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 described in this technical report has been established to ensure that 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-S67.04-2006, and U.S. Nuclear Regulatory Commission Regulatory Guide 1.105 Revision 3, and addresses the regulatory issues identified in Regulatory Issue Summary 2006-17.

The detailed setpoint calculation processes for the module protection system are described in this report and may change according to the plant-specific data. The 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.

Executive Summary

This technical report describes the instrument setpoint determination methodology applied to the safety-related instrumentation and control (I&C) functions. The methodology described in this report has been established to ensure that the Reactor Trip System (RTS) and Engineered Safety Features Actuation System (ESFAS) setpoints are consistent with the assumptions made in the safety analysis and conform to the setpoint-related requirements of industry standard, ANSI/ISA-S67.04-2006, U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.105 Revision 3, and addresses the regulatory issues identified in Regulatory Issue Summary (RIS) 2006-17.

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 that the analytical limit applied to safety-related MPS protective actions is satisfied in accordance with the Chapter 15 safety analysis. The instrument setpoint methodology is used to establish module protection system (MPS) setpoints for the safety-related instrumentation. 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.

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 between trip setpoints, analytical limits, and the plant safety limits that are used to properly account for the total instrument channel uncertainty in the establishment of the setpoints are described in Section 4.0.

The assumptions applicable to the NuScale Instrument Setpoint Methodology are described in Section 5.0.

Sample uncertainty and setpoint calculations based on the methodology described in this document are provided in Section 6.0, to demonstrate the application of the methodologies presented in this document and are not to be used in plant calibration procedures or for development of Technical Specifications. The detailed setpoint calculation processes for the module protection system are described in this report and may change according to the plant-specific data. This methodology does not included 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 7.0.

1.0 Introduction

1.1 Purpose

This document describes the methodology for determining setpoints for the safety-related instrumentation and control (I&C) functions. Setpoints for the Reactor Trip System (RTS) and Engineered Safety Features Actuation 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 U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.105, Revision 3 (Reference 9.4). RG 1.105 endorses conformance with ANSI/ISA–S67.04, Part I–1994 (with certain exceptions and clarifications) as an acceptable method for satisfying the NRC's regulations for ensuring that setpoint for safety-related instrumentation are established and maintained within the Technical Specification limits. To address updated industry guidance and account for the regulatory issues raised in Regulatory Issue Summary (RIS) 2006-17 (Reference 9.6), the NuScale Instrument Setpoint Methodology is based on the updated International Society of Automation (ISA) standard ISA-67.04.01-2006 (Reference 9.11), and ISA-RP67.04.02-2000 (Reference 9.12). These standards provide updated guidance which is equivalent to the regulatory guidance contained in RG 1.105.

The NRC released Draft RG (DG) 1141 in June 2014, as a proposed Revision 4 to RG 1.105 (Reference 9.5). DG 1141 endorses Reference 9.11 and includes criteria, guidance, and concepts that have not been addressed in previous revisions of RG 1.105. The NuScale Instrument Setpoint Methodology addresses established regulatory guidance and the additional concepts proposed by NRC in the DG 1141.

Channel uncertainty calculations include instrument setpoint drift allowances. Periodic surveillance testing is required by the Technical Specifications in accordance with 10 CFR 50.36 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 that 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 in this document.

1.2 Scope

The NuScale Instrument Setpoint Methodology is used to establish module protection system (MPS) setpoints for the safety-related instrumentation. The scope of this report documents the methodology for establishing safety-related trip setpoints and their associated uncertainties to ensure the analytical limit applied to safety-related MPS protective actions is satisfied in accordance with the plant safety analysis. Sample uncertainty and setpoint calculations based on the methodology described in this document are provided in Section 6.0, to demonstrate the application of the methodologies presented in this document and are not to be used in plant calibration procedures or for development of Technical Specifications. This methodology does not included provisions for using a graded approach for non-safety related instrumentation.

1.3 Acronyms and 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 Acronyms and abbreviations

Term	Definition
AFT	as-found tolerance
AL	analytical limit
ALT	as-left tolerance
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
CFR	Code of Federal Regulations
CNV	containment vessel
cps	counts per second
CS	calibrated span
CT	calibration tolerance
COT	channel operational test
DDR	digital system drift
DG	Draft Regulatory Guide
DME	digital system measurement and test equipment error
DPE	digital system processing error
DPM	decades per minute
DRA	digital system reference accuracy
DSRS	Design Specific Review Standard
dt	doubling time
DTE	digital system temperature error
ECCS	emergency core cooling system
ESFAS	engineered safety features actuation system
ft^3/s	cubic feet per second
GDC	General Design Criterion
HELB	high energy line break
I&C	instrumentation and controls
IEEE	Institute of Electrical and Electronics Engineers
IR	intermediate range
IRE	instrument channel uncertainty
ISA	International Society of Automation
LOCA	loss of coolant accident
LSSS	limiting safety system setting
LTSP	limiting trip setpoint
M&TE	measurement and test equipment
MPS	module protection system

Term	Definition
NDR	NMS drift
NME	NMS M&TE error
NMS	neutron monitoring system
NRA	NMS reference accuracy
NRC	Nuclear Regulatory Commission
NTE	NMS temperature error
NTSP	nominal trip setpoint
PE	primary element
PEA	primary element accuracy
PM	process measurement
PME	process measurement error
PR	power range
PT	potential transformer
PTAC	performance and test acceptance criteria
psi	pounds per square inch
psia	pounds per square inch absolute
psig	pounds per square inch gauge
PV	pressure variation
Pzr	pressurizer
RG	Regulatory Guide
RCS	reactor coolant system
RIS	Regulatory Issue Summary
RPV	reactor pressure vessel
RTD	resistance temperature detector
RTP	rated thermal power
RTS	reactor trip system
SAE	sensor accident environmental effect
SBM	scheduling and bypass module
SCA	sensor calibration accuracy
SDR	sensor drift
SFM	safety function module
SG	steam generator
SME	sensor M&TE
SPE	sensor pressure effects
SPE_A	sensor accident pressure effect
SR	source range
SRA	sensor reference accuracy
SRE_A	sensor accident radiation effect
SRSS	square-root-sum-of-squares
SenSE	sensor seismic effect
STE	sensor temperature effects
STE_A	sensor accident temperature effect
SUR	startup rate
SVM	scheduling and voting module
TBD	to be determined

Term	Definition
T_{hot}	reactor coolant system hot leg temperature
TLU	total loop uncertainty
TSTF	Technical Specifications Task Force
U.S.	United States
URL	upper range limit
ºF	degree Fahrenheit
∆P	differential pressure
%	percent

Table 1-2 Definitions

Term	Definition
Analytical Limit (AL)	Limit of a measured or calculated variable established by the safety analysis to ensure that a safety limit is not exceeded. Source: Reference 9.11
As Found	The condition in which a channel, or portion of a channel, is found after a period of operation and before recalibration (if necessary). Source: Reference 9.11
As Left	The condition in which a channel, or portion of a channel, is left after calibration or final setpoint device setpoint verification. Source: Reference 9.11
Bias	An uncertainty component that consistently has the same algebraic sign and is expressed as an estimated limit of error. Source: Reference 9.12
Channel Calibration	A channel calibration shall be the adjustment, as necessary, of the channel output such that it responds within the necessary range and accuracy to known values of the parameter that the channel monitors. The channel calibration shall encompass all devices in the channel required for channel operability. Calibration of instrument channels with resistance temperature detector (RTD) or thermocouple sensors may consist of an in place qualitative assessment of sensor behavior and normal calibration of the remaining adjustable devices in the channel. The channel calibration may be performed by means of any series of sequential, overlapping, or total channel steps. Source: Reference 9.8
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 9.12
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 9.11
Error	The arithmetic difference between the indication and the ideal value of the measured signal. Source: Reference 9.11
Independent Uncertainty	Uncertainty components are independent of each other if their magnitudes or algebraic signs are not significantly correlated. Source: Reference 9.12

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: References 9.10 and 9.11
Instrument Range	The region between the limits within which a quantity is measured, received, or transmitted and is expressed by stating the lower and upper range values. Sources: Reference 9.12
Limiting Safety System Setting (LSSS)	Limiting safety system settings for nuclear reactors are settings for automatic protective devices related to those variables having significant safety functions. Where a limiting safety system setting is specified for a variable on which a safety limit has been placed, the setting must so be chosen that automatic protective action will correct the abnormal situation before a safety limit is reached. Source: Reference 9.3
Limiting Trip Setpoint (LTSP)	The limiting value for the nominal trip setpoint so that the trip or actuation will occur before the analytical limit is reached, regardless of the process or environmental conditions affecting the instrumentation. Source: Reference 9.11
Margin	In setpoint determination, margin is an allowance added to the instrument channel uncertainty to add conservatism. Margin moves the setpoint farther away (more conservative) from the analytical limit. Source: Reference 9.12
Nominal Trip Setpoint (NTSP)	A predetermined value for actuation of a final setpoint device to initiate protective action. Source: Reference 9.11
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 9.11
Random	Describing a variable whose value at a particular future instant cannot be predicted exactly but can only be estimated by a probability distribution function. Source: Reference 9.12
Reference Accuracy	A number or quantity that defines a limit that errors will not exceed when a device is used under specified operating conditions. Source: Reference 9.11

Term	Definition
Safety Limit	A limit on an important process variable that is necessary to reasonably protect the integrity of physical barriers that guard against the uncontrolled release of radioactivity. Source: Reference 9.3
Sensor	The portion of a channel that responds to changes in a process variable and converts the measured process variable into an instrumentation signal. Source: Reference 9.11
Signal conditioning	One or more modules that perform signal conversion, buffering, isolation, or mathematical operations on the signal as needed. Source: Reference 9.12
Total Loop Uncertainty (TLU)	The TLU represents the expected performance of the instrumentation under any applicable process and environmental conditions. Note that 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 9.11
Uncertainty	The amount to which an instrument channel's output is in doubt (or the allowance made therefore) due to possible errors, either random or systematic, that have not been corrected. The uncertainty is generally identified within a probability and confidence level. Source: Reference 9.11

2.0 Background

I&C safety systems control plant parameters to assure that safety limits will not be exceeded under the most severe design basis accident. 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 and/or terminated before plant conditions exceed safety limits. Accident analyses establish the limits for credited protective actions. These analytical limits, as established by accident analyses, do not normally include considerations for the accuracy (uncertainty) of installed instrumentation. Additional analyses and procedures are necessary to assure that the limiting trip setpoint 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's 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, assures that the transient will be avoided and/or terminated before the process parameters exceed the established safety limits.

Early versions of 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. This led to numerous abnormal occurrence reports, or Licensing Event Reports, as required by 10 CFR 50.36 when Technical Specification limits are exceeded.

The ISA sponsored a review of the setpoint drift problem in April 1975. Revision 1 to RG 1.105 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 Revision 1 to RG 1.105 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 to be used for establishing and maintaining setpoints of individual instrument channels in safety-related systems (see Reference 9.11).

This standard 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 effort between the industry and NRC staff) and current industry practice established in the Standard Technical Specifications (e.g., Reference 9.8), which included a nominal trip setpoint and an allowable value to establish limits of instrument channel operability during period surveillance testing.

Conformance with Part I of Reference 9.11, with the exceptions and clarifications specified in RG 1.105, Revision 3, provides a method acceptable to the NRC for ensuring that setpoints for safety-related instrumentation are established and maintained within the Technical Specification limits. RG 1.105, Revision 3, does not address or endorse Part II of Reference 9.11. Part II provides 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 the industry standard Part II of Reference 9.11 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, industry and the NRC worked together to develop requirements to ensure that instrument channels will actuate safety systems to perform their preventive or mitigation functions as assumed in the accident analysis. As a result of this joint effort the industry Technical Specifications Task Force (TSTF) issued suggested changes for NRC review. The NRC responded to the TSTF request, in Reference 9.6, which requested that a generic list of applicable functions be added and provided as additional guidance for acceptable as-found and as-left calibration tolerances. These comments were incorporated in Reference 9.9, issued on July 31, 2009.

The NuScale Design Specific Review Standard (DSRS) for Chapter 7 provides the NRC staff guidance in the review of the NuScale licensing submittals describing instrumentation setpoints (Reference 9.13). In particular, section 7.2.7 of the DSRS provides review and acceptance criteria for acceptable as-found and as-left tolerances used in the setpoint methodology.

In accordance with the regulatory and industry standard guidance cited in Section 2.2, 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 References 9.11 and 9.12. These updated industry standards provide updated guidance based on best-industry practices that have not been included in previous regulatory guidance. Additionally, this methodology has considered the guidance contained in DG 1141 to address a number of concerns and issues with regard to setpoint drift, periodic surveillance testing, and operability determinations.

2.1 Theory

2.1.1 Statistics and Instrument Uncertainties

Because all instruments are subject to errors, it is impossible to know the actual value of the measured process variable; there is always some inherent error that must be accounted for. 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. Since the actual value of the error is unknown, the accuracy of the instrument measurement can only be expressed in terms of statistical probabilities. Therefore, in accordance with the recommended practice described Reference 9.12, the term uncertainty is utilized to reflect the distribution of possible errors.

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.

2.1.1.1 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. 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, as outlined in Reference 9.12, 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. This means that 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 describes using a 95/95 tolerance limit which has an actual confidence level of 1.96-sigma. The methodology described in this document used 95/95 tolerance interval for consistency with regulatory guidance.

Using probability levels that correspond to three or more standard deviations may be unnecessarily conservative, resulting in reduced operating margin. For example, if a reference accuracy for a 99 percent probability level (3 sigma) is given as ±6 psig, the 95 percent probability level corresponds to ±4 psig (i.e., 2/3 x 6).

2.1.2 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 illustrated in Figure 2-1 and discussed below.

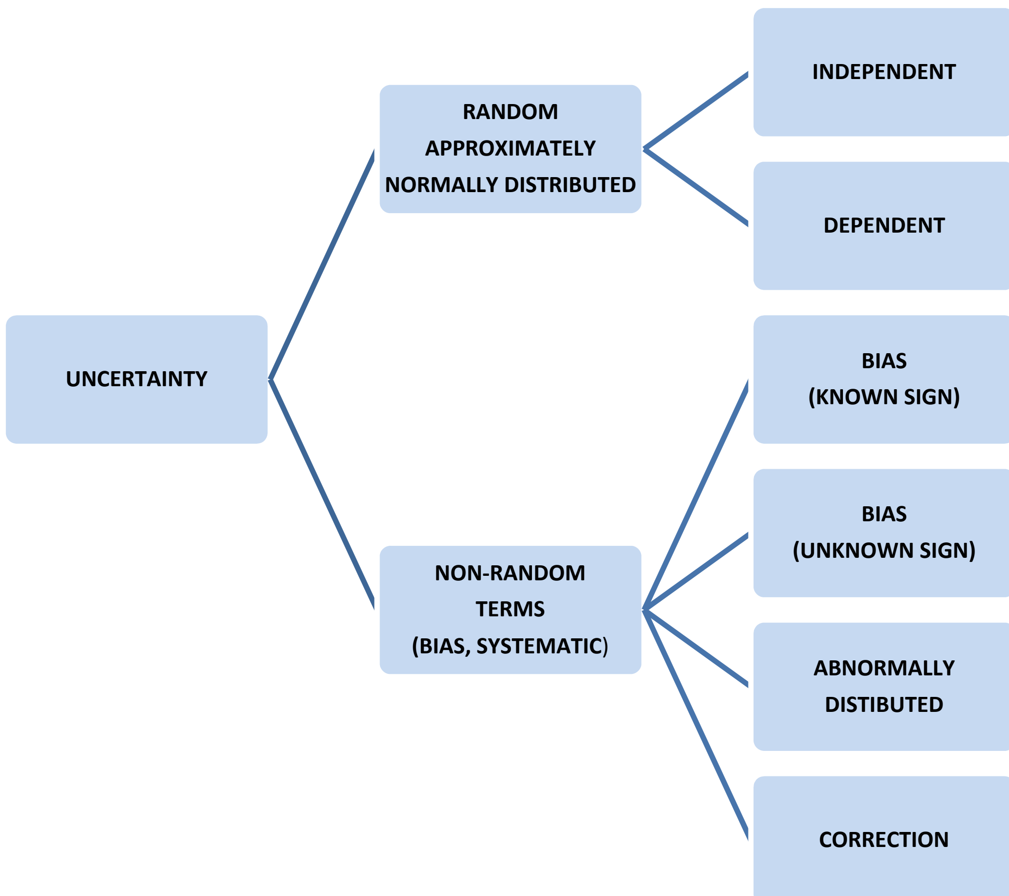

Figure 2-1 Statistical uncertainty

2.1.2.1 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. This uncertainty is often called the statistical uncertainty and is one of the so-called precision indices. The most commonly used 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.

It is usually expected that those instrument uncertainties that a manufacturer specifies as having a ± magnitude are random uncertainties. However, the uncertainty must be mean-centered and approximately normally distributed to be considered random. The hazards of assuming that the ± in vendor data implies that the instrument's performance represents a normal statistical distribution are addressed in Section 2.1.1.1. After uncertainties have been categorized as random, any dependencies between the random uncertainties should be identified.

2.1.2.2 Independent Uncertainties

Independent uncertainties are those uncertainties for which no common root cause exists. It is generally accepted that most instrument channel uncertainties are independent of each other.

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.

2.1.2.3 Dependent Uncertainties

Dependent uncertainties are those for which the user knows or suspects that 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.

2.1.3 Nonrandom Uncertainties

2.1.3.1 Bias (Known Sign)

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

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

2.1.3.2 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.

2.1.4 Bias (Unknown Sign)

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

2.1.5 Correction

Errors or offsets that are of a known direction and magnitude are corrected for in the calibration of the 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.

2.1.6 Combining Uncertainties

The total loop uncertainty (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 calibrated span (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 percent CS

B (random / independent) = ±1.0 percent CS

C (random / independent) = ±1.0 percent CS

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

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

F (Abnormally Distributed) = ±2.5 percent CS (Treated as ± Bias value)

L (Bias: Known Direction) = +3.0 percent CS

M (Bias; Known Direction) = −4.0 percent CS

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

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

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

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

TLU = ±3.9 percent CS + 5.5 percent CS −6.5 percent CS

TLU^+ = (+)3.9 percent CS + 5.5 percent CS

= +9.4 percent CS

TLU^- = (-)3.9 percent CS - 6.5 percent CS

= −10.4 percent 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.

2.1.7 Sign Convention

The sign convention used in this setpoint methodology is consistent with the ISA definition of error (see 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. This can be expressed mathematically in one or two ways:

Error = Indicated Value – Actual Value; or

Indicated Value = Actual Value + Error.

Using the example above, if the actual process value is 25 percent CS, the measured value may be anywhere from 14.6 percent CS to 34.4 percent CS.

Conversely, if the measured value is 25 percent CS, the actual process value may be anywhere between 15.6 percent CS and 35.4 percent CS.

2.2 Regulatory Requirements

2.2.1 NRC Regulations

10 CFR 50.55a(h), "Protection and Safety Systems," requires compliance with IEEE Standard 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," and the correction sheet dated January 30, 1995. (Reference 9.10) Clause 4.4 of IEEE Standard 603-1991 requires identification of the analytical limit associated with each variable. Clause 6.8.1 requires that allowances for uncertainties between the analytical limit and device setpoint be determined using a documented methodology.

10 CFR Part 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. (Reference 9.2)

10 CFR 50 Appendix A, General Design Criterion (GDC) 13, “Instrumentation and Control,” requires, in part, that instrumentation be provided to monitor variables and systems, and that controls be provided to maintain these variables and systems within prescribed operating ranges. (Reference 9.1)

GDC 20, “Protection System Functions,” requires, in part, that the protection system be designed to initiate automatically the operation of appropriate systems including the reactivity control systems, to assure that 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 that, where a LSSS is specified for a variable on which a safety limit has been placed, the setting be so chosen that automatic protective action will correct the abnormal situation before a safety level is exceeded. 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 assure that the necessary quality of systems and components is maintained, that facility operation will be within safety limits, and that the limiting conditions for operation will be met.

2.2.2 Regulatory Guidance

The following regulatory guidance is applicable to the NuScale Instrument Setpoint Methodology described in this document.

NRC RG 1.105, Revision 3, “Setpoints for Safety-Related Instrumentation,” provides guidance for ensuring that instrument setpoints are initially - and remain - within the Technical Specification limits. This RG endorses ISA-S67.04-1994, Part I, “Setpoints for

Nuclear Safety-Related Instrumentation Used in Nuclear Power Plants." The NRC has issued DG 1141, a proposed revision to Regulatory Guide 1.105. Currently, this proposed revision has been issued for public comment.

NRC RIS 2006-17, "NRC Staff Position on the Requirements of 10 CFR 50.36, 'Technical Specifications,' Regarding Limiting Safety System Settings During Periodic Testing and Calibration of Instrument Channels," discusses issues that could occur during testing of the LSSSs.

NRC 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. (Reference 9.7)

TSTF-493, Revision 4, dated July 31, 2009, "Clarify Application of Setpoint Methodology for LSSS Functions." NRC issued a Notice of Availability of the models for plant-specific adoption of TSTF–493, Revision 4, in the Federal Register on May 11, 2010 (75 FR 26294).

NuScale DSRS for Chapter 7, Section 7.2.7, provides NRC staff review guidance of safety related setpoint determination for the NuScale reactor protection systems.

2.2.3 Industry Standards

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

ISA-67.04.01-2006, "Setpoints for Nuclear Safety-Related Instrumentation."

ISA-RP67.04.02-2000, "Methodology for the Determination of Setpoints for Nuclear Safety-Related Instrumentation," provides additional guidance; however, RG 1.105, Revision 3, does not endorse or address this recommended practice.

3.0 Sources of Uncertainty

3.1 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 neutron monitoring system (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 since 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.

3.1.1 Process Measurement Uncertainties

Process measurement errors (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.

3.1.2 Primary Element Uncertainties

Sensor primary element accuracy (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 PE for flow measurements. These uncertainties are independent of sensor uncertainties.

3.2 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.

3.2.1 Sensor Reference Accuracy

Sensor reference accuracy (SRA) is provided by the manufacturer as a limit for measurement errors when the sensor is in operation under specified conditions. SRA includes linearity, hysteresis, dead band, and repeatability. The SRA also includes the accuracy effects associated with digital processing elements that are part of the sensor. The sensor reference accuracy provided by instrument vendors must be verified to conform to the 95/95 criterion in order to support the use of the sensor reference accuracy in the calculation of the total loop uncertainty described in this document. If the sensor reference accuracy 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.

3.2.2 Sensor Drift

Sensor drift (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 such that any changes in the conditions between the calibrations are analyzed and accounted for. For example, if the previous and current calibrations were performed at different ambient temperatures, the calibration temperatures must be recorded and accounted for since it would be impossible to distinguish between sensor drift and changes due to ambient temperature conditions.

The source of the SDR allowance may be the manufacturer’s 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.

3.2.3 M&TE Uncertainties

M&TE reference accuracy (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. M&TE calibration and use is controlled by plant procedures to ensure that 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 in use during the calibration process. If the overall uncertainty of the M&TE is less than 1/10th of the reference accuracy of the device being tested, the M&TE uncertainty can be disregarded).

3.2.4 Sensor Calibration Accuracy

Sensor calibration accuracy (SCA) refers to the uncertainties introduced into the sensor during the calibration process. This accuracy is sometimes referred to the “setting tolerance” or the “as-left tolerance.” Sensor calibration errors are the result of measurement and test equipment 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.

The calibration, or performance verification, process 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 approach is not practical for field calibration, and plant procedures typically require only a single up-down cycle. Since 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 9.12 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; 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, it is assumed that calibration is performed at essentially the same ambient temperature. Ambient temperature data is recorded in the calibration procedure to verify this assumption (see Section 3.2.2). 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, if needed.

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 (SCA) = Sensor Reference Accuracy (SRA) Equation 3-1

3.2.5 Sensor Temperature Effects

Sensor temperature effects (STE) account for ambient temperature variations which 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 to be statistically independent with random errors in the ± direction. It is assumed that temperature effects will be minimal at the time of calibration since surveillance testing is performed at essentially the same ambient temperature. The temperature effect allowance accounts for ambient temperature variations during plant operation.

For example, if surveillance testing is performed at a normal ambient temperature of 75 degree Fahrenheit, and normal ambient temperature could vary between 40 degree Fahrenheit and 120 degree Fahrenheit, then the ambient temperature variation is -35 degree Fahrenheit to +45 degree Fahrenheit. A temperature change of ±50 degree Fahrenheit provides a bounding limit for this set of ambient temperature limits. A pressure transmitter operating in this environment with a temperature effect of 0.5 percent CS per 50 degree Fahrenheit ambient temperature change would therefore, have a temperature effect uncertainty of 0.5 percent CS.

3.2.6 Sensor Pressure Effects

Sensor pressure effects (SPE) account for differences between operating pressure and calibration pressure for differential pressure (ΔP) transmitters. Manufacturer's specifications typically include this uncertainty as static pressure effect and treat it as a random uncertainty. ΔP transmitters are used for process parameters such as flow and level. ΔP transmitters 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.

This effect can typically be calibrated out using a correction factor provided by the manufacturer so that the transmitter will provide the desired output at high pressure operating conditions. To calculate the sensor pressure effect 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. For 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:

$$SPE = (\pm 0.5 \text{ percent CS})\ PV \text{ psig} / 1000 \text{ psig}$$

$$SPE = (\pm 0.5 \text{ percent CS})(2100 - 1600) \text{ psig} / 1000 \text{ psig}$$

$$SPE = (\pm 0.5 \text{ percent CS})(500 \text{ psig} / 1000 \text{ psig})$$

$$SPE = \pm 0.25 \text{ percent CS}$$

3.2.7 Insulation Resistance Effects

The instrument channel uncertainty is dependent on the insulation resistance effects (IRE), which quantifies 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. IRE is a known sign bias term.

3.2.8 Accident Environment Effects

Instruments which can be exposed to severe ambient conditions as a result of an accident, and which are required to remain functional during or after an accident, may have additional accident related error terms which 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 conservatively treated as a bias term in the calculation of total loop uncertainty. Each contributing effect is described below.

3.2.8.1 Accident Temperature Effect

Frequently, the effect of abnormal temperature during accident conditions (STE_A) is the largest contributor to an instrument's 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 degree Fahrenheit can cause severe changes in performance. Typical inaccuracies of 5 percent 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's specific profiles should be fully enveloped by the actual test profiles, or differences evaluated for acceptability, for the specification to be valid.

3.2.8.2 Accident Pressure Effect

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

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

3.2.8.3 Accident Radiation Effect

The accident radiation effects (SRE_A) are considered in cases where high radiation levels caused by an accident are yet another effect which can greatly influence an instrument's accuracy. Electronic instrumentation may be affected by both the rate of radiation, and the total radiation dose to which it is exposed. In normal operation, radiation effects are small and can be calibrated out during periodic calibrations. Accident radiation effects are also determined as part of a manufacturer's 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 so as to envelope maximum dose levels expected at a large sampling of plants.

3.2.9 Seismic Effect

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

}}2(c)

3.3 Digital System Processing Error

Digital system processing error (DPE) sometimes commonly referred to as “rack error” or “rack uncertainty” includes a set of parameters combined as a group to account for signal processing errors typically associated with the analog to digital conversion by the digital I&C system. In general, these uncertainties include reference accuracy, calibration error, drift, and other parameters, as appropriate, such as normal ambient temperature effects. The digital reference accuracy (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 digital reference accuracy includes linearity, hysteresis, dead band, and repeatability.

The instrument setpoint methodology specifically considers the error associated with the safety-related digital I&C system. The 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 performs the filtering of 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 scheduling and voting module (SVM) are purely digital signal transmissions, such that there are no more instrument errors that need to be considered, as shown in Figure 3-1.

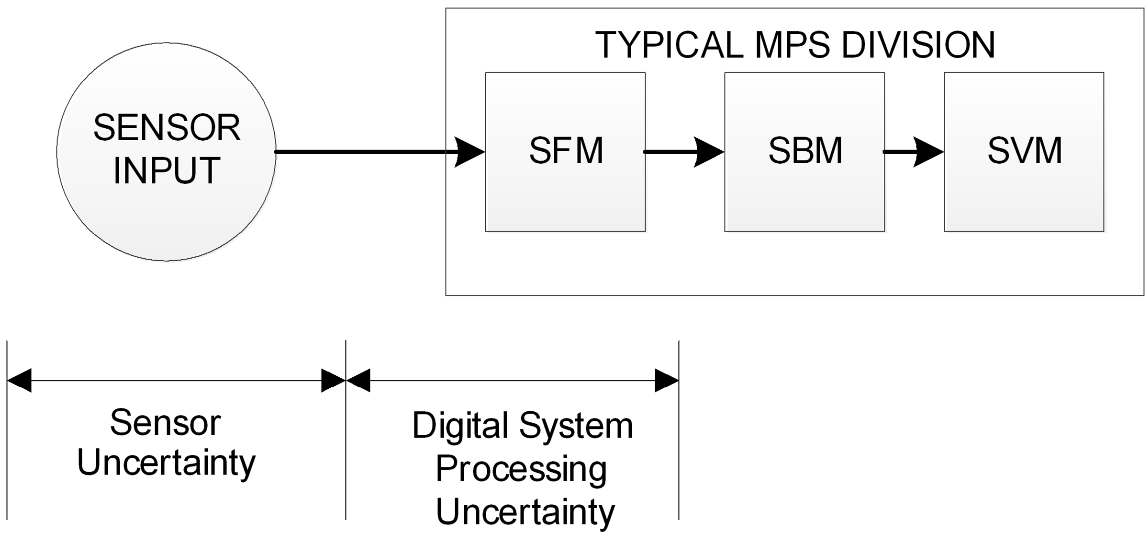

Figure 3-1 Simplified loop block diagram for the NuScale Module Protection system

Therefore, the error associated with the SFM in the MPS is a function of the DPE 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 the HIPS Topical Report (Reference 9.14).

3.3.1 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 SFM within the MPS.

3.3.2 Digital System Drift

The digital system drift (DDR) is considered negligible due to the self-calibration functions of MPS hardware; however, it will be verified with the system manufacturer.

3.3.3 Digital System Temperature Error

The digital system temperature error (DTE) is an error term that is typically supplied by the MPS hardware vendor, and is a representative term that is a function of any errors associated with temperature variations experienced by the MPS hardware. The DTE is considered negligible due to the self-calibration functions of MPS hardware; however, it will be verified with the system manufacturer.

3.3.4 Digital System M&TE Error

The MPS digital system M&TE error (DME) is the error associated with the M&TE equipment used to calibrate the MPS. The DME is considered negligible due to the self-calibration functions of MPS hardware; however, it will be verified with the system manufacturer.

3.4 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 input. 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. See Figure 3-2 for a block diagram of the NMS hardware. The following sections describe the uncertainties associated with NMS protective functions.

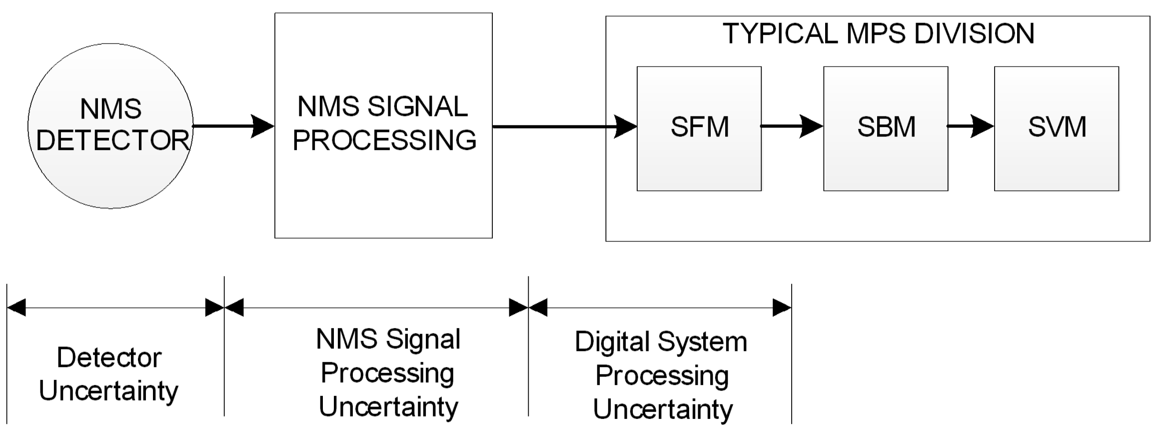

Figure 3-2 Simplified loop block diagram for NMS functions

3.4.1 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 or digital-to-analog conversion, and processing performed by the NMS hardware. Due to the uncertainty in the design of the NMS signal processing equipment, the NMS reference accuracy is treated as a separate, independent uncertainty term from other sources of uncertainty in the NMS hardware and signal processing function.

3.4.2 Neutron Monitoring System Drift

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

3.4.3 Neutron Monitoring System Temperature Error

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

3.4.4 Neutron Monitoring System M&TE Error

The NMS M&TE error (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.

3.5 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 (See 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 sign of the bias is known and predictable, they are applied algebraically based on their magnitude and sign in the conservative direction. For conservatism, in cases were the magnitude and sign of the bias is known; only the biases that affect the 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:

$$\begin{aligned} TLU = \pm \{ & [(PEA)^2 + (PME)^2 + (SRA)^2 + (SDR)^2 + (SME)^2 + (SCA)^2 + (STE)^2 + (SPE)^2 + (SenSE)^2 \\ & + (NRA)^2 + (NDR)^2 + (NTE)^2 + (NME)^2 + (DRA)^2 + (DTE)^2 + (DDR)^2 + (DME)^2]^{1/2} \\ & + [IRE + SAE + Bias] \} \end{aligned}$$

Equation 3-2

Table 3-1 Total loop uncertainty category summary

Uncertainty Parameter	Section
Process and Miscellaneous Effects Error	
Primary Element Accuracy (PEA)	3.1.1
Process Measurement Error (PME)	3.1.2
Sensor Error	
Sensor Reference Accuracy (SRA)	3.2.1
Sensor Drift (SDR)	3.2.2
Sensor Measurement and Test Equipment (SME)	3.2.3
Sensor Calibration Accuracy (SCA)	3.2.4
Sensor Temperature Effect (STE)	3.2.5
Sensor Static Pressure Effect (SPE)	3.2.6
Insulation Resistance Error (IRE)	3.2.7
Sensor Accident Environmental Effect (SAE)	3.2.8
Sensor Seismic Effect (SenSE)	3.2.9
Digital Processing Error	
Digital System Reference Accuracy (DRA)	3.3.1
Digital System Drift Error (DDR)	3.3.2
Digital System Temperature Error (DTE)	3.3.3
Digital System Measurement and Test Equipment Error (DME)	3.3.4
Neutron Monitoring System Error	
NMS Reference Accuracy (NRA)	3.4.1
NMS Drift (NDR)	3.4.2
NMS Temperature Error (NTE)	3.4.3
NMS M&TE Error (NME)	3.4.4

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.

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 departure from nucleate boiling ratio or linear heat generation rate. Requirements for establishing setpoints and relationships between the nominal trip setpoint, limiting trip setpoint, analytical limit, and safety limit are discussed in a safety analysis analytical limits report. This section discusses the concepts used to determine limiting trip setpoint and nominal trip setpoints.

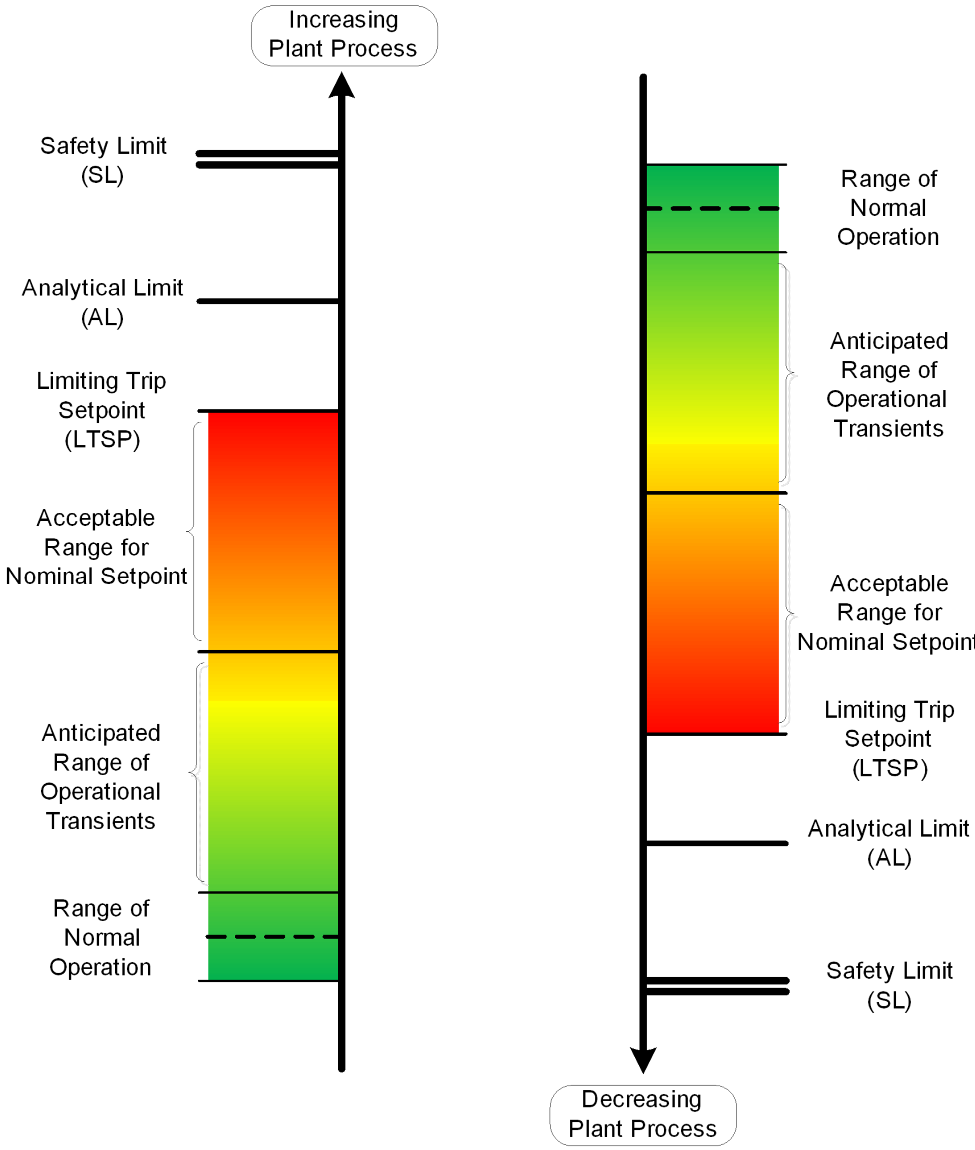

Figure 4-1 Nuclear safety-related setpoint relationships

4.1.1 Safety Limits

Nuclear power plants include barriers to limit the 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 on the environment or population. They are critical design values to protect the integrity of the key fission product barriers to guard against the release of radioactive materials. All 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

The analytical limits are based on the results of plant safety analyses, and are used to ensure that the 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, the analytical limits are established for various plant safety parameters, processes, and variables. The determined 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 where the protective actuation devices of the instruments perform a protective function (e.g., trip a breaker, de-energize a solenoid). The LTSP is the least conservative value the trip setpoint can be accounting for all uncertainties and still ensure the 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 must be equal to or more conservative than the LTSP.The NTSP is the value of the trip setpoint chosen for plant operation and generally contains added margin based on engineering judgement to add a level of conservatism to ensure the LTSP is not exceeded. For the purposes of this document, the NTSP value is rounded, where appropriate, to the nearest whole number in the conservative direction for simplification and to add margin. For example, the NTSP is rounded down for an increasing process, and rounded up for a decreasing process.

4.1.5 Actual Trip Setpoint

The actual trip setpoint is known only at the precise time of measurement or surveillance testing, since uncertainties due to instrument drift will cause the actual trip setpoint to vary over time. The actual trip setpoint is equal to the as-found or as-left value during surveillance testing and measurement.

4.2 Calculation of Trip Setpoint

The NuScale Instrument Setpoint Methodology uses a procedure based on evaluation of the as-found setpoint conditions in comparison to the NTSP for the instrument loop in question. This method is based on conditions established in NRC RIS 2006-17. These conditions are 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 as equal to the sensor reference accuracy.

- The setting (or calibration) tolerance is included in the overall TLU (see Section 3.2.4) and Equation 3-2.

- The predefined performance and test acceptance criteria band for evaluation of the as-found trip setpoint value includes either the setting or calibration tolerance (see Section 3.2.4) or the uncertainties associated with the calibration or setting tolerance band, but not both.

- The NuScale Instrument Setpoint Methodology specifies acceptance criteria for the loop as-found tolerance (AFT) based on the NTSP includes the SRSS of the reference accuracy, M&TE errors, and drift.

As shown in Figure 4-1, the evaluation of setpoints should assure that 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 NTSP is established that places margin upon the LTSP for conservatism (see Section 4.1.4). The calculation of the LTSP and NTSP are shown below:

$$\text{Limiting trip setpoint} = AL \pm |\,TLU\,| \qquad \text{Equation 4-1}$$

$$\text{Nominal trip setpoint} = AL \pm (\,|\,TLU\,| + \text{Margin}\,) \qquad \text{Equation 4-2}$$

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

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

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

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 include: 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 the safety-related instrument loops, these components are comprised of the as-left tolerance (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 as-left tolerances as shown below. Since loop calibration is typically performed as a series of overlapping tests in individual components, or modules, the as-left tolerances 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:

$$ALT_{Sensor} = \pm [(SRA)^2 + (SME)^2]^{1/2} \quad \text{Equation 4-5}$$

NMS As-Left Tolerance:

$$ALT_{NMS} = \pm [(NRA)^2 + (NME)^2]^{1/2} \quad \text{Equation 4-6}$$

Digital System As-Left Tolerance:

$$ALT_{Digital} = \pm [(DRA)^2 + (DME)^2]^{1/2} \quad \text{Equation 4-7}$$

Total As-Left Tolerance, ALT_{Total} :

$$\pm [(ALT_{Sensor})^2 + (ALT_{NMS})^2 + (ALT_{Digital})^2]^{1/2} \quad \text{Equation 4-8}$$

Alternatively, the total loop ALT can be shown as the SRSS of the reference accuracy and measurement and test equipment error for the total instrument loop, as shown below:

Total Loop Reference Accuracy:

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

Total Loop M&TE error:

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

Total Loop As-Left Tolerance:

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

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

Sensor As-Found Tolerance:

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

NMS As-Found Tolerance:

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

Digital System As-Found Tolerance:

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

Total Loop As-Found Tolerance:

$$AFT_{Total} = \pm [(AFT_{Sensor})^2 + (AFT_{NMS})^2 + (AFT_{Digital})^2]^{1/2}$$ 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:

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

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

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

4.4 Performance Test and Acceptance Criteria

Periodic surveillances of instrument loops are 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 exceed) 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 that using a double-sided band around the NTSP.

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

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

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

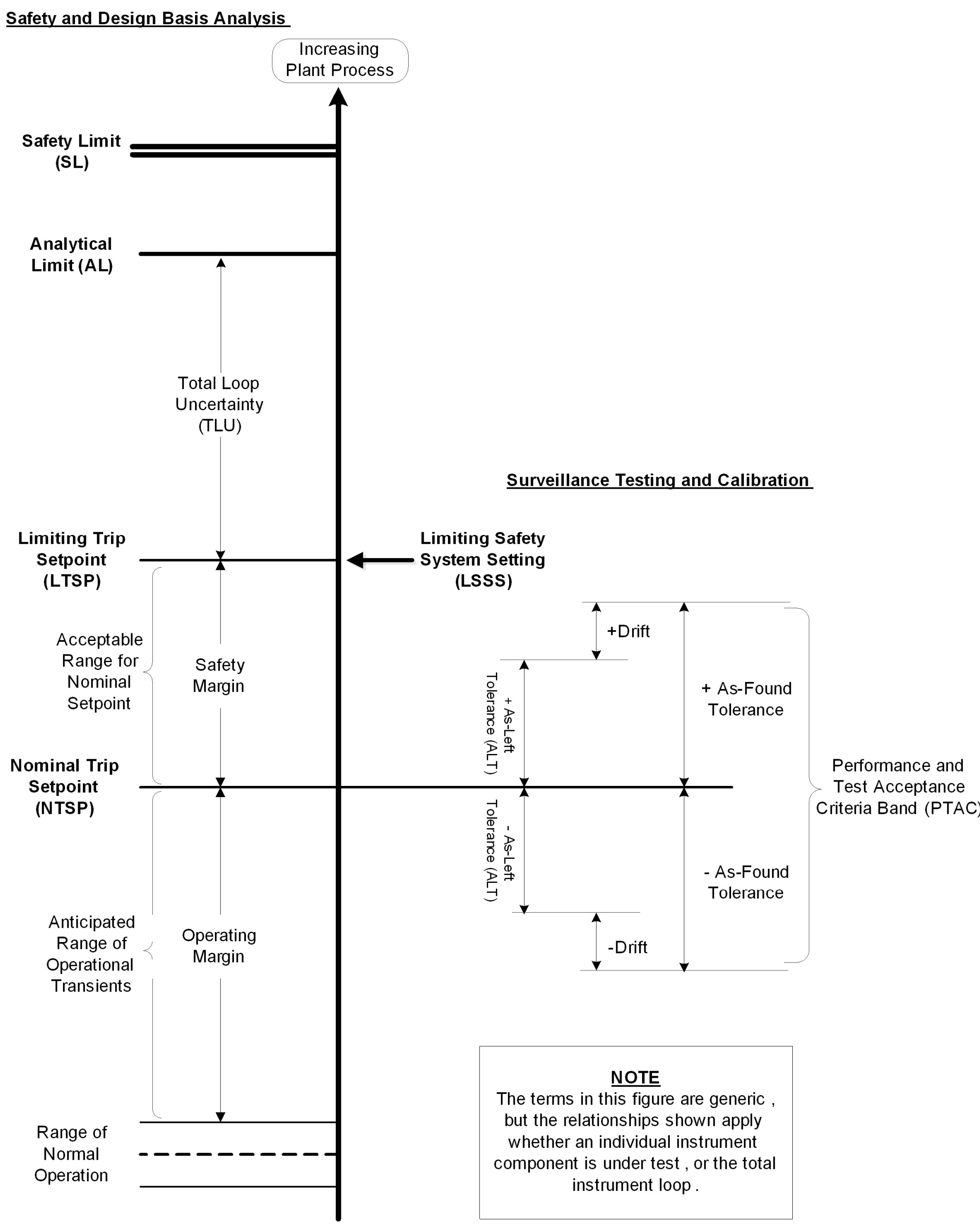

Figure 4-2 Setpoint relationships during surveillance testing and calibration

4.4.1 Operability Determination and Evaluation

The operability of the instrument channel under test is evaluated by performance of channel operability tests and/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 as required by NRC RIS 2006-17. 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 all 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, no additional actions are required.

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

If during channel operability or calibration testing, the measured trip setpoint values are within the AFT band (refer to Equation 4-17 but outside the ALT Band (refer to Equation 4-11), 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.

5.0 Assumptions

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

5.1 Any random independent term whose value is less than {{ }}2(c) of any of the other associated device random uncertainties can be statistically neglected.

5.2 Uncertainty terms of devices are calculated in terms of percent CS unless otherwise stated.

5.3 For the purposes of the setpoint analyses, the instrumentation is assumed to be calibrated at the reference ambient conditions for which the instrumentation is required to operate as specified in plant calibration procedures. The STE for the instrumentation is an allowance based on the maximum expected ambient temperature deviation from the reference calibration conditions. {{ }}2(c) (in units of ± X percent CS per Y degree Fahrenheit). {{ }}2(c)

5.4 The insulation resistance error is {{ }}2(c)

5.5 The random terms are assumed to have approximately normal probability distribution functions for the purposes of this document. Common industry practice is to assume that published vendor specifications conform to a 95/95 confidence level unless specific information is available to indicate otherwise.

5.6 For all sensors except neutron detectors, the SDR is conservatively assumed to be {{ }}2(c)

5.7 For all sensors except neutron detectors, the SME is conservatively assumed to be {{ }}2(c) The M&TE readability error is assumed to be zero as it is assumed all M&TE will have digital readouts.

5.8 An aggregate value for the SAE is assumed to be {{ }}2(c) The SAE term is applied to the protective functions associated with protection against loss of coolant accident (LOCA) or high energy line break (HELB) events. Accident pressure effects will generally not be included in an error analysis except, as discussed in Section 3.2.8.2.

The SAE uncertainty is applied to the following protective functions based on safety analysis analytical limits:

Table 5-1 Protective functions with accident environment effect uncertainties applied

Protective Function	Sensor	Mitigating Event
High narrow range containment pressure	Containment pressure	RCS or secondary leaks above allowable limits to protect RCS inventory and ECCS function during these events
Low pressurizer level	Pressurizer level	Primary HELB outside CNV
Low-low pressurizer level	Pressurizer level	LOCA and primary HELB outside CNV
Low pressurizer pressure	Pressurizer pressure	HELB outside CNV
Low-low pressurizer pressure	Pressurizer pressure	HELB outside CNV
Low main steam pressure	Main steam pressure	Secondary HELB outside CNV
Low-low main steam pressure	Main steam pressure	Secondary HELB outside CNV
Low RPV riser level	RPV riser level	LOCA
High containment water level	CNV level	LOCA
High under the bioshield temperature	Under the bioshield temperature	HELB outside CNV

5.9 The sensor seismic effect error is {{ }}2(c) (see Section 3.2.9).

5.10 The sensor PME and SRA are shown for the sensors listed in Table 5-2. The PME terms were {{

}}2(c)

Table 5-2 Instrument sensor uncertainties

Pressure Sensor Applications	PME	SRA
Narrow range pressurizer pressure	{{	}}2(c)
Narrow range containment pressure	{{	}}2(c)
Main steam pressure	{{	}}2(c)

Water Level Applications	PME	SRA
Pressurizer level	{{	}}2(c)
RPV riser water level	{{	}}2(c)
Containment water level	{{	}}2(c)

Flow Rate Sensor Applications	PME	SRA
RCS flow rate	{{ }}2(c)	{{ }}2(c)

Temperature Sensor Applications	PME	SRA
RCS T_{hot}	{{	}}2(c)
Main steam temperature	{{	}}2(c)
Under the bioshield temperature	{{	}}2(c)

5.11 Assumptions for NMS uncertainties:

5.11.1 There are no sensor errors associated with the neutron detectors used in the power range detector instrument channel functions. {{

}}2(c)

5.11.2 The intermediate range neutron detector SRA and drift is assumed to be {{ }}2(c) respectively. This value is based on preliminary data and includes all errors associated with the NMS processing function. The indicated value is in units of counts per second, which is directly proportional to percent RTP. Therefore, the accuracy values specified is applied to the indicated value for percent RTP on a logarithmic scale spanning six decades (1.00 x 10^{-4} percent RTP to 125 percent RTP).

5.11.3 The intermediate range neutron monitoring detector PME was {{

}}2(c)

5.11.4 The NMS uncertainty for NME is {{

}}2(c)

5.11.5 {{

}}2(c)

5.11.5.1 PEA and PME are assumed to have been accounted in the NMS reference and stability accuracies.

5.11.5.2 All uncertainties are assumed to be the aggregate of both sensor and system processing uncertainties. To accommodate this assumption in the setpoint methodology, all sensor uncertainties are assigned a value of {{

}}2(c)

5.11.5.3 NDE is assumed to be {{

}}2(c)

5.11.5.4 The analytical limit value will be used as input for percent of indicated value.

5.11.5.5 For the subcritical multiplication protective function, this is a ratio of source range count rates. The errors are based on the true indicated count rate, and therefore, cancel out in determination of the subcritical multiplication factor. An overall total loop uncertainty value of 10 percent is applied to add conservatism to the LTSP.

5.12 Assumptions for digital system uncertainties:

5.12.1 The digital system uncertainties for DRA are {{ }}2(c) These values are {{

}}2(c)

5.12.2 The MPS digital system uncertainties for DTE, DDR, and DMTE are {{

}}2(c) (Reference 9.14).

5.13 The values for the process parameter operating points were obtained from the NuScale ASME design specification for the reactor pressure vessel and the plant safety analyses.

5.14 The values for the analytical limits were obtained from the plant safety analyses.

5.15 Sensor static pressure effect applies to differential pressure sensors. {{

}}2(c)

5.16 The source and intermediate range log power rate analytical limit is {{ }}2(c) The log power rate trip will be implemented on both the source range and the intermediate range signals of NMS. NMS provides the reactor power doubling time (dt) to the MPS (which scales as SUR = 18.06/dt). {{ }}2(c)

The SR doubling time output accuracy is specified as {{

}}2(c)

The SR Doubling Time output is {{

}}2(c) based upon industry practice.

5.17 The Power Rate Trip will be enabled at 15 percent RTP. The Power Rate Trip is expressed in percent RTP per minute with an AL of 15 percent RTP per minute. It is assumed that process error, sensor errors, NMS errors, and digital processing errors will {{ }}2(c)

{{ }}2(c) Based upon engineering judgment, {{ }}2(c) in the determination of the NTSPt.

5.18 {{ }}2(c) A PT has a fixed ratio of primary to secondary windings. Process and sensor errors do not apply when a potential transformer is the primary element. {{ }}2(c) where analog to digital conversion occurs. {{ }}2(c)

6.0 Calculation of Reactor Protection and Engineered Safeguards Actuation System Setpoints

This section provides a demonstration of the NuScale Instrument Setpoint Methodology described in this document and contains preliminary calculations of instrument uncertainties associated with analytical limits for credited protective actuation functions defined by the plant safety analyses. The protective actuation functions consist of RTS functions listed in Table 6-1 and ESFAS functions listed in Table 6-2. 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 and 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 as part of the final, detailed system design using actual, verified instrument sensor uncertainty data.

Table 6-3 through Table 6-24 contain detailed individual TLU calculations (see Section 3.5) and Limiting Trip Setpoints (see Section 4.1.3) for the RTS functions listed in Table 6-1 and ESFAS functions listed in Table 6-2. The tables contain the parameter ranges, calibrated spans, and normal operating points for the parameters of interest and list values in both the engineering units and calibrated spans for the particular instrument loop.

Table 6-1 Reactor trip functions

Reactor Trip Function	Reactor Trip Signal
High power range linear power	Power range neutron flux
High source range count rate	Source range neutron flux
High intermediate range log power rate	Intermediate range neutron flux
High source range log power rate	Source range neutron flux
High power range rate	Power range neutron flux
High narrow range RCS T_{hot} temperature	RCS narrow range T_{hot} temperature
High narrow range containment pressure	Narrow range containment pressure
High pressurizer pressure	Pressurizer pressure
High pressurizer level	Pressurizer level
Low pressurizer pressure	Pressurizer pressure
Low-low pressurizer pressure	Pressurizer pressure
Low pressurizer level	Pressurizer level
High main steam pressure	Main steam pressure
Low main steam pressure	Main steam pressure
Low-low main steam pressure	Main steam pressure
High steam superheat (MS temperature and pressure)	Main steam pressure and temperature
Low steam superheat (MS temperature and pressure)	Main steam pressure and temperature
Low-low RCS flow	RCS flow
Low ELVS 480 VAC voltage to EDSS battery chargers	ELVS bus voltage
High under the bioshield temperature	Under the bioshield temperature

Table 6-2 Engineered Safety Features Actuation System Functions

Safety Function	Protective Action Signal
Emergency core cooling system	High containment water level
	Low RPV riser level
	Low AC voltage 24 hour timer
DHRS actuation	High pressurizer pressure
	High RCS T_{hot} temperature
	High narrow range containment pressure
	Low pressurizer pressure
	Low-low pressurizer level
	Low main steam pressure
	Low-low main steam pressure
	High main steam pressure
	High steam superheat
	Low steam superheat
	Low AC voltage
	High under the bioshield temperature
Containment system isolation	High narrow range containment pressure
	Low-low pressurizer level
	Low AC voltage
	High under the bioshield temperature
Demineralized water system isolation	Reactor trip
	High subcritical multiplication
Chemical and volume control system isolation	High pressurizer level
	Low pressurizer pressure
	High narrow range containment pressure
	Low-low pressurizer level
	Low-low RCS flow
Pressurizer heater trip	Low pressurizer level
	DHRS actuation

The general process for calculating instrument loop uncertainties and setpoints is shown in Figure 6-1. The general representation of an instrument channel is presented in Figure 3-1.

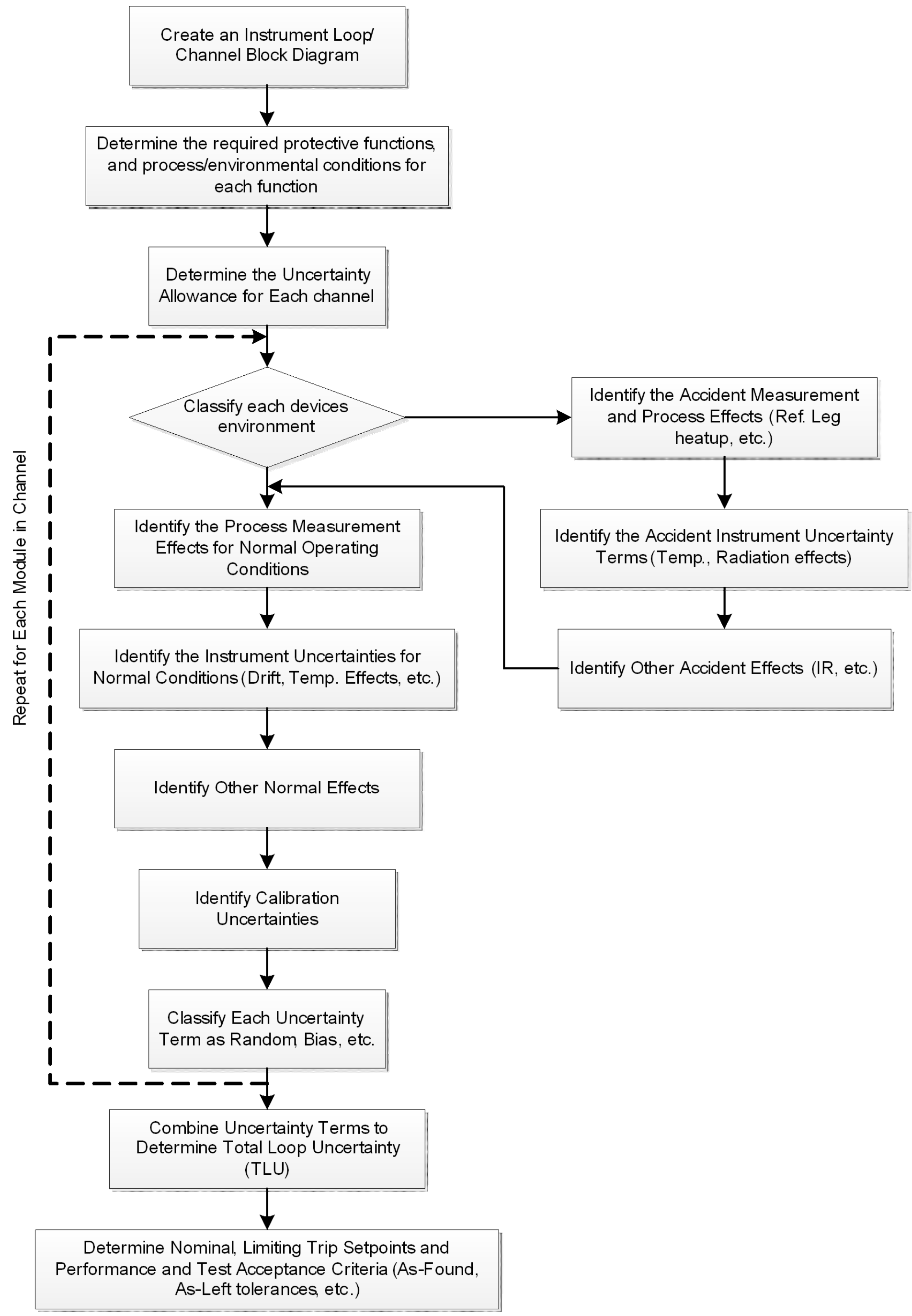

Figure 6-1 Setpoint calculation flowchart

Table 6-3 Setpoint calculation for high count rate protective function

Actuation Function	**High SR Count Rate**	
Sensor	**SR Detector**	
Engineering Units of Measurement	CPS	
Upper Limit	1.00E+06	
Lower Limit	5.00E+00	
Calibrated Span (CS)	1.00E+06	
Process and Miscellaneous Effects Error	**CPS**	**Source/ Reference**
Primary Element Accuracy (PEA)	0.00	Assumption 5.11.5.1
Process Measurement Error (PME)	0.00	Assumption 5.11.5.1
Sensor Error		
Sensor Reference Accuracy (SRA)	{{ }}2(c)	Assumption 5.11.5.2
Sensor Drift (SDR)	{{ }}2(c)	Assumption 5.11.5.2
Sensor Measurement and Test Equipment (SME)	{{ }}2(c)	Assumption 5.11.5.2
Sensor Calibration Accuracy (SCA)	{{ }}2(c)	Assumption 5.11.5.2
Sensor Temperature Effect (STE)	{{ }}2(c)	Assumption 5.11.5.2
Sensor Static Pressure Effect (SPE)	{{ }}2(c)	Assumption 5.11.5.2
Insulation Resistance Effect (IRE) [Bias]	{{ }}2(c)	Assumption 5.11.5.2
Sensor Accident Effect (SAE) [Bias]	{{ }}2(c)	Assumption 5.11.5.2
Sensor Seismic Effect (SenSE)	{{ }}2(c)	Assumption 5.11.5.2
Neutron Monitoring System Error		
Neutron Monitoring System Reference Accuracy (NRA)	{{ }}2(c)	Assumption 5.11.5
Neutron Monitoring System Drift Error (NDE)	{{ }}2(c)	Assumption 5.11.5.3
Neutron Monitoring System Temperature Error (NTE)	{{ }}2(c)	Assumption 5.11.5.2
Neutron Monitoring System M&TE Error (NMTE)	{{ }}2(c)	Assumption 5.11.4
Digital Processing Error		
Digital System Reference Accuracy (DRA)	{{ }}2(c)	Assumption 5.12.1
Digital System Drift Error (DDR)	{{ }}2(c)	Assumption 5.12.2

Digital System Temperature Error (DTE)	{{ }}2(c)	Assumption 5.12.2
Digital System Measurement and Test Equipment Error (DME)	{{ }}2(c)	Assumption 5.12.2

Total Loop Uncertainty (TLU)	{{ }}2(c)
Units	**CPS**

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

Table 6-4 Setpoint calculation for high subcritical multiplication protective function

Actuation Function	**High Subcritical Multiplication**	
Sensor	**Source Range Detectors**	
Engineering Units of Measurement	Note 1	**Source/Reference**
Upper Limit	5.00	Note 2
Lower Limit	0.00	Note 2
Calibrated Span (CS)	5.00	Note 2
Process and Miscellaneous Effects Error	{{ }}2(c)	Assumption 5.11.5.4
Neutron Monitoring System Error	{{ }}2(c)	Assumption 5.11.5.4
Digital Processing Error	{{ }}2(c)	Assumption 5.11.5.4
Margin	{{ }}2(c)	Assumption 5.11.5.4
Total Loop Uncertainty (TLU)	{{ }}2(c)	
Units	Note 1	
Analytical Limit	3.2	
Limiting Trip Setpoint (Equation 4-1)	{{ }}2(c)	
Nominal Trip Setpoint (Equation 4-2)	{{ }}2(c)	

1. The subcritical multiplication factor (M) is calculated by the MPS and is defined as the current source range count rate (CR) divided by the average baseline source range count rate (CR_o) and is a unitless term:

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

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

Table 6-5 Setpoint calculation for SR and IR high startup rate protective functions

Actuation Function	**High SR and IR Log Power Rate**	**Source/Reference**
Sensor	**Source and Intermediate Range Detectors**	Note 1
Engineering Units of Measurement	DPM	
Upper Limit	5.00	Assumption 5.16
Lower Limit	0.00	Assumption 5.16
Calibrated Span (CS)	5.00	
Process and Miscellaneous Effects Error	{{ }}[2(c)]	Assumption 5.16
Neutron Monitoring System Error	{{ }}[2(c)]	Assumption 5.16
Digital Processing Error	{{ }}[2(c)]	Assumption 5.16
Total Loop Uncertainty (TLU)	{{ }}[2(c)]	
Units	**DPM**	
Analytical Limit	3.00 DPM	
Limiting Trip Setpoint (Equation 4-1)	{{ }}[2(c)] DPM	
Nominal Trip Setpoint (Equation 4-2)	{{ }}[2(c)] DPM	

Note 1: The Source Range Log Power Rate Trip and Intermediate Range Log Power Rate Trip are separate trips which are developed by their respective NMS channels. A trip in either channel will initiate the trip logic in MPS.

Table 6-6 Setpoint calculation for high power rate protective function

Actuation Function	**High Power Range Rate**	
Sensor	**Power Range Neutron Detector**	
Engineering Units of Measurement	% RTP/min	**Source/Reference**
Upper Limit	N/A	Assumption 5.17
Lower Limit	N/A	Assumption 5.17
Calibrated Span (CS)	N/A	
Process and Miscellaneous Effects Error	{{ }}[2(c)]	Assumption 5.17
Sensor Error	{{ }}[2(c)]	Assumption 5.17
Neutron Monitoring System Error	{{ }}[2(c)]	Assumption 5.17
Digital Processing Error	{{ }}[2(c)]	Assumption 5.17
Margin	{{ }}[2(c)]	Assumption 5.17

Total Loop Uncertainty (TLU)	{{ }}[2(c)]
Units	**% RTP/min**

Analytical Limit	15.00	% RTP/min
Limiting Trip Setpoint (Equation 4-1)	{{ }}[2(c)]	% RTP/min
Nominal Trip Setpoint (Equation 4-2)	{{ }}[2(c)]	% RTP/min

Table 6-7 Setpoint calculation for high power protective functions

Actuation Function	**High Power Range Linear Power**		
Sensor	**Power Range Neutron Detector**		
Engineering Units of Measurement	% RTP		
Upper Limit	125		
Lower Limit	0		
Calibrated Span (CS)	125		
Process and Miscellaneous Effects Error	**% RTP**	**% CS**	**Source/ Reference**
Primary Element Accuracy (PEA)	0.00	0.00	
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.11.1
Sensor Error			
Sensor Reference Accuracy (SRA)	{{	}}2(c)	Assumption 5.11.1
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.11.1
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.11.1
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Assumption 5.11.1
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.11.1
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	Assumption 5.11.1
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.11.1
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.11.1
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.11.1
Neutron Monitoring System Error			
Neutron Monitoring System Reference Accuracy (NRA)	{{	}}2(c)	Assumption 5.11.4
Neutron Monitoring System Drift Error (NDE)	{{	}}2(c)	Assumption 5.11.4
Neutron Monitoring System Temperature Error (NTE)	{{	}}2(c)	Assumption 5.11.4
Neutron Monitoring System M&TE Error (NMTE)	{{	}}2(c)	Assumption 5.11.4

Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c)	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}2(c)	Assumption 5.12

Total Loop Uncertainty (TLU)	{{	}}2(c)

Units	**% RTP**	**% CS**
Analytical Limit	120.00	% RTP
Limiting Trip Setpoint (Equation 4-1)	{{ }}2(c)	% RTP
Nominal Trip Setpoint (Equation 4-2)	{{ }}2(c)	% RTP

Analytical Limit	25.0	% RTP
Limiting Trip Setpoint (Equation 4-1)	{{ }}2(c)	% RTP
Nominal Trip Setpoint (Equation 4-2)	{{ }}2(c)	% RTP

Table 6-8 Setpoint calculation for high RCS T_{hot} temperature protective function

Actuation Function	**High RCS T_{hot} Temperature**		
Sensor	**RCS Narrow Range RCS T_{hot}**		
Engineering Units of Measurement	°F		
Upper Limit	650		
Lower Limit	400		
Calibrated Span (CS)	250		
Process and Miscellaneous Effects Error	**°F**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00	
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.10
Sensor Error			
Sensor Reference Accuracy (SRA)	{{	}}2(c)	Assumption 5.10
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.6
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.7
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Equation 3-1
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.3
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	Assumption 5.15
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.4
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.8
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.9
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c)	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}2(c)	Assumption 5.12

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

Analytical Limit	610.00	°F
Limiting Trip Setpoint (Equation 4-1)	{{ }}2(c)	°F
Nominal Trip Setpoint (Equation 4-2)	{{ }}2(c)	°F

Table 6-9 Calculation of main steam temperature loop uncertainty

Actuation Function	**Main Steam Temperature**		
Sensor	**Main Steam Temperature**		
Engineering Units of Measurement	°F		
Upper Limit	700		
Lower Limit	100		
Calibrated Span (CS)	600		
Process and Miscellaneous Effects Error	°F	% CS	
Primary Element Accuracy (PEA)	0.00	0.00	
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.10
Sensor Error			
Sensor Reference Accuracy (SRA)	{{	}}2(c)	Assumption 5.10
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.6
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.7
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Equation 3-1
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.3
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.4
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.8
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.9
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c)	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DMTE)	{{	}}2(c)	Assumption 5.12

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

To calculate the uncertainty associated with the superheat protective function, a simple equation for determining the steam superheat temperature (T_{SH}) for main steam is used. 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 main steam temperature (T_{STM}). The main steam saturation temperature is found via a simple steam table lookup function using the measured steam pressure value.

$$T_{SH} = T_{STM} - T_{SAT}(P_{STM}) \quad \text{(Equation 6-1)}$$

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 superheat error (E_{TSH}) is calculated using the SRSS of the steam temperature error (E_{TSTM}) and steam pressure error (E_{PSTM}) from Table 6-14 TLU. As the steam temperature loop uncertainty contains a bias term for IRE, it is necessary to subtract it from the E_{TSTM} 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

$$E_{TSH} = [(E_{TSTM}-E_{TSTM(IRE)})^2 + (E_{PSTM})^2]^{1/2} + E_{TSTM(IRE)} \qquad \text{(Equation 6-2)}$$

Therefore, to calculate the TLU 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 6-2 below.

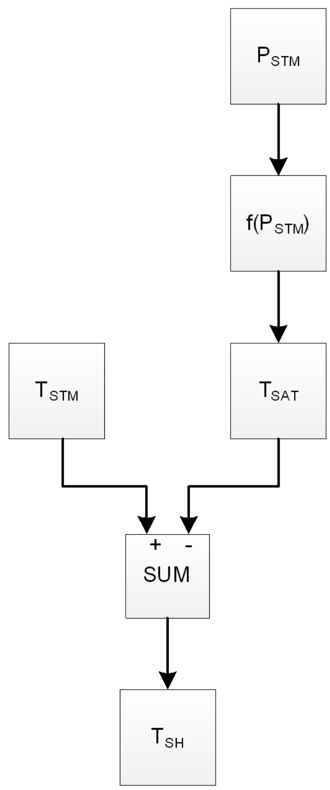

Figure 6-2 Function block diagram for steam superheat calculation

Table 6-10 Setpoint calculation for high main steam pressure protective function

Actuation Function	**High Main Steam Pressure**		
Sensor	**Main Steam Pressure**		
Engineering Units of Measurement	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	
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.10
Sensor Error			
Sensor Reference Accuracy (SRA)	{{	}}2(c)	Assumption 5.10
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.6
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.7
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Equation 3-1
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.3
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.4
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.8
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.9
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c)	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}2(c)	Assumption 5.12

Total Loop Uncertainty (TLU)	{{	}}2(c)
Units	**psia**	**% CS**

Analytical Limit	800.0	psia
Limiting Trip Setpoint (Equation 4-1)	{{ }}2(c)	psia
Nominal Trip Setpoint (Equation 4-2)	{{ }}2(c)	psia

Table 6-11 Setpoint calculation for high steam superheat protective function

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

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

Analytical Limit	150.00 °F
Limiting Trip Setpoint (Equation 4-1)	{{ }}2(c) °F
Nominal Trip Setpoint (Equation 4-2)	{{ }}2(c) °F

$$E_{TSH} = [(E_{TSTM} - E_{TSTM(IRE)})^2 + (E_{PSTM})^2]^{1/2} + E_{TSTM(IRE)}$$

$$E_{TSH} = [(3.75\% - 1.00\%)^2 + (1.87)^2]^{1/2} +1\%$$

$$E_{TSH} = 4.32\% \text{ CS}$$

Table 6-12 Setpoint calculation for low steam superheat protective function

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

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

Analytical Limit	0.00	°F
Limiting Trip Setpoint (Equation 4-1)	{{ }}2(c)	°F
Nominal Trip Setpoint (Equation 4-2)	{{ }}2(c)	°F

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

$$E_{TSH} = [\ ((3.75\% - 1.00\%)^2 + (1.87)^2\ ]^{1/2} + 1\%$$

$$E_{TSH} = 4.32\%\ CS$$

Table 6-13 Setpoint calculation for high containment pressure protective function

Actuation Function	**High Containment Pressure**
Sensor	**Narrow Range Containment Pressure**
Engineering Units of Measurement	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	
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.10
Sensor Error			
Sensor Reference Accuracy (SRA)	{{	}}2(c)	Assumption 5.10
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.6
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.7
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Equation 3-1
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.3
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	Assumption 5.15
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.4
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.8
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.9
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c)	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}2(c)	Assumption 5.12

Total Loop Uncertainty (TLU)	{{	}}2(c)
Units	**psia**	**% CS**

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

Table 6-14 Setpoint calculation for high pressurizer pressure protective function

Actuation Function	**High Pressurizer Pressure**		
Sensor	**Pressurizer Pressure**		
Engineering Units of Measurement	psia		
Upper Limit	2200		
Lower Limit	1500		
Calibrated Span (CS)	700		
Process and Miscellaneous Effects Error	**psia**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00	
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.10
Sensor Error			
Sensor Reference Accuracy (SRA)	{{	}}2(c)	Assumption 5.10
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.6
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.7
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Equation 3-1
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.3
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	Assumption 5.15
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.4
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.8
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.9
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c)	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}2(c)	Assumption 5.12

Total Loop Uncertainty (TLU)	{{	}}2(c)
Units	**psia**	**% CS**

Analytical Limit	2000.0	psia
Limiting Trip Setpoint (Equation 4-1)	{{ }}2(c)	psia
Nominal Trip Setpoint (Equation 4-2)	{{ }}2(c)	psia

Table 6-15 Setpoint calculation for low and low-low pressurizer pressure protective function

Actuation Function	**Low and Low-Low Pressurizer Pressure**		
Sensor	**Pressurizer Pressure**		
Engineering Units of Measurement	psia		
Upper Limit	2200		
Lower Limit	1500		
Calibrated Span (CS)	700		
Process and Miscellaneous Effects Error	**psia**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00	
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.10
Sensor Error			
Sensor Reference Accuracy (SRA)	{{	}}2(c)	Assumption 5.10
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.6
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.7
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Equation 3-1
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.3
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.4
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.8
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.9
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}2(c)	Assumption 5.12

Total Loop Uncertainty (TLU)	{{	}}2(c)
Units	**psia**	**% CS**

	Low Pzr Pressure	
Analytical Limit	1720.00	psia
Limiting Trip Setpoint (Equation 4-1)	{{ }}2(c)	psia
Nominal Trip Setpoint (Equation 4-2)	{{ }}2(c)	psia

	Low-Low Pzr Pressure	
Analytical Limit	1600.00	psia
Limiting Trip Setpoint (Equation 4-1)	{{ }}2(c)	psia
Nominal Trip Setpoint (Equation 4-2)	{{ }}2(c)	psia

Table 6-16 Setpoint calculation for low and low-low main steam pressure protective function

Actuation Function	**Low and Low-Low Main Steam Pressure**		
Sensor	**Main Steam Pressure**		
Engineering Units of Measurement	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	
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.10
Sensor Error			
Sensor Reference Accuracy (SRA)	{{	}}2(c)	Assumption 5.10
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.6
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.7
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Equation 3-1
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.3
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.4
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.8
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.9
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c)	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}2(c)	Assumption 5.12

Total Loop Uncertainty (TLU)	{{	}}2(c)
Units	**psia**	**% CS**

	Power > 15%	Power ≤15%
Analytical Limit	300 psia	100 psia
Limiting Trip Setpoint (Equation 4-1)	{{ }}2(c) psia	{{ }}2(c) psia
Nominal Trip Setpoint (Equation 4-2)	{{ }}2(c) psia	{{ }}2(c) psia

Table 6-17 Setpoint calculation for high containment water level protective function

Actuation Function	**High Containment Water Level**		
Sensor	**Containment Water Level**		
Engineering Units of Measurement	Inches		
Upper Limit	270		Note 1
Lower Limit	170		Note 1
Calibrated Span (CS)	100		
Process and Miscellaneous Effects Error	**Inches**	**% CS**	**Source/ Reference**
Primary Element Accuracy (PEA)	0.00	0.00	
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.10
Sensor Error			
Sensor Reference Accuracy (SRA)	{{	}}2(c)	Assumption 5.10
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.6
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.7
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Equation 3-1
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.3
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.4
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.8
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.9
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c)	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}2(c)	Assumption 5.12
Total Loop Uncertainty (TLU)	{{	}}2(c)	
Units	**Inches**	**% CS**	

	High Limit (Note 2)		Low Limit (Note 2)	
Analytical Limit	260.00	Inches	220.00	Inches
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(c)}$	Inches	{{ }}$^{2(c)}$	Inches
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(c)}$	Inches	{{ }}$^{2(c)}$	Inches

Note 1: All levels are reported in terms of module elevation with the global zero elevation at the bottom of the reactor pool.

Note 2: The limiting and nominal setpoints are specified as a range such that establishment of the LTSP and NTSP within this range will protect the analytical limit range.

Table 6-18 Setpoint calculation for high pressurizer level protective function

Actuation Function	**High Pressurizer Level**
Sensor	**Pressurizer Level**
Engineering Units of Measurement	% 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	
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.10
Sensor Error			
Sensor Reference Accuracy (SRA)	{{	}}2(c)	Assumption 5.10
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.6
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.7
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Equation 3-1
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.3
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	Assumption 5.15
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.4
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.8
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.9
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c)	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}2(c)	Assumption 5.12

Total Loop Uncertainty (TLU)	{{	}}2(c)
Units	**% Level**	**% CS**

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

Table 6-19 Setpoint calculation for low and low-low pressurizer level protective function

Actuation Function	**Low and Low-Low Pressurizer Level**		
Sensor	**Pressurizer Level**		
Engineering Units of Measurement	% 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	
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.10
Sensor Error			
Sensor Reference Accuracy (SRA)	{{	}}2(c)	Assumption 5.10
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.6
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.7
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Equation 3-1
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.3
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	Assumption 5.15
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.4
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.8
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.9
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c)	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}2(c)	Assumption 5.12
Total Loop Uncertainty (TLU)	{{	}}2(c)	
Units	**% Level**	**% CS**	

	Low Pressurizer Level	
Analytical Limit	35.00	% Level
Limiting Trip Setpoint (Equation 4-1)	{{ }}2(c)	% Level
Nominal Trip Setpoint (Equation 4-2)	{{ }}2(c)	% Level

	Low-Low Pressurizer Level	
Analytical Limit	20.00	% Level
Limiting Trip Setpoint (Equation 4-1)	{{ }}2(c)	% Level
Nominal Trip Setpoint (Equation 4-2)	{{ }}2(c)	% Level

Table 6-20 Setpoint calculation for low RCS level protective function

Actuation Function	**Low RPV Riser Level**		
Sensor	**RPV Riser Water Level**		
Engineering Units of Measurement	Inches		
Upper Limit	420		Note 1
Lower Limit	320		Note 1
Calibrated Span (CS)	100		
Process and Miscellaneous Effects Error	**Inches**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00	
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.10
Sensor Error	0	0	
Sensor Reference Accuracy (SRA)	{{	}}2(c)	Assumption 5.10
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.6
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.7
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Equation 3-1
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.3
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.4
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.8
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.9
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c)	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}2(c)	Assumption 5.12

Total Loop Uncertainty (TLU)	{{	}}2(c)
Units	**Inches**	**% CS**

	High Limit (Note 2)		Low Limit (Note 2)	
Analytical Limit	390.00	Inches	350.00	Inches
Limiting Trip Setpoint (Equation 4-1)	{{ }}2(c)	Inches	{{ }}2(c)	Inches
Nominal Trip Setpoint (Equation 4-2)	{{ }}2(c)	Inches	{{ }}2(c)	Inches

Note 1: All levels are reported in terms of module elevation with the global zero elevation at the bottom of the reactor pool.

Note 2: The limiting and nominal setpoints are specified as a range such that establishment of the LTSP and NTSP within this range will protect the analytical limit range.

Table 6-21 Setpoint calculation for low RCS flow protective function

Actuation Function	**Low RCS Flow**
Sensor	**RCS Flow**
Engineering Units of Measurement	ft^3/s
Upper Limit	26.19
Lower Limit	0.00
Calibrated Span (CS)	26.19

Process and Miscellaneous Effects Error	**ft^3/s**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00	
Process Measurement Error (PME)	{{	}}$^{2(c)}$	Assumption 5.10
Sensor Error			
Sensor Reference Accuracy (SRA)	{{	}}$^{2(c)}$	
Sensor Drift (SDR)	{{	}}$^{2(c)}$	Assumption 5.6
Sensor Measurement and Test Equipment (SME)	{{	}}$^{2(c)}$	Assumption 5.7
Sensor Calibration Accuracy (SCA)	{{	}}$^{2(c)}$	Equation 3-1
Sensor Temperature Effect (STE)	{{	}}$^{2(c)}$	Assumption 5.3
Sensor Static Pressure Effect (SPE)	{{	}}$^{2(c)}$	
Insulation Resistance Effect (IRE) [Bias]	{{	}}$^{2(c)}$	Assumption 5.4
Sensor Accident Effect (SAE) [Bias]	{{	}}$^{2(c)}$	Assumption 5.8
Sensor Seismic Effect (SenSE)	{{	}}$^{2(c)}$	Assumption 5.9
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}$^{2(c)}$	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}$^{2(c)}$	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}$^{2(c)}$	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}$^{2(c)}$	Assumption 5.12

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

Analytical Limit	1.70	ft^3/s
Limiting Trip Setpoint (Equation 4-1)	{{ }}$^{2(c)}$	ft^3/s
Nominal Trip Setpoint (Equation 4-2)	{{ }}$^{2(c)}$	ft^3/s

Table 6-22 Setpoint calculation for low-low RCS flow protective function

Actuation Function	**Low-Low RCS Flow**		
Sensor	**Narrow Range RCS Flow**		
Engineering Units of Measurement	ft^3/s		
Upper Limit	26.19		
Lower Limit	0.00		
Calibrated Span (CS)	26.19		
Process and Miscellaneous Effects Error	**ft^3/s**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	0.00	0.00	
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.10
Sensor Error			
Sensor Reference Accuracy (SRA)	{{	}}2(c)	
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.6
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.7
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Equation 3-1
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.3
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	Assumption 5.15
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.4
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.8
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.9
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c)	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}2(c)	Assumption 5.12

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

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

Table 6-23 Setpoint calculation for low AC voltage to EDSS battery chargers protective function

Actuation Function	**Low ELVS 480 VAC Voltage to EDSS Battery Chargers**		
Sensor	**ELVS Bus Voltage**		
Engineering Units of Measurement	VAC		**Source/Reference**
Upper Limit	480		Assumption 5.18
Lower Limit	0.00		Assumption 5.18
Calibrated Span (CS)	480		
Process and Miscellaneous Effects Error	**VAC**	**% CS**	
Primary Element Accuracy (PEA)	{{	}}2(c)	Assumption 5.18
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.18
Sensor Error			Assumption 5.18
Sensor Reference Accuracy (SRA)	{{	}}2(c)	Assumption 5.18
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.18
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.18
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Assumption 5.18
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.18
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	Assumption 5.18
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.18
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.18
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.18
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c)	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}2(c)	Assumption 5.12

Total Loop Uncertainty (TLU)	{{	}}2(c)
Units	**VAC**	**% CS**

Analytical Limit	Note 1	VAC
Limiting Trip Setpoint (Equation 4-1)	Note 1	VAC
Nominal Trip Setpoint (Equation 4-2)	Note 1	VAC

Table 6-23 Continued

Note 1: Normal AC voltage is monitored at the bus(s) supplying the battery chargers for the highly reliable DC power system. The Analytical Limit is based on loss of AC power to plant busses (0 volts); the actual bus voltage used is based upon the voltage ride-thru characteristics of the EDSS battery chargers.

Table 6-24 Setpoint calculation for high bioshield temperature protective function

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

Process and Miscellaneous Effects Error	**°F**	**% CS**	**Source/Reference**
Primary Element Accuracy (PEA)	{{	}}2(c)	Section 3.1.2
Process Measurement Error (PME)	{{	}}2(c)	Assumption 5.10
Sensor Error			
Sensor Reference Accuracy (SRA)	{{	}}2(c)	Assumption 5.10
Sensor Drift (SDR)	{{	}}2(c)	Assumption 5.6
Sensor Measurement and Test Equipment (SME)	{{	}}2(c)	Assumption 5.7
Sensor Calibration Accuracy (SCA)	{{	}}2(c)	Equation 3-1
Sensor Temperature Effect (STE)	{{	}}2(c)	Assumption 5.3
Sensor Static Pressure Effect (SPE)	{{	}}2(c)	
Insulation Resistance Effect (IRE) [Bias]	{{	}}2(c)	Assumption 5.4
Sensor Accident Effect (SAE) [Bias]	{{	}}2(c)	Assumption 5.8
Sensor Seismic Effect (SenSE)	{{	}}2(c)	Assumption 5.9
Digital Processing Error			
Digital System Reference Accuracy (DRA)	{{	}}2(c)	Assumption 5.12
Digital System Drift Error (DDR)	{{	}}2(c)	Assumption 5.12
Digital System Temperature Error (DTE)	{{	}}2(c)	Assumption 5.12
Digital System Measurement and Test Equipment Error (DME)	{{	}}2(c)	Assumption 5.12

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

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

7.0 RTS and ESFAS Summary of Analytical Limits, Uncertainties and Setpoints

The analytical limits, uncertainties, and setpoints for each RTS and ESFAS function are summarized Table 7-1.

Table 7-1 RTS/ESFAS actuation function setpoint, limits, and uncertainty summary

Parameter	Analytical Limit	Total Loop Uncertainty	Limiting Trip Setpoint	Nominal Trip Setpoint
High SR count rate	5.00E+05 CPS	{{		}}$^{2(c)}$
High subcritical multiplication	3.2	{{		}}$^{2(c)}$
High SR log power rate	3.00 DPM	{{		}}$^{2(c)}$
High IR log power rate	3.00 DPM	{{		}}$^{2(c)}$
High PR linear rate	±15% RTP/min	{{		}}$^{2(c)}$
High PR (>15% RTP)	120% RTP	{{		}}$^{2(c)}$
High PP(≤ 15% RTP)	25% RTP	{{		}}$^{2(c)}$
High RCS hot leg temperature	610°F	{{		}}$^{2(c)}$
High steam superheat	150°F	{{		}}$^{2(c)}$
Low steam superheat	0°F	{{		}}$^{2(c)}$
High containment pressure	9.5 psia	{{		}}$^{2(c)}$
High pressurizer pressure	2000 psia	{{		}}$^{2(c)}$
Low pressurizer pressure	1720 psia	{{		}}$^{2(c)}$
Low-low pressurizer pressure	1600 psia	{{		}}$^{2(c)}$
High main steam pressure	800 psia	{{		}}$^{2(c)}$
Low main steam pressure	300 psia	{{		}}$^{2(c)}$
Low-low main steam pressure	100 psia	{{		}}$^{2(c)}$
High containment water level (upper limit)	260 inches	{{		}}$^{2(c)}$
High containment water level (lower limit)	220 inches	{{		}}$^{2(c)}$
High pressurizer level	80% Pzr Level	{{		}}$^{2(c)}$

Parameter	Analytical Limit	Total Loop Uncertainty	Limiting Trip Setpoint	Nominal Trip Setpoint
Low pressurizer level	35% Pzr Level	{{		}}2(c)
Low-low pressurizer level	20% Pzr Level	{{		}}2(c)
Low RPV riser level (upper limit)	390 inches	{{		}}2(c)
Low RPV riser level (lower limit)	350 inches	{{		}}2(c)
Low RCS flow	1.7 ft^3/s	{{		}}2(c)
Low-low RCS flow	0.0 ft^3/s	{{		}}2(c)
Low ELVS 480 VAC voltage to EDSS battery chargers	Note 2	{{ }}2(c)	Note 2	Note 2
High under-the-bioshield temperature	250°F	{{		}}2(c)

Note 1: All levels in inches are reported in terms of module elevation with the global zero elevation at the bottom of the reactor pool.

Note 2: Normal AC voltage is monitored at the bus(s) supplying the battery chargers for the highly reliable DC power system. The Analytical Limit is based on loss of AC power to plant busses (0 volts); the actual bus voltage used is based upon the voltage ride-thru characteristics of the EDSS battery chargers.

8.0 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 9.11, which is endorsed by RG 1.105 Revision 3, and addresses the regulatory issues identified in RIS 2006-17.

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 Chapter 15 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.

9.0 References

9.1 *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).

9.2 *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).

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

9.4 U.S. Nuclear Regulatory Commission, “Setpoints for Safety-Related Instrumentation,” Regulatory Guide 1.105, Revision 3, December 1999.

9.5 U.S. Nuclear Regulatory Commission, “Setpoints for Safety-Related Instrumentation,” Draft Regulatory Guide DG-1141, Revision 4, June 2014.

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9.7 U.S. Nuclear 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.

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