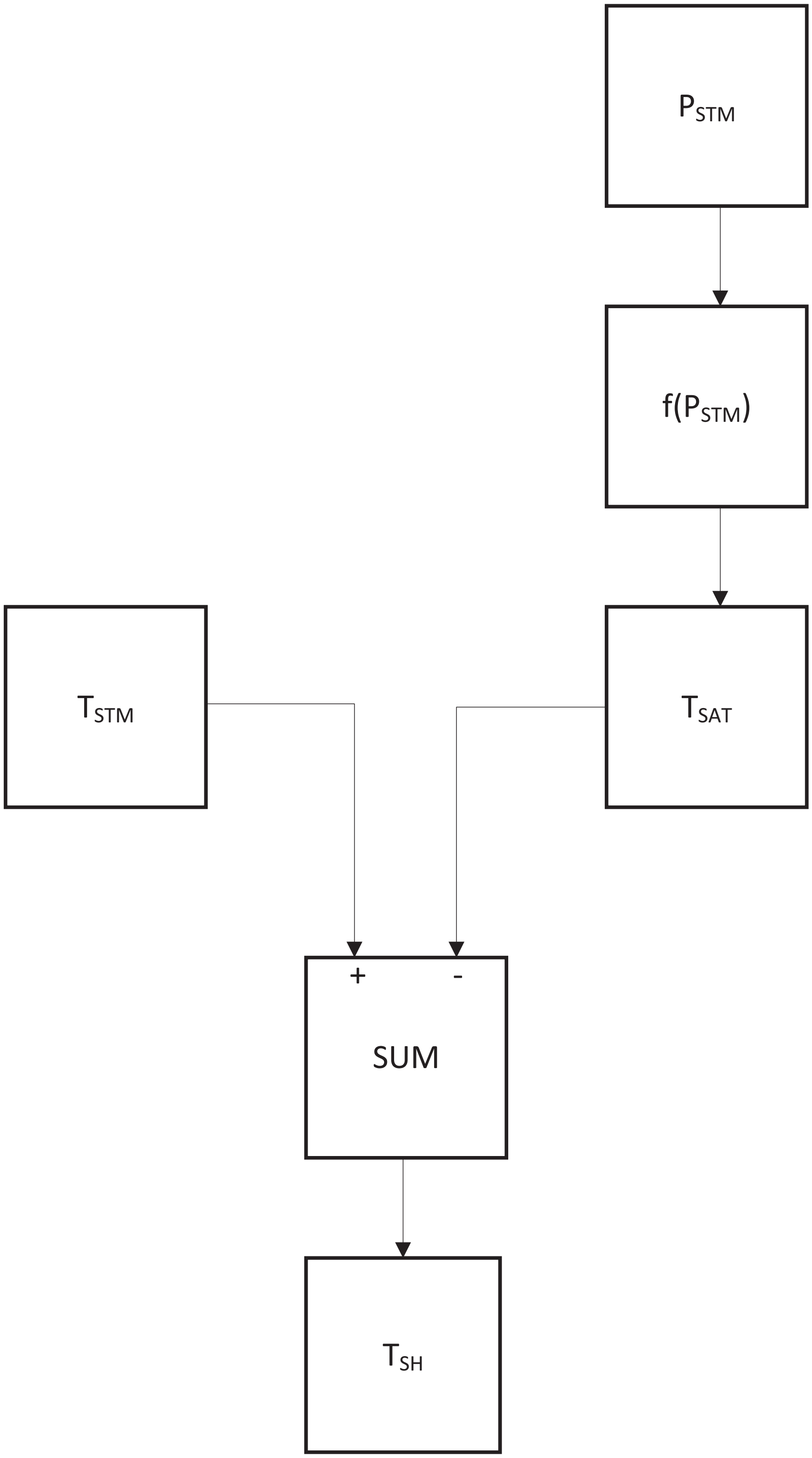

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Table 5-16 Setpoint Calculation for High Steam Superheat Protective Function

Actuation Function	**High Steam Superheat**
Sensor	**Main Steam Temperature and Pressure**
Engineering Units of Measure	**ºF**
Upper Limit	180
Lower Limit	0
Calibrated Span (CS)	180

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**ºF**	**% CS**

Analytical Limit	150.00 ºF
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ ºF
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ ºF

Table 5-17 Setpoint Calculation for Low Steam Superheat Protective Function

Actuation Function	**Low Steam Superheat**
Sensor	**Main Steam Temperature and Pressure**
Engineering Units of Measure	**ºF**
Upper Limit	180
Lower Limit	0
Calibrated Span (CS)	180

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**ºF**	**% CS**

Analytical Limit	0.00 ºF
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ ºF
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ ºF

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Table 5-18 Setpoint Calculation for Low Reactor Coolant System Flow Protective Function

Actuation Function	**Low RCS Flow**
Sensor	**RCS Flow**
Engineering Units of Measure	**ft^3/sec**
Upper Limit	31.89
Lower Limit	0.00
Calibrated Span (CS)	31.89

Process and Miscellaneous Effects Error	**ft^3/s**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	3.4.1.1
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.2
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	(Equation 3-1)
STE	{{	}}$^{2(a),(c)}$	Assumption 2.1.4
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.9
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.1
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.1.5
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**ft^3/s**	**% CS**

Analytical Limit	1.00 ft^3/s
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ ft^3/s
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ ft^3/s

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Table 5-19 Setpoint Calculation for the Low-Low Reactor Coolant System Flow Protection Function

Actuation Function	**Low-Low RCS Flow**
Sensor	**RCS Flow**
Engineering Units of Measure	**ft^3/sec**
Upper Limit	31.89
Lower Limit	0.00
Calibrated Span (CS)	31.89

Process and Miscellaneous Effects Error	**ft^3/s**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	3.4.1.1
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.2
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	(Equation 3-1)
STE	{{	}}$^{2(a),(c)}$	Assumption 2.1.4
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.9
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.1
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.1.5
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**ft^3/s**	**% CS**

Analytical Limit	0.00 ft^3/s
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ ft^3/s
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ ft^3/s

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Table 5-20 Setpoint Calculation for Low RPV Water Level Protective Function

Actuation Function	**Low RPV Riser Level**
Sensor	**RPV Riser Level**
Engineering Units of Measure	**Inches**
Spacing between sensors	200 mm
Spacing converted to inches	7.874 inches

Process and Miscellaneous Effects Error	**Inches**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	3.4.1.1
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.2
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	(Equation 3-1)
STE	{{	}}$^{2(a),(c)}$	Assumption 2.1.4
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.9
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.1
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.1.5
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**Inches**	**% CS**

	Low Limit	**High Limit**
Analytical Limit	540.00 Inches	552.00 Inches
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ Inches	{{ }}$^{2(a),(c)}$ Inches
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ Inches	{{ }}$^{2(a),(c)}$ Inches

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Table 5-21 Setpoint Calculation for Low-Low RPV Water Level Protective Function

Actuation Function	**Low-Low RPV Riser Level**
Sensor	**RPV Riser Level**
Engineering Units of Measure	**Inches**
Spacing between sensors	200 mm
Spacing converted to inches	7.874 inches

Process and Miscellaneous Effects Error	**Inches**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	3.4.1.1
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.4
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.2
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	(Equation 3-1)
STE	{{	}}$^{2(a),(c)}$	Assumption 2.1.4
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.9
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.1
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.3
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.1.5
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**Inches**	**% CS**

	Low Limit	**High Limit**
Analytical Limit	460.00 Inches	472.00 Inches
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ Inches	{{ }}$^{2(a),(c)}$ Inches
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ Inches	{{ }}$^{2(a),(c)}$ Inches

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Table 5-22 Setpoint Calculation for Low AC Voltage Protective Function

Actuation Function	**Low ELVS AC Bus Voltage**		
Sensor	**ELVS Bus Voltage**		
Engineering Units of Measure	**VAC**		**Source/Reference**
Upper Limit	480		Assumption 2.2.12
Lower Limit	0		Assumption 2.2.12
Calibrated Span (CS)	480		N/A
Process and Miscellaneous Effects Error	**VAC**	**% CS**	
Primary Element Accuracy (PEA)	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
STE	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**VAC**	**% CS**

Analytical Limit	384.00 VAC
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ VAC
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ VAC

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Table 5-23 Setpoint Calculation for High-Under-the-Bioshield Temperature Protective Function

Actuation Function	**High-Under-the-Bioshield Temperature**
Sensor	**High-Under-the-Bioshield Temperature**
Engineering Units of Measure	**°F**
Upper Limit	700
Lower Limit	40
Calibrated Span (CS)	660

Process and Miscellaneous Effects Error	**°F**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00%	Assumption 2.2.12
Process Measurement Error (PME)	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
Sensor Error			
SRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
SDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
Sensor Measurement and Test Equipment (SMTE)	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
STE	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
SPE	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
IRE [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
Sensor Accident Effect (SEA) [Bias]	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
SSE	{{	}}$^{2(a),(c)}$	Assumption 2.2.12
Digital Processing Error			
DRA	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.1
DDR	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2
DMTE	{{	}}$^{2(a),(c)}$	Assumption 2.2.6.2

Total Loop Uncertainty (TLU)	{{	}}$^{2(a),(c)}$
Units	**°F**	**% CS**

Analytical Limit	250.00 °F
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(a),(c)}$ °F
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(a),(c)}$ °F

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6.0 Reactor Protections System and Engineered Safety Features Actuation System Summary of Analytical Limits, Uncertainties and Setpoints

Table 6-1 Reactor Protections System and Engineered Safety Features Actuation System Actuation Function Setpoint, Limits and Uncertainty Summary

Parameter	Analytical Limit	Total Loop Uncertainty {{	Limiting Trip Setpoint	Nominal Trip Setpoint
High PR Linear Power [=15% RTP] Table 5-1	25.0 % RTP			
High PR Linear Power [>15% RTP] Table 5-1	115.0% RTP			
High Source Range & Intermediate Range Log Power Rate	3.00 DPM			
High Power Linear Rate Table 5-3	± 7.5% RTP/30 Sec			
High Source Range Count Rate Table 5-4	5.00E+05 CPS			
High Subcritical Multiplication Table 5-5	3.20			
High RCS Hot Temperature Table 5-6	620.0°F			
High RCS Average Temperature Table 5-7	555.0°F			
High Containment Pressure Table 5-8	9.50 psia			
High Pressurizer Pressure Table 5-9	2100 psia			
High Pressurizer Level Table 5-10	80% Level			
Low Pressurizer Pressure Table 5-11	1850 psia			
Low-Low Pressurizer Pressure Table 5-11	1200 psia			

}}2(a),(c)

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Table 6-1 Reactor Protections System and Engineered Safety Features Actuation System Actuation Function Setpoint, Limits and Uncertainty Summary (Continued)

Parameter	**Analytical Limit**	**Total Loop Uncertainty** {{	**Limiting Trip Setpoint**	**Nominal Trip Setpoint**
Low Pressurizer Level Table 5-12	35% Level			
Low-Low Pressurizer Level Table 5-12	15% Level			
Low Main Steam Pressure Table 5-13	300 psia			
Low-Low Main Steam Pressure Table 5-13	20 psia			
High Main Steam Pressure Table 5-14	1200 psia			
High Main Steam Superheat Table 5-16	150°F			
Low Main Steam Superheat Table 5-17	0.0°F			
Low RCS Flow Table 5-18	1.00 ft^3/s			
Low-Low RCS Flow Table 5-19	0.0 ft^3/s			
Low RPV Riser Level [Upper Limit][1] Table 5-20	552 in			
Low RPV Riser Level [Lower Limit][1] Table 5-20	540 in			
Low-Low RPV Riser Level [Upper Limit][1] Table 5-21	472 in			
Low-Low RPV Riser Level [Lower Limit][1] Table 5-21	460 in			
Low ELVS AC Bus Voltage Table 5-22	384 VAC			

}}$^{2(a),(c)}$

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Table 6-1 Reactor Protections System and Engineered Safety Features Actuation System Actuation Function Setpoint, Limits and Uncertainty Summary (Continued)

Parameter	Analytical Limit	Total Loop Uncertainty {{	Limiting Trip Setpoint	Nominal Trip Setpoint
High-Under-the-Bioshield Temperature Table 5-23	250°F			

}}2(a),(c)

1. The total loop uncertainty is applied to the upper analytical limit and the lower analytical limit to establish an acceptable range for the limiting trip setpoint
2. FSAR Chapter 7 contains final analytical limit values.
3. The design calculation contains actual TLU, LTS and NTS values.

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7.0 Summary and Conclusions

This technical report described the instrument setpoint determination methodology applied to the safety-related I&C functions. The methodology ensures that the RTS and ESFAS setpoints are consistent with the assumptions made in the safety analysis and conform to the setpoint-related requirements of industry standard, Reference 8.11, which is endorsed by RG 1.105 Revision 4.

Setpoints for the RTS and ESFAS have been selected to provide sufficient allowance between the trip setpoint and the safety limit to account for instrument channel uncertainties to ensure that the analytical limit applied to safety-related MPS protective actions satisfy the plant safety analysis requirements.

The instrument setpoint methodology determines calibration uncertainty allowances, including as-found and as-left tolerances, used in plant surveillance tests to verify that setpoints for safety-related protective functions are within Technical Specification limits.

The methodology also establishes performance and test acceptance criteria to evaluate setpoints during surveillance testing and calibration for setpoint drift.

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8.0 References

8.1 U.S. Code of Federal Regulations, “General Design Criteria for Nuclear Power Plants,” Appendix A, Part 50, Chapter I, Title 10, “Energy,” (10 CFR 50 Appendix A).

8.2 U.S. Code of Federal Regulations, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants,” Appendix B, Part 50, Chapter I, Title 10, “Energy,” (10 CFR 50 Appendix B).

8.3 U.S. Code of Federal Regulations, “Technical Specifications,” Section 50.36, Part 50, Chapter I, Title 10, “energy,” (10 CFR 50.36).

8.4 U.S. Nuclear Regulatory Commission, “Setpoints for Safety-Related Instrumentation,” Regulatory Guide 1.105, Revision 4, February 2021.

8.5 U.S. Regulatory Commission, Generic Letter 91-04, “Guidance on Preparation of a Licensee Amendment Request for Changes in Surveillance Intervals to Accommodate a 24-Month Fuel Cycle,” April, 1991.

8.6 Technical Specification Task Force, TSTF-493, Rev. 4, “Clarify Application of Setpoint Methodology for LSSS Functions,” July 31, 2009.

8.7 Institute of Electrical and Electronics Engineers, IEEE Standard 603-1991, “IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations.” Research Triangle Park, NC.

8.8 International Society of Automation, ISA-67.04.01-2018, “Setpoints for Nuclear Safety Related Instrumentation,” Research Triangle Park, NC.

8.9 International Society of Automation, ISA-RP67.04.02-2010, “Methodologies for the Determination of Setpoints for Nuclear Safety Related Instrumentation,” Research Triangle Park, NC.

8.10 U.S. Nuclear Regulatory Commission, “Design Specific Review Standard for NuScale SMR Design,” Revision 0, ADAMS Accession Number ML15356A416.

8.11 Design of Highly Integrated Protection System Platform Topical Report, TR-1015-18653-P-A, Revision 2.

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