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Westinghouse Setpoint Methodology for Protection Systems – AP1000

Westinghouse

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ABSTRACT

This report has been prepared to document the preliminary instrument uncertainty calculations for the Reactor Trip System (RTS) and Engineered Safeguards Features Actuation System (ESFAS) functions for the AP1000 plant. Reconciliation of the final setpoint study for each plant cannot be performed until the design for that plant is finalized. This report is provided for submission with Combined Operating License (COL) applications, and includes typical industry uncertainty values and assumptions that reflect the AP1000 Instrumentation and Control (I&C) design, to the extent that is required to support a COL application. Prior to initial fuel load, a reconciliation of this setpoint study against the final design for each plant will be performed, as required by the AP1000 Inspection, Test, and Analysis Acceptance Criteria (ITAAC) (AP1000 DCD Tier 1 Table 2.5.2-8, item 10).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Continued)

1.0 INTRODUCTION

This report has been prepared to document the instrument uncertainty calculations for the Reactor Trip System (RTS) and Engineered Safeguards Features Actuation System (ESFAS) functions identified on Table 3-35 of this report for the AP1000 plant. The Combined Operating License (COL) for the AP1000 design requires that a setpoint study be performed. Reconciliation of the final setpoint study for each plant cannot be performed until the design for that plant is finalized. This report is provided for submission with COL applications, and includes typical industry uncertainty values and assumptions that reflect the AP1000 Instrumentation and Control (I&C) design, to the extent that is required to support a COL application. Prior to initial fuel load, a reconciliation of this setpoint study against the final design for each plant will be performed, as required by the AP1000 Inspection, Test, and Analysis Acceptance Criteria (ITAAC) (AP1000 DCD Tier 1 Table 2.5.2-8, item 10).

This document is divided into four sections. Section 2.0 identifies the general algorithm used as a basis to determine the overall instrument uncertainty for an RTS/ESFAS function. This approach is defined in a Westinghouse paper presented at an Instrument Society of America/Electric Power Research Institute (ISA/EPRI) conference in June, 1992[1]. This approach is consistent with ANSI/ISA-67.04.01-2000[2]. The basic uncertainty algorithm is the Square-Root-Sum-of-the-Squares (SRSS) of the applicable uncertainty terms, which is endorsed by the ISA standard. The appropriate uncertainties, as defined by a review of the plant baseline design input documentation, have been included in each RTS/ESFAS function uncertainty calculation. ISA-RP67.04-02-2000[3] was utilized as a general guideline, but each uncertainty and its treatment is based on Westinghouse methods which are consistent or conservative with respect to this document. The latest version of NRC Regulatory Guide 1.105 (Revision 3[4]) endorses the 1994 version of ISA S67.04, Part I. Westinghouse has evaluated this NRC document and has determined that the RTS/ESFAS function uncertainty calculations contained in this report are consistent with the guidance contained in Revision 3[4]. It is believed that the total channel uncertainty (Channel Statistical Allowance or CSA) represents a 95/95 value as requested in Regulatory Guide 1.105[4].

Section 3.0 of this report provides definitions and associated acronyms used in the RTS/ESFAS function uncertainty calculations. Appropriate references to industry standards have been provided where applicable. This section includes detailed tables of the uncertainty terms and values for each RTS/ESFAS function uncertainty calculation performed by Westinghouse. Each table includes the function specific uncertainty algorithm which notes the appropriate combination of instrument uncertainties to determine the channel statistical allowance. A summary table (Table 3-35) is provided which lists the Safety Analysis Limit (SAL), Nominal Trip Setpoint (NTS), Total Allowance (TA is the difference between the SAL and NTS, in % span), CSA, margin, and the Allowable Value (AV). In all cases, it was determined that positive margin exists between the SAL and the NTS after accounting for the channel instrument uncertainties.

Section 4.0 describes how the AP1000 technical specifications NTS and AVs were determined. This section also includes a list of assumptions that were employed in performing these calculations, given that the RTS/ESFAS design has not been finalized.

1.1 References / Standards

[1] Tuley, C. R., Williams, T. P., "The Significance of Verifying the SAMA PMC 20.1-1973 Defined Reference Accuracy for the Westinghouse Setpoint Methodology," Instrumentation, Controls and Automation in the Power Industry, Vol. 35, Proceedings of the Thirty-Fifth Power Instrumentation Symposium (2nd Annual ISA/EPRI Joint Controls and Automation Conference), Kansas City, Mo., June, 1992, p. 497.

[2] ANSI/ISA-67.04.01-2000, "Setpoints for Nuclear Safety-Related Instrumentation," February, 2000.

[3] ISA-RP67.04.02-2000, "Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation," January, 2000.

[4] Regulatory Guide 1.105, Revision 3, "Setpoints for Safety-Related Instrumentation," 1999.

2.0 COMBINATION OF UNCERTAINTY COMPONENTS

This section describes the Westinghouse setpoint methodology used to combine the AP1000 uncertainty components to determine the overall CSA for the functions listed in Table 3-35 of this report. All appropriate and applicable uncertainties, as defined (to date) by a review of the AP1000 baseline design input documentation, have been considered for each RTS/ESFAS function CSA calculation.

2.1 Methodology

The methodology used to combine the uncertainty components for a channel is an appropriate combination of those groups which are statistically and functionally independent. Those uncertainties which are not independent are conservatively treated by arithmetic summation and then systematically combined with the independent terms.

The basic methodology used is the SRSS technique. This technique, or others of a similar nature, has been used in WCAP-10395[1] and WCAP-8567[2]. WCAP-8567 is approved by the NRC, noting acceptability of statistical techniques for the application requested. Also, various American National Standards Institute (ANSI), American Nuclear Society (ANS), and Instrument Society of America (ISA) standards approve the use of probabilistic and statistical techniques in determining safety-related setpoints[3,4]. The basic methodology used in this report is essentially the same as that identified in a Westinghouse paper presented at an ISA/EPRI conference in June, 1992[5]. Differences between the algorithm presented Reference 5 and the equations presented in Tables 3-1 through 3-34 are due to AP1000 specific characteristics in design and should not be construed as differences in approach.

The generalized relationship between the uncertainty components and the calculated uncertainty for a channel is noted in Eq. 2.1:

$$CSA = \{(PMA)^2 + (PEA)^2 + (SRA)^2 + (SMTE + SD)^2 + (SMTE + SCA)^2 + (SPE)^2 + (STE)^2 + (RRA)^2 + (RMTE + RD)^2 + (RMTE + RCA)^2 + (RTE)^2\}^{1/2} + EA + BIAS \qquad \text{Eq. 2.1}$$

where:

CSA	=	Channel Statistical Allowance
PMA	=	Process Measurement Accuracy
PEA	=	Primary Element Accuracy
SRA	=	Sensor Reference Accuracy
SMTE	=	Sensor Measurement & Test Equipment Accuracy
SD	=	Sensor Drift
SCA	=	Sensor Calibration Accuracy
SPE	=	Sensor Pressure Effects
STE	=	Sensor Temperature Effects
RRA	=	Rack Reference Accuracy
RMTE	=	Rack Measurement & Test Equipment Accuracy
RD	=	Rack Drift
RCA	=	Rack Calibration Accuracy
RTE	=	Rack Temperature Effects
EA	=	Environmental Allowance
BIAS	=	One directional, known magnitude allowance

Each of the above terms is defined in Section 3.2, Definitions for Protection System Setpoint Tolerances.

Eq. 2.1 is based on the following: 1) The sensor and rack measurement and test equipment uncertainties are treated as dependent parameters with their respective drift and calibration accuracy allowances. 2) While the environmental allowances are not considered statistically dependent with all other parameters, the equipment qualification testing generally results in large magnitude, non-random terms that are conservatively treated as limits of error which are added to the statistical summation. Westinghouse generally considers a term to be a limit of error if the term is a bias with an unknown sign. The term is added to the SRSS in the direction of conservatism. 3) Bias terms are one directional with known magnitudes (which may result from several sources, e.g., drift or calibration data evaluations) and are also added to the statistical summation. 4) The calibration terms are treated in the same radical with the other terms based on the assumption that general trending, i.e., drift and calibration data are evaluated on a periodic and timely basis. This evaluation should confirm that the distribution function characteristics assumed as part of treatment of the terms are still applicable. This approach results in a net reduction of the CSA magnitude (over that which would be determined if trending was not performed). Consistent with the request of Regulatory Guide 1.105[6], the CSA value from Eq. 2.1 is believed to have been determined at a 95 % probability and a 95 % confidence level (95/95).

2.2 Sensor Allowances

Seven parameters are considered to be sensor allowances: SRA, SCA, SMTE, SD, STE, SPE and EA. Three of these parameters (SRA, STE and SPE) are considered to be independent, two-sided, unverified (by plant calibration or drift determination processes), vendor supplied terms. Based on vendor supplied data, typically product data sheets and qualification reports, these parameters are treated as 95/95 values unless specified otherwise by the vendor. Three of the remaining parameters (SCA, SMTE and SD) are considered dependent with at least one other term, are two-sided, and are the result of the plant calibration and drift determination process. The SCA and SD terms are treated as 95/95 values based on the calibration and drift data evaluations. The SMTE term is treated as a 95/95 value based on vendor product data sheets. For the AP1000 calculations typical sensor allowances for Westinghouse supplied sensors are assumed.

The EA term is associated with the sensor exposure to adverse environmental conditions (elevated temperature and/or radiation) due to mass and energy loss from a break in the primary or secondary side piping, or adverse effects due to seismic events. Where appropriate, e.g., steambreak, only the elevated temperature term may be used for this uncertainty. For sensors provided by Westinghouse, the EA term magnitudes are conservatively treated as limits of error and each individual device was verified by testing to be bounded by the EA temperature component.

SRA is the manufacturer's reference accuracy that is achievable by the device. This term is introduced to address repeatability and hysteresis effects when performing only a single pass calibration, i.e., one up and one down[5]. STE and SPE are considered to be independent due to the manner in which the instrumentation is checked; i.e., the instrumentation is calibrated and drift determined under conditions in which pressure and temperature are assumed constant. For example, assume a sensor is placed in some position in the containment during a refueling outage. After placement, an instrument technician calibrates the sensor at ambient pressure and temperature conditions. Some time later with the plant shutdown, an instrument technician checks for sensor drift using the same technique as used for calibrating the sensor. The conditions under which this drift determination is made are again ambient pressure and temperature. The temperature and pressure should be essentially the same at both measurements. Thus, they should have no significant impact on the drift determination and are, therefore, independent of the drift allowance.

SCA and SD are considered to be dependent with SMTE due to the manner in which the instrumentation is evaluated. A transmitter is calibrated by providing a known process input (measured with a high accuracy gauge) and evaluating the electrical output with a digital multimeter (DMM) or digital voltmeter (DVM). The gauge and DVM accuracies form the SMTE terms. The transmitter response is known, at best, to within the accuracy of the measured input and measured output. Thus the SCA is functionally dependent with the SMTE. Since the gauge and DVM are independent of each other (they operate on two different physical principles), the two SMTE terms may be combined by SRSS prior to addition with the SCA term. Transmitter drift is determined using the same process used to perform a transmitter calibration. That is, a known process input (measured with a high accuracy gauge) is provided and the subsequent electrical output is measured with a DMM or DVM. In most cases the same measurement and test equipment is used for both calibration and drift determination. Thus the SD is functionally dependent with the SMTE and is treated in the same manner as SMTE and SCA.

While the data is gathered in the same manner, SD is independent of SCA in that they are two different parameters. SCA is the difference between the "as left" value and the desired value. SD is the difference between the "as found" value and the "as left" value. It is assumed that a mechanistic cause and effect relationship between SCA and SD has not been demonstrated and that the data evaluation determined the distribution function characteristics for both SCA and SD and confirmed that SD is random and independent of SCA.

2.3 Rack Allowances

Five parameters are considered to be rack allowances: RRA, RCA, RMTE, RTE, and RD. RRA is the manufacturer's reference accuracy that is achievable by the process rack. This term is introduced to address repeatability and hysteresis effects when performing only a single pass calibration, i.e., one up and one down[5]. For digital racks such as will be employed for AP1000, this term is considered insignificant and is considered to be included in the RCA term. RTE is considered to be an independent, two-sided, unverified (by plant calibration or drift determination processes), vendor supplied parameter. Process racks are typically located in areas with ambient temperature control, making consistency with the rack evaluation temperature easy to achieve. Based on vendor data, this parameter is treated as a 95/95 value.

RCA and RD are considered to be two-sided terms dependent with RMTE. The functional dependence is due to the manner in which the process racks are evaluated. The RCA and RD terms are treated as 95/95 values. The RMTE term is treated as a two-sided, 95/95 value based on vendor product data sheets. To calibrate or determine drift for the process rack portion of a channel, a known input (in the form of a voltage, current or resistance) is provided and the point at which the trip is confirmed. The input parameter is either measured by the use of a DMM or DVM (for a current or voltage signal) or is known to some degree of precision by use of precision equipment, e.g., a precision decade box for a resistance input. For simple channels, only a DMM or DVM is necessary to measure the input and the trip is noted by a trip indicator light or similar device. For more complicated channels, multiple DVMs may be used or a DVM in conjunction with a decade box. The process rack response is known at best to within the accuracy of the measured input. Thus the RCA is functionally dependent with the RMTE. In those instances where multiple pieces of measurement and test equipment are utilized, the uncertainties are combined via SRSS when appropriate.

The RCA term represents the total calibration uncertainty for the process rack. Drift for the process racks is determined using the same process used to perform the rack calibration and in most cases utilizes the same measurement and test equipment. Thus, the RD is also functionally dependent with the RMTE and is treated in the same manner as RMTE and RCA.

While the data is gathered in the same manner, RD is independent of RCA in that they are different parameters. RCA is the difference between the "as left" value and the desired value. RD is the difference between the "as found" and the "as left" values. The RD term represents the drift for all process racks in an instrument string, regardless of the channel complexity. For multiple channel inputs there may be multiple RD terms, e.g., Overtemperature ΔT. It is assumed that a mechanistic cause and effect relationship between RCA and RD is not demonstrated and that any data evaluation will determine the distribution function characteristics for RCA and RD and show that RD is random and independent of RCA.

2.4 Process Allowances

The PMA and PEA parameters are considered to be independent of both sensor and rack parameters. The PMA terms provide allowances for the non-instrument related effects; e.g., neutron flux, calorimetric power uncertainty assumptions, fluid density changes, and temperature streaming. There may be more than one independent PMA uncertainty allowance for a channel if warranted. The PEA term typically accounts for uncertainties due to metering devices, such as elbows, venturis, and orifice plates. In this report, examples of the use of this type of uncertainty are Reactor Coolant System (RCS) flow (hot leg elbow taps) and potential transformers for battery voltage relays. In these two specific applications, the PEA terms have been determined to be independent of the sensors and process racks. It should be noted that treatment as an independent parameter does not preclude determination that a PMA or PEA term should be treated as a bias. If that is determined appropriate, Eq. 2.1 would be modified such that the affected term would be treated by arithmetic summation with appropriate determination and application of the sign of the uncertainty.

2.5 Measurement and Test Equipment Accuracy

A sample of plant procedures is typically reviewed to determine the Measurement and Test Equipment (M&TE) used for calibration and functional testing of the transmitters and racks. When this evaluation concludes that the M&TE accuracies exceed the ANSI/ISA S51.1 - 1979[7] criterion for M&TE deletion (10 to 1 ratio of calibration accuracy magnitude to M&TE accuracy magnitude) explicit M&TE uncertainties are included. For the AP1000 calculations, allowances based on a 1 to 1 (sensors) and 4 to 1 (racks) ratio of calibration tolerance to M&TE accuracy were employed.

2.6 References / Standards

[1] Grigsby, J. M., Spier, E. M., Tuley, C. R., "Statistical Evaluation of LOCA Heat Source Uncertainty," WCAP-10395 (Proprietary), WCAP-10396 (Non-Proprietary), November, 1983.

[2] Chelemer, H., Boman, L. H., and Sharp, D. R., "Improved Thermal Design Procedure," WCAP-8567 (Proprietary), WCAP-8568 (Non-Proprietary), July, 1975.

[3] ANSI/ANS Standard 58.4-1979, "Criteria for Technical Specifications for Nuclear Power Stations."

[4] ANSI/ISA-67.04.01-2000, "Setpoints for Nuclear Safety-Related Instrumentation," February, 2000.

[5] Tuley, C. R., Williams, T. P., "The Significance of Verifying the SAMA PMC 20.1-1973 Defined Reference Accuracy for the Westinghouse Setpoint Methodology," Instrumentation, Controls and Automation in the Power Industry, Vol. 35, Proceedings of the Thirty-Fifth Power Instrumentation Symposium (2nd Annual ISA/EPRI Joint Controls and Automation Conference), Kansas City, Mo., June, 1992, p. 497.

[6] Regulatory Guide 1.105, Revision 3, "Setpoints for Safety Related Instrumentation," 1999.

[7] ANSI/ISA Standard S51.1, 1979 (Reaffirmed 1993), "Process Instrumentation Terminology," p. 32.

3.0 PROTECTION SYSTEM SETPOINT METHODOLOGY

This section defines the terms used in the AP1000 RTS/ESFAS function uncertainty calculations, and includes detailed tables and a summary table of the uncertainty values for each calculation. It was determined that in all cases sufficient margin exists between the NTS and the SAL after accounting for uncertainties.

3.1 Instrument Channel Uncertainty Calculations

Tables 3-1 through 3-34 provide individual component uncertainties and CSA calculations for the protection functions noted in Tables 3.3.1-1 and 3.3.2-1 of the AP1000 technical specifications. Table 3-35 of this report provides a summary of the RTS/ESFAS channel uncertainty allowances for AP1000. This table lists the SAL, NTS, and AV (in engineering units), the CSA, margin, and TA (in % span). As a general rule, Westinghouse reports the values in Tables 3-1 through Table 3-34 to one decimal place using the technique of rounding down values less than 0.05 % span and rounding up values greater than or equal to 0.05 % span where appropriate. However, the exceptions to this rounding convention are the Rack values and the AVs, which may be reported to additional decimal places. This is being done to provide nonzero values (for the Racks) and to distinguish the AV from the NTS. Parameters reported as "0.0" have been identified as having a value of ≤ 0.04 % span. Parameters reported as "0" in the tables are not applicable (i.e., have no value) for that channel.

3.2 Definitions for Protection System Setpoint Tolerances

For the channel uncertainty values used in this report, the following definitions are provided in alphabetical order:

- A/D Converter

  Signal conditioning module which converts an analog input from an RTD or transmitter to a digital signal for the process racks.

- As Found

  The condition in which a transmitter, process rack, or process instrument loop is found after a period of operation. For example, after one cycle of operation, a Steam Generator (SG) Level transmitter's output at 50 % span was measured to be 12.05 mA. This would be the "as found" condition.

- As Left

  The condition in which a transmitter, process rack, or process instrument loop is left after calibration or trip setpoint verification. This condition is typically better than the calibration accuracy for that piece of equipment. For example, the calibration point for a Steam Generator Level transmitter at 50 % span is 12.0 ± 0.08 mA. A measured "as left" condition of 12.03 mA would satisfy this calibration tolerance. In this instance, if the calibration was stopped at this point (i.e., no additional efforts were made to decrease the deviation) the "as left" error would be + 0.03 mA or + 0.19 % span, assuming a 16 mA (4 to 20 mA) instrument span.

- Channel

  The sensing and process equipment, i.e., transmitter and racks, for one input to the voting logic of a protection function. Westinghouse designs protection functions with voting logic made up of multiple channels, e.g. 2 out of 3 Steam Generator Level - Low-Low channels for one steam generator must be in the tripped condition for a reactor trip to be initiated.

- Channel Statistical Allowance (CSA)

  The combination of the various channel uncertainties via SRSS and algebraic techniques. It includes instrument (sensor and process rack) uncertainties and non-instrument related effects (process measurement accuracy), see Eq. 2.1. This parameter is compared with the TA for determination of instrument channel margin.

- Environmental Allowance (EA)

  The change in a process signal (transmitter or process rack output) due to adverse environmental conditions from a limiting accident condition or seismic event. Typically this value is determined from a conservative set of enveloping conditions and may represent the following:

  · Temperature effects on a transmitter
  · Radiation effects on a transmitter
  · Seismic effects on a transmitter
  · Temperature effects on a level transmitter reference leg
  · Temperature effects on signal cable insulation

- Margin

  The calculated difference (in % instrument span) between the TA and the CSA.

  Margin = TA - CSA

- Nominal Trip Setpoint (NTS)

  The trip setpoint defined in the plant technical specifications and plant procedures. This value is the nominal value programmed into the digital process racks.

- Normalization

  The process of establishing a relationship, or link, between a process parameter and an instrument channel. This is in contrast with a calibration process. A calibration process is performed with independent known values, i.e., the racks are calibrated to trip when a specific voltage is reached. This voltage corresponds to a process parameter magnitude with the relationship established through the scaling process. A normalization process typically involves an indirect measurement, e.g., determination of steam flow via the Δp drop across a flow restrictor. The flow coefficient for this device (effectively an orifice which has not been calibrated in a laboratory setting) is not known. Therefore, a mass balance between feedwater flow and steam flow must be made. The mass feedwater flow is known through measurement via the Δp across the venturi, feedwater pressure and feedwater temperature. Presuming no mass losses prior to the measurement of the steam flow, the mass steam flow can be claimed to equal the mass feedwater flow. Measurement of the steam flow Δp and the steam pressure (to correct for density) can then be utilized to translate to a volumetric flow.

- Primary Element Accuracy (PEA)

  Uncertainty due to the use of a metering device. In Westinghouse calculations, this parameter is generally limited to use on a venturi, orifice, elbow or potential transformer. Typically, this is a calculated or measured accuracy for the device.

- Process Loop (Instrument Process Loop)

  The process equipment for a single channel of a protection function.

- Process Measurement Accuracy (PMA)

  Allowance for non-instrument related effects which have a direct bearing on the accuracy of an instrument channel's reading, e.g., temperature stratification in a large diameter pipe, fluid density in a pipe or vessel.

- Process Racks

  The analog or digital modules downstream of the transmitter or sensing device, which condition a signal and act upon it prior to input to a voting logic system. For Westinghouse process systems, this includes (where applicable) all the equipment contained in the process equipment cabinets, e.g., applies to digital converters and microprocessor. The go/no go signal generated by the microprocessor trip logic is the input to the voting logic.

- Rack Calibration Accuracy (RCA)

  Rack calibration accuracy is defined as the two-sided calibration tolerance of the process racks as reflected in the plant calibration procedures.

  The Westinghouse supplied digital racks, RCA represents calibration of the signal conditioning – A/D converter providing input to the microprocessor. Typically there is only one module present in the digital process loop, thus compensation between multiple modules for errors is not applicable. However, for protection functions with multiple inputs, compensation between multiple modules for error is applicable and each signal conditioning A/D converter module is calibrated to within the specified accuracy.

- Rack Drift (RD)

  The change in input-output relationship over a period of time at reference conditions, e.g., at constant temperature. Because of the self-calibrating / self-checking feature of digital racks, this value is typically quite small.

- Rack Measurement & Test Equipment Accuracy (RMTE)

  The accuracy of the test equipment (typically a transmitter simulator, voltage or current power supply, and DVM) used to calibrate a process loop in the racks. When the magnitude of RMTE meets the requirements of ANSI/ISA S51.1, 1979 (reaffirmed 1993)[1] it is considered an integral part of RCA. Uncertainties due to M&TE that are 10 times more accurate than the device being calibrated are considered insignificant and are not included in the uncertainty calculations.

- Rack Reference Accuracy (RRA)

  Rack Reference Accuracy is the same as accuracy rating, as defined by ANSI/ISA S51.1, 1979 (reaffirmed 1993)[2] for a process rack. It is defined as the reference accuracy or accuracy rating that is achievable by the instrument as specified in the manufacturer's specification sheets. Inherent in this definition is the verification of the following under a reference set of conditions; 1) conformity[3], 2) hysteresis[4] and 3) repeatability[5].

  Because of the self-calibrating / self-checking feature of digital racks, the reference accuracy is implicitly included with the RCA term.

- Rack Temperature Effects (RTE)

  Change in input-output relationship for the process rack due to a change in the ambient environmental conditions (temperature, humidity), and voltage and frequency from the reference calibration conditions. It has been determined that temperature is the most significant, with the other parameters being second order effects.

- Range

  The upper and lower limits of the operating region for a device, e.g., for a Pressurizer Pressure transmitter, 1700 to 2500 psig, and for a Steam Generator Level transmitter, 139 to 32 inches of water column. This is not necessarily the calibrated span of the device, although quite often the two are close. For further information see ANSI/ISA S51.1, 1979 (reaffirmed 1993)[6].

- Safety Analysis Limit (SAL)

  The parameter value in the Final Safety Analysis Report (FSAR) safety analysis or other plant operating limit at which a reactor trip or actuation function is assumed to be initiated.

- Sensor Calibration Accuracy (SCA)

  The calibration accuracy for a sensor or transmitter as defined by the plant calibration procedures. For transmitters, this accuracy is typically [ ]^{a,c} and for RTD cross-calibration, this accuracy is typically [ ]^{a,c} for the hot and cold leg Narrow Range RTDs.

- Sensor Drift (SD)

  The change in input-output relationship over a period of time at reference calibration conditions, e.g., at constant temperature. For example, assume a steam generator level transmitter at 50 % level (presuming a 4 to 20 mA span) has an "as found" value of 12.05 mA and an "as left" value of 12.01 mA. The magnitude of the drift would be {(12.05 - 12.01)(100/16) = + 0.25 % span} in the positive direction.

- Sensor Measurement & Test Equipment Accuracy (SMTE)

  The accuracy of the test equipment (typically a high accuracy local readout gauge and DVM) used to calibrate a sensor or transmitter in the field or in a calibration laboratory. When the magnitude of SMTE meets the requirements of ANSI/ISA S51.1, 1979 (reaffirmed 1993)[1] it is considered an integral part of SCA. Uncertainties due to M&TE that are 10 times more accurate than the device being calibrated are considered insignificant and are not included in the uncertainty calculations.

- Sensor Pressure Effects (SPE)

  The change in input-output relationship due to a change in the static head pressure from the calibration conditions or the accuracy to which a correction factor is introduced for the difference between calibration and operating conditions for a Δp transmitter.

- Sensor Reference Accuracy (SRA)

  The reference accuracy that is achievable by the device as specified in the manufacturer's specification sheets. This term is introduced into the uncertainty calculation to address repeatability effects when performing only a single pass calibration, i.e., one up and one down, or repeatability and hysteresis when performing a single pass calibration in only one direction.

- Sensor Temperature Effects (STE)

  The change in input-output relationship due to a change in the ambient environmental conditions (temperature, humidity), and voltage and frequency from the reference calibration conditions. It has been determined that temperature is the most significant, with the other parameters being second order effects.

- Span

  The region for which a device is calibrated and verified to be operable, e.g., for a Pressurizer Pressure transmitter with a calibrated range of 1700-2500 psig would have a span of 800 psig.

- Square-Root-Sum-of-the-Squares (SRSS)

  That is,

$$\varepsilon = \sqrt{(a)^2 + (b)^2 + (c)^2}$$

  as approved for use in setpoint calculations by ANSI/ISA-67.04.01-2000[7].

- Total Allowance (TA)

  The absolute value of the difference (in % instrument span) between the SAL and the NTS.

$$\text{TA} = |\ \text{SAL} - \text{NTS}\ |$$

  Two examples of the calculation of TA are:

  - *Steam Generator Level - Low*

SAL	0 % Level
NTS	-21 % Level
TA	|-21 % Level| = 21 % Level

If the instrument span = 100 % Level, then

$$TA = \frac{(21\ \%\ level) * (100\ \%\ span)}{(100\ \%\ level)} = 21.0\ \%\ span$$

- *Pressurizer Pressure - Low Trip*

SAL	1800 psia
NTS	-1825 psia
TA	$\lvert$-25 psia$\rvert$ = 25 psia

If the instrument span = 800 psia, then

$$TA = \frac{(25\ psia) * (100\ \%\ span)}{(800\ psia)} = 3.1\ \%\ span$$

3.3 References / Standards

[1] ANSI/ISA Standard S51.1, 1979 (reaffirmed 1993), "Process Instrumentation Terminology," p 32.

[2] Ibid, p 6.

[3] Ibid, p 8.

[4] Ibid, p 20.

[5] Ibid, p 27.

[6] Ibid, p 25.

[7] ANSI/ISA-67.04.01-2000, "Setpoints for Nuclear Safety-Related Instrumentation," February, 2000.

TABLE 3-1
POWER RANGE NEUTRON FLUX - HIGH & LOW

Parameter	Allowance*
	a,c
Process Measurement Accuracy [ ]^{a,c} [ ]^{a,c}	
Primary Element Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy (AC160 – RCA_1) (NIMOD – RCA_2)	
Rack Measurement & Test Equipment Accuracy (AC160 – $RMTE_1$) (NIMOD – $RMTE_2$)	
Rack Temperature Effect (AC160 – RTE_1) (NIMOD – RTE_2)	
Rack Drift (AC160 – RD_1) (NIMOD – RD_2)	

* In percent span (120 % Rated Thermal Power)

TABLE 3-1 (continued)
POWER RANGE NEUTRON FLUX - HIGH & LOW

Channel Statistical Allowance =

[ ] a,c

TABLE 3-2
POWER RANGE NEUTRON FLUX - HIGH POSITIVE RATE

Parameter	Allowance*
	a,c
Process Measurement Accuracy	
Primary Element Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy (AC160 – RCA_1) (NIMOD – RCA_2)	
Rack Measurement & Test Equipment Accuracy (AC160 – $RMTE_1$) (NIMOD – $RMTE_2$)	
Rack Temperature Effect (AC160 – RTE_1) (NIMOD – RTE_2)	
Rack Drift (AC160 – RD_1) (NIMOD – RD_2)	

* In percent span (120 % Rated Thermal Power)

TABLE 3-2 (continued)
POWER RANGE NEUTRON FLUX - HIGH POSITIVE RATE

Channel Statistical Allowance =

a,c

TABLE 3-3
INTERMEDIATE RANGE NEUTRON FLUX - HIGH

Parameter	Allowance*
	a,c
Process Measurement Accuracy [ ]a,c	
Primary Element Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy (AC160 – RCA_1) (NIMOD – RCA_2)	
Rack Measurement & Test Equipment Accuracy (AC160 – $RMTE_1$) (NIMOD – $RMTE_2$)	
Rack Temperature Effect (AC160 – RTE_1) (NIMOD – RTE_2)	
Rack Drift (AC160 – RD_1) (NIMOD – RD_2)	

* In percent span (120% Rated Thermal Power)

TABLE 3-3 (continued)
INTERMEDIATE RANGE NEUTRON FLUX - HIGH

Channel Statistical Allowance =

a,c

TABLE 3-4
SOURCE RANGE NEUTRON FLUX - HIGH

Parameter	Allowance*
	a,c
Process Measurement Accuracy [ ]a,c	
Primary Element Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy (AC160 – RCA_1) (NIMOD – RCA_2)	
Rack Measurement & Test Equipment Accuracy (AC160 – $RMTE_1$) (NIMOD – $RMTE_2$)	
Rack Temperature Effect (AC160 – RTE_1) (NIMOD – RTE_2)	
Rack Drift (AC160 – RD_1) (NIMOD – RD_2)	

* In percent span (1 x 10^6 cps)

TABLE 3-4 (continued)
SOURCE RANGE NEUTRON FLUX - HIGH

Channel Statistical Allowance =

a,c

TABLE 3-5
SOURCE RANGE NEUTRON FLUX MULTIPLICATION BORON DILUTION BLOCK

Parameter	**Allowance*** a,c
Process Measurement Accuracy	
Primary Element Accuracy	
Sensor Calibration Accuracy – 2 phi meter setpoint setting allowance	
Sensor Measurement & Test Equipment Accuracy	
Sensor Temperature Effects – 2 phi meter temperature sensitivity allowance	
Sensor Drift – NIMOD Allowance	
Bias	
2 phi meter reproducibility allowance for count rate < 10 cps	
2 phi meter reproducibility allowance for count rate > 10 cps	
Rack Calibration Accuracy – AC160	
Rack Measurement & Test Equipment Accuracy – AC160	
Rack Temperature Effect – AC160	
Rack Drift – AC160	

* In percent setting

TABLE 3-5 (continued)
SOURCE RANGE NEUTRON FLUX MULTIPLICATION BORON DILUTION BLOCK

Channel Statistical Allowance = (for count rate <10 cps)

[ ] a,c

Channel Statistical Allowance = (for count rate >10 cps)

[ ] a,c

TABLE 3-6
OVERTEMPERATURE ΔT
Assumes normalization of ΔT_0 and T'

Parameter	**Allowance***
	a,c
Process Measurement Accuracy	[
[ ]^{a,c}	
[ ]^{a,c}	
[ ]^{a,c}	
[ ]^{a,c}	
[ ]^{a,c}	
[ ]^{a,c}	
[ ]^{a,c}	
[ ]^{a,c}	
Primary Element Accuracy	
Sensor Reference Accuracy	
[ ]^{a,c}	
[ ]^{a,c}	
Sensor Calibration Accuracy	
[ ]^{a,c}	
[ ]^{a,c}	
Sensor Measurement & Test Equipment Accuracy	
[ ]^{a,c}	
[ ]^{a,c}	
Sensor Pressure Effects	
Sensor Temperature Effects	
[ ]^{a,c}	
Sensor Drift	
[ ]^{a,c}	
[ ]^{a,c}	
Bias	]

TABLE 3-6 (continued)
OVERTEMPERATURE ΔT
Assumes normalization of ΔT_0 and T'

Parameter | **Allowance*** a,c

Rack Calibration Accuracy
[ ]a,c
[ ]a,c
[ ]a,c
[ ]a,c
[ ]a,c

Measurement & Test Equipment Accuracy
[ ]a,c
[ ]a,c
[ ]a,c
[ ]a,c
[ ]a,c

Rack Temperature Effect
[ ]a,c
[ ]a,c
[ ]a,c
[ ]a,c
[ ]a,c

Rack Drift
[ ]a,c
[ ]a,c
[ ]a,c
[ ]a,c
[ ]a,c

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* In percent ΔT span (ΔT - 105 °F = 150 % RTP; Pressure - 800 psi; ΔI - ±60 % ΔI; Tavg = 100 °F)
See Table 3-36 for gain and conversion calculation.

2 Number of Hot Leg RTDs used.

1 Number of Cold Leg RTDs used.

TABLE 3-6 (continued)
OVERTEMPERATURE ΔT
Assumes normalization of ΔT_0 and T'

Channel Statistical Allowance =

$$\left[\qquad \qquad \qquad \right]^{a,c}$$

$$PMA := PMA_{\Delta I1}^{2} + PMA_{\Delta I2}^{2} + PMA_{calorimetric}^{2}$$

$$S_{RTD} := \left(\sqrt{\frac{SRA_{rtd}^{2}}{N_{Hot}} + \frac{SRA_{rtd}^{2}}{N_{Cold}}} \right)^{2}$$

$$S1_{prz} := \left(SMTE_{ps} + SD_{ps}\right)^{2} + STE_{ps}^{2} + SRA_{ps}^{2} + SPE_{ps}^{2}$$

$$S2_{prz} := \left(SCA_{ps} + SMTE_{ps}\right)^{2}$$

$$r1_{\Delta T} := \left(RMTE_{\Delta T} + RD_{\Delta T}\right)^{2} + RTE_{\Delta T}^{2} \qquad r2_{\Delta T} := \left(RCA_{\Delta T} + RMTE_{\Delta T}\right)^{2}$$

$$r1_{Tavg} := \left(RMTE_{Tavg} + RD_{Tavg}\right)^{2} + RTE_{Tavg}^{2} \qquad r2_{Tavg} := \left(RCA_{Tavg} + RMTE_{Tavg}\right)^{2}$$

$$r1_{prz} := \left(RMTE_{ps} + RD_{ps}\right)^{2} + RTE_{ps}^{2} \qquad r2_{prz} := \left(RCA_{ps} + RMTE_{ps}\right)^{2}$$

$$r1_{\Delta I} := \left(RMTE_{\Delta I} + RD_{\Delta I}\right)^{2} + RTE_{\Delta I}^{2} \qquad r2_{\Delta I} := \left(RCA_{\Delta I} + RMTE_{\Delta I}\right)^{2}$$

$$r1_{NIS} := \left(RMTE_{NIS} + RD_{NIS}\right)^{2} + RTE_{NIS}^{2} \qquad r2_{NIS} := \left(RMTE_{NIS} + RCA_{NIS}\right)^{2}$$

TABLE 3-7
OVERPOWER ΔT
Assumes normalization of ΔT_o and T"

Parameter | **Allowance*** a,c

Process Measurement Accuracy
[ ]^{a,c}
[ ]^{a,c}
[ ]^{a,c}
[ ]^{a,c}
[ ]^{a,c}
[ ]^{a,c}

Primary Element Accuracy

Sensor Reference Accuracy
[ ]^{a,c}

Sensor Calibration Accuracy
[ ]^{a,c}

Sensor Measurement & Test Equipment Accuracy
[ ]^{a,c}

Sensor Pressure Effects

Sensor Temperature Effects

Sensor Drift
[ ]^{a,c}

Environmental Allowance
[ ]^{a,c}

Bias

Rack Calibration Accuracy
[ ]^{a,c}
[ ]^{a,c}
[ ]^{a,c}

Rack Measurement & Test Equipment Accuracy
[ ]^{a,c}
]^{a,c}

Rack Temperature Effect
[ ]^{a,c}
[ ]^{a,c}

TABLE 3-7 (continued)
OVERPOWER ΔT
Assumes normalization of ΔT_0 and T"

Parameter	**Allowance***
Rack Drift	[ ]^{a,c}
[ ]^{a,c}	
[ ]^{a,c}	

* In percent ΔT span (ΔT – 105 °F = 150 % RTP)
2 Number of Hot Leg RTDs used.
1 Number of Cold Leg RTDs used.
See Table 3-37 for gain calculations.

TABLE 3-7 (continued)
OVERPOWER ΔT
Assumes normalization of ΔT_o and T"

Channel Statistical Allowance =

[ ] a,c

$$PMA := PMA_{calorimetric}^{2}$$

$$S_{RTD} := \left(\sqrt{\frac{SRA_{rtd}^{2}}{N_{Hot}} + \frac{SRA_{rtd}^{2}}{N_{Cold}}}\right)^{2}$$

$$r1_{\Delta T} := \left(RMTE_{\Delta T} + RD_{\Delta T}\right)^{2} + RTE_{\Delta T}^{2} + alpha^{2}$$

$$r2_{\Delta T} := \left(RCA_{\Delta T} + RMTE_{\Delta T}\right)^{2}$$

$$r1_{Tavg} := \left(RMTE_{Tavg} + RD_{Tavg}\right)^{2} + RTE_{Tavg}^{2}$$

$$r2_{Tavg} := \left(RCA_{Tavg} + RMTE_{Tavg}\right)^{2}$$

TABLE 3-8
PRESSURIZER PRESSURE - LOW & HIGH

Parameter	Allowance*
	a,c
Process Measurement Accuracy	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (800 psi)

Channel Statistical Allowance =

a,c

TABLE 3-9
PRESSURIZER WATER LEVEL - HIGH 3, HIGH 2, HIGH 1

Parameter	**Allowance***
	[ ] a,c
Process Measurement Accuracy	
[ ]a,c	
[ ]a,c	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

---

* **In percent span (100 % Level)**

Channel Statistical Allowance =

[ ] a,c

TABLE 3-10
RC FLOW - LOW
(Hot Leg Elbows)

Parameter	Allowance*
	a,c
Process Measurement Accuracy [ ]^{a,c}	
Primary Element Accuracy [ ]^{a,c}	
Sensor Reference Accuracy [ ]^{a,c}	
Sensor Calibration Accuracy [ ]^{a,c}	
Sensor Measurement & Test Equipment Accuracy [ ]^{a,c}	
Sensor Pressure Effects [ ]^{a,c}	
Sensor Temperature Effects [ ]^{a,c}	
Sensor Drift [ ]^{a,c}	
Bias	
Rack Calibration Accuracy [ ]^{a,c}	
Rack Measurement & Test Equipment Accuracy [ ]^{a,c}	
Rack Temperature Effect [ ]^{a,c}	
Rack Drift [ ]^{a,c}	

* In percent flow span (120 % flow). Percent Δp span converted to flow span via Eq. 3-38.8, with F_{max} = 120 % and F_N = 90 %.

TABLE 3-10 (continued)
RC FLOW - LOW
(Hot Leg Elbows)

Channel Statistical Allowance =

[ ] a,c

TABLE 3-11
STEAM GENERATOR NARROW RANGE WATER LEVEL - LOW

Parameter	Allowance*
	^{a,c}
Process Measurement Accuracy	
[ ]^{a,c}	
[ ]^{a,c}	
[ ]^{a,c}	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Environmental Allowance	
[ ]^{a,c}	
[ ]^{a,c}	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (100 % Narrow Range Level)

TABLE 3-11 (continued)
STEAM GENERATOR NARROW RANGE WATER LEVEL - LOW

Channel Statistical Allowance =

[ ] a,c

TABLE 3-12
REACTOR COOLANT PUMP SPEED - LOW

Parameter	Allowance*
	a,c
Process Measurement Accuracy	
Primary Element Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (120 % rated speed)

Channel Statistical Allowance =

a,c

TABLE 3-13
REACTOR COOLANT PUMP BEARING WATER TEMPERATURE - HIGH

Parameter	Allowance*
Process Measurement Accuracy [ ][a,c]	[ ][a,c]
Primary Element Accuracy	
Sensor Calibration Accuracy	
Sensor Reference Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (380 °F)

Channel Statistical Allowance =

[ ][a,c]

TABLE 3-14
CONTAINMENT PRESSURE - HIGH 2

Parameter	Allowance*
Process Measurement Accuracy	[ ] a,c
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (15 psi)

Channel Statistical Allowance =

[ ] a,c

TABLE 3-15
PRESSURIZER PRESSURE - LOW SAFEGUARDS ACTUATION

Parameter	**Allowance***
Process Measurement Accuracy	[ ]a,c
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Environmental Allowance [ ]a,c [ ]a,c	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (800 psi)

Channel Statistical Allowance =

[ ]a,c

TABLE 3-16
STEAM LINE PRESSURE - LOW (ADVERSE)

Parameter	**Allowance***
	[ ]a,c
Process Measurement Accuracy	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Environmental Allowance [ ]a,c [ ]a,c	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (1200 psi)

Channel Statistical Allowance =

[ ]a,c

TABLE 3-17
STEAM LINE PRESSURE - LOW (NORMAL)

Parameter	**Allowance***
Process Measurement Accuracy	[ ]a,c
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (1200 psi)

Channel Statistical Allowance =

[ ]a,c

TABLE 3-18
NEGATIVE STEAM LINE PRESSURE RATE - HIGH

Parameter	Allowance*
Process Measurement Accuracy	[ ]a,c
Primary Element Accuracy	
Sensor Reference Accuracy [ ]a,c	
Sensor Calibration Accuracy [ ]a,c	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects [ ]a,c	
Sensor Drift [ ]a,c	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (250 psi/sec)

Channel Statistical Allowance =

[ ]a,c

TABLE 3-19
Tcold - LOW

Parameter	Allowance*
Process Measurement Accuracy [ ][a,c]	[ ][a,c]
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent Tcold span (120 °F)

Channel Statistical Allowance =

[ ][a,c]

TABLE 3-20
Thot - HIGH

Parameter	Allowance*
	^{a,c}
Process Measurement Accuracy	[
[ ]^{a,c}	
[ ]^{a,c}	
[ ]^{a,c}	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	]

* In percent span (120 °F)
2 Number of Hot Leg RTDs used.

TABLE 3-20 (continued)
Thot - HIGH

$$srdt = (SCA+SMTE)^2 + (SD+SMTE)^2 + (SRA)^2 + (SPE)^2 + (STE)^2$$

$$rack = (RCA+RMTE)^2 + (RD+RMTE)^2 + (RTE)^2$$

Channel Statistical Allowance =

a,c

TABLE 3-21
STEAM GENERATOR NARROW RANGE WATER LEVEL – HIGH 2

Parameter	Allowance*
Process Measurement Accuracy	
[ ]a,c	
[ ]a,c	
[ ]a,c	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

a,c

* In percent span (100 % Narrow Range Level)

Channel Statistical Allowance =

[ ]a,c

TABLE 3-22
STARTUP FEEDWATER FLOW - LOW

Parameter	Allowance*
Process Measurement Accuracy [ ]^{a,c}	[ ]^{a,c}
Primary Element Accuracy	
Sensor Reference Accuracy [ ]^{a,c}	
Sensor Calibration Accuracy [ ]^{a,c}	
Sensor Measurement & Test Equipment Accuracy [ ]^{a,c}	
Sensor Pressure Effects [ ]^{a,c}	
Sensor Temperature Effects [ ]^{a,c}	
Sensor Drift [ ]^{a,c}	
Bias	
Rack Calibration Accuracy [ ]^{a,c}	
Rack Measurement & Test Equipment Accuracy [ ]^{a,c}	
Rack Temperature Effect [ ]^{a,c}	
Rack Drift [ ]^{a,c}	

* In percent startup feedwater flow span (1000 GPM). Percent Δp span converted to flow span via Eq. 3-38.8, with F_{max} = 1000 gpm and F_N = 200 gpm.

TABLE 3-22 (continued)
STARTUP FEEDWATER FLOW - LOW

Channel Statistical Allowance =

[ ] a,c

TABLE 3-23
STEAM GENERATOR WIDE RANGE WATER LEVEL - LOW

Parameter	Allowance*
	[ ][a,c]
Process Measurement Accuracy	
[ ][a,c]	
[ ][a,c]	
[ ][a,c]	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Environmental Allowance	
[ ][a,c]	
[ ][a,c]	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (100 % Wide Range Level)

Channel Statistical Allowance =

[ ][a,c]

TABLE 3-24
PRESSURIZER WATER LEVEL - LOW 1 & 2

Parameter	Allowance*
Process Measurement Accuracy	[ ]a,c
[ ]a,c	
[ ]a,c	
[ ]a,c	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Environmental Allowance	
Insulation Resistance Effects	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (100 % Level)

Channel Statistical Allowance =

[ ]a,c

TABLE 3-25
CORE MAKEUP TANK LEVEL - LOW 1 & 2

Parameter	**Allowance***
	[ ][a,c]
Process Measurement Accuracy	
[ ][a,c]	
[ ][a,c]	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects (included in EA term)	
Sensor Drift	
Environmental Allowance	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (100 % span)

Channel Statistical Allowance =

[ ][a,c]

TABLE 3-26
RCS PRESSURE - LOW

Parameter	**Allowance***
	a,c
Process Measurement Accuracy	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (3300 psi)

Channel Statistical Allowance =

a,c

TABLE 3-27
RCS Tavg - LOW

Parameter	**Allowance***
	a,c
Process Measurement Accuracy	
[ ]a,c	
[ ]a,c	
[ ]a,c	
[ ]a,c	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (100 °F)
2 Number of Hot Leg RTDs used.
1 Number of Cold Leg RTDs used.

TABLE 3-27 (continued)
RCS Tavg - LOW

$$srdt = (SCA+SMTE)^2 + (SD+SMTE)^2 + (SRA)^2 + (SPE)^2 + (STE)^2$$

$$rack = (RCA+RMTE)^2 + (RD+RMTE)^2 + (RTE)^2$$

Channel Statistical Allowance =

[ ]a,c

TABLE 3-28
HOT LEG LEVEL - LOW

Parameter	Allowance*
	[ ]a,c
Process Measurement Accuracy [ ]a,c	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (31 inches)

Channel Statistical Allowance =

[ ]a,c

TABLE 3-29
IRWST LEVEL - LOW 3

Parameter	**Allowance***
	a,c
Process Measurement Accuracy [ ]a,c	[
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Environmental Allowance	
Insulation Resistance Effects	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	]

* In percent span (24 feet)

Channel Statistical Allowance =

[ ]a,c

TABLE 3-30
SPENT FUEL POOL LEVEL - LOW

Parameter	Allowance*
	[a,c]
Process Measurement Accuracy	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (28 feet)

Channel Statistical Allowance =

[a,c]

TABLE 3-31
BATTERY CHARGER INPUT VOLTAGE - LOW

Parameter	Allowance*
	a,c
Process Measurement Accuracy	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (480 V)

Channel Statistical Allowance =

a,c

TABLE 3-32
CONTROL ROOM AIR SUPPLY RADIATION – HIGH 2

Parameter	Allowance*
	a,c
Process Measurement Accuracy	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent reading

Channel Statistical Allowance =

a,c

TABLE 3-33
CONTAINMENT RADIOACTIVITY – HIGH 1

Parameter	**Allowance***
	a,c
Process Measurement Accuracy	
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent reading

Channel Statistical Allowance =

a,c

TABLE 3-34
CONTAINMENT RADIOACTIVITY – HIGH 2

Parameter	Allowance*
Process Measurement Accuracy	a,c
Primary Element Accuracy	
Sensor Reference Accuracy	
Sensor Calibration Accuracy	
Sensor Measurement & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift	
Bias	
Rack Calibration Accuracy	
Rack Measurement & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent reading

Channel Statistical Allowance =

a,c

TABLE 3-35
RTS/ESFAS UNCERTAINTY ALLOWANCES

PROTECTION CHANNEL		SAFETY ANALYSIS LIMIT	ALLOWABLE VALUE	TRIP SETPOINT	TOTAL ALLOWANCE (1)	CHANNEL STATISTICAL ALLOWANCE (1)	MARGIN (1)
POWER RANGE NEUTRON FLUX – HIGH & LOW	HIGH	118% RTP	109.06% RTP	109% RTP	7.5		a,c
	LOW	35% RTP	25.06% RTP	25% RTP	8.3		
POWER RANGE NEUTRON FLUX – HIGH POSITIVE RATE		6.0% RTP	5.06% RTP	5.0% RTP	0.8		
INTERMEDIATE RANGE NEUTRON FLUX – HIGH		—	25.23% RTP	25% RTP	—		
SOURCE RANGE NEUTRON FLUX – HIGH		—	$1.01x10^{5}$ cps	$1.0 x10^{5}$ cps	—		
SOURCE RANGE NEUTRON FLUX MULTIPLICATION BORON	SRM1	2.48(4)	1.601(3)	1.6(4)	0.9(3)		
DILUTION BLOCK	SRM2	2.008(4)	1.601(3)	1.6(4)	0.4(3)		
OVERTEMPERATURE ΔT	ΔT	1.40	0.10% ΔT span	1.255	9.7		
	Tavg		0.13% ΔT span				
	PRESS		0.04% ΔT span				
	ΔI		0.09% ΔT span				
OVERPOWER ΔT	ΔT	1.157	0.10% ΔT span	1.102	3.7		
	Tavg		0.01% ΔT span				
PRESSURIZER PRESSURE	LOW	1785.3 psig	1809.9 psig	1810.3 psig	3.1		
	HIGH	2445.3 psig	2420.7 psig	2420.3 psig	3.1		
PRESSURIZER WATER LEVEL – HIGH	HIGH 1	27.7% Span	23.05% Span	23% Span	4.7		
	HIGH 2	63.4% Span	59.05% Span	59% Span	4.4		
	HIGH 3	76% Span	71.05% Span	71% Span	5.0		
RC FLOW – LOW		87% Flow	89.96% Flow	90% Flow	2.5		
STEAM GENERATOR NARROW RANGE WATER LEVEL – LOW		0% Span	20.95% Span	21% Span	21		
REACTOR COOLANT PUMP SPEED – LOW		90% Rated Speed	90.9% Rated Speed	91% Rated Speed	0.8		
REACTOR COOLANT PUMP BEARING WATER TEMPERATURE – HIGH		—	230.4°F	230°F	—		
CONTAINMENT PRESSURE – HIGH 2		6.7 psig	6.21 psig	6.2 psig	3.3		
PRESSURIZER PRESSURE – LOW SAFEGUARDS ACTUATION		1685.3 psig	1794.9 psig	1795.3 psig	13.7		
STEAM LINE PRESSURE – LOW – ADVERSE		390.3 psig	504.7 psig	505.3 psig	9.6		
STEAM LINE PRESSURE – LOW – NORMAL		525.3 psig	559.7 psig	560.3 psig	2.9		
NEGATIVE STEAM LINE PRESSURE RATE – HIGH		—	100.1 psig	100 psig	—		
Tcold – LOW		500/510°F	504.9/505.1°F	505°F	4.2		
Thot – HIGH		—	636.1°F	636°F	—		
STEAM GENERATOR NARROW RANGE WATER LEVEL – HIGH 2		95% Span	82.05% Span	82% Span	13.0		
STARTUP FEEDWATER FLOW – LOW		—	198.8 gpm	200 gpm	—		
STEAM GENERATOR WIDE RANGE WATER LEVEL – LOW		22.3% Span	53.95% Span	54% Span	31.7		
PRESSURIZER WATER LEVEL	LOW 1	—	19.95% Span	20% Span	—		
	Early Actuation - LOW 2	27.7% Span	10.05% Span	10% Span	17.7		
	Late Actuation - LOW 2	0% Span	9.95% Span	10% Span	10.0		
CORE MAKEUP TANK LEVEL – LOW 1 & 2	LOW 1	10.0 / 67.5(2)	56.9	61.9	51.4		
	LOW 2	10.0 / 25.0(2)	56.9	61.9	51.4		
RCS PRESSURE – LOW		—	1198 psig	1200 psig	—		
RCS Tavg – LOW 1/2		—	549.9°F / 541.9°F	550°F / 542°F	—		
HOT LEG LEVEL – LOW	LOW 1	—	17.98 in	18 in	—		
	LOW 2	—	2.98 in	3 in	—		
IRWST LEVEL – LOW 3		108.5 ft	109.99 ft	110 ft	6.3		
SPENT FUEL POOL WATER LEVEL – LOW		—	37.49 ft	37.5 ft	—		
BATTERY CHARGER INPUT VOLTAGE – LOW		336 V	342.6 V	345 V	1.9		
CONTROL ROOM AIR SUPPLY RADIATION – HIGH 2		$2x10^{4}$ Ci/m³	$1.5x10^{4}$ Ci/m³	$1x10^{4}$ Ci/m³	10		
CONTAINMENT RADIOACTIVITY – HIGH 1		—	3 Rad/hr	2 Rad/hr	—		
CONTAINMENT RADIOACTIVITY – HIGH 2		—	150 Rad/hr	100 Rad/hr	—		

NOTES: 1 All values in percent span unless otherwise indicated. 2. Percent (%) tank volume. 3. Percent (%) setting. 4. Multiplication of source range flux in 50 minutes.

TABLE 3-36
OVERTEMPERATURE ΔT CALCULATIONS

■ The equation for Overtemperature ΔT:

$$\Delta T \frac{(1+\tau_4 S)}{(1+\tau_5 S)} \leq \Delta T_0 \{ K_1 - K_2 \frac{(1+\tau_1 S)}{(1+\tau_2 S)} (T - T') + K_3 (P - P') - f_1(\Delta I) \}$$

K_1 (nominal)	= 1.255 Technical Specification value
K_1 (max)	= [ ]^{a,c}
K_2	= 0.02/°F
K_3	= 0.0014/psi
Vessel ΔT	= 70 °F
ΔI gain	= 2.23 % RTP / % ΔI

■ Full power ΔT calculation:

ΔT span	= [ ]^{a,c}
ΔT span power	= 150 % RTP

■ Process Measurement Accuracy Calculations:

[ ]^{a,c}

[ ]^{a,c}

[ ]^{a,c}

[ ]^{a,c}

*Presumes normalization of ΔT_0 and T' to as found full power indicated values.

TABLE 3-36 (continued)
OVERTEMPERATURE ΔT CALCULATIONS

ΔI - Incore / Excore Mismatch

[ ] a,c

ΔI - Incore Map Delta-I

[ ] a,c

■ Pressure Channel Uncertainties

Gain = [ ] a,c

SCA =
SRA =
SMTE =
STE =
SD =
[ ] a,c

RCA =
RMTE =
RTE =
RD =
[ ] a,c

TABLE 3-36 (continued)
OVERTEMPERATURE ΔT CALCULATIONS

■ ΔI Channel Uncertainties

a,c

Gain = [ ]

a,c

RCA =
RMTE =
RTE =
RD =

■ Tavg Channel Uncertainties

a,c

Gain = [ ]

a,c

RCA =
RMTE =
RTE =
RD =

TABLE 3-36 (continued)
OVERTEMPERATURE ΔT CALCULATIONS

■ NIS Channel Uncertainties

a,c

Gain = [ ]

a,c

RCA =

RMTE =

RTE =

RD =

■ Total Allowance

a,c

TABLE 3-37
OVERPOWER ΔT CALCULATIONS

■ The equation for Overpower ΔT:

$$\Delta T \frac{(1+\tau_4 S)}{(1+\tau_5 S)} \leq \Delta T_0 \{ K_4 - K_5 (\frac{\tau_3 S}{(1+\tau_3 S)}) T - K_6 [T - T''] \}$$

K_4 (nominal)	= 1.102 Technical Specification value
K_4 (max)	= [ ]^{a,c}
K_5	= 0.0 for decreasing average temperature
K_5	= 0.02 for increasing average temperature
K_6	= 0.0021
Vessel ΔT	= 70 °F

■ Full power ΔT calculation:

ΔT span	= [ ]^{a,c}
ΔT span_power	= 150 % RTP

■ Process Measurement Accuracy Calculations:

[ ]^{a,c}

[ ]^{a,c}

[ ]^{a,c}

[ ]^{a,c}

*Presumes normalization of ΔT_0 and T" to as found full power indicated values.

TABLE 3-37 (continued)
OVERPOWER ΔT CALCULATIONS

■ Tavg Channel Uncertainties

a,c

Gain = [ ]

a,c

RCA =

RMTE =

RTE =

RD =

■ Total Allowance

a,c

TABLE 3-38
ΔP MEASUREMENTS EXPRESSED IN FLOW UNITS

The Δp accuracy expressed as percent of span of the transmitter applies throughout the measured span, i.e., ±1.5 % of 100 inches Δp = ±1.5 inches anywhere in the span. Because $F^2 = f(\Delta p)$ the same cannot be said for flow accuracies. When it is more convenient to express the accuracy of a transmitter in flow terms, the following method is used:

$$(F_N)^2 = \Delta p_N$$

where N = Nominal Flow

$$2 F_N \partial F_N = \partial \Delta p_N$$

thus

$$\partial F_N = \frac{\partial \Delta p_N}{2 F_N} \qquad \text{Eq. 3-38.1}$$

Error at a point (not in percent) is:

$$\frac{\partial F_N}{F_N} = \frac{\partial \Delta p_N}{2(F_N)^2} = \frac{\partial \Delta p_N}{2 \Delta p_N} \qquad \text{Eq. 3-38.2}$$

and

$$\frac{\Delta p_N}{\Delta p_{max}} = \frac{(F_N)^2}{(F_{max})^2} \qquad \text{Eq. 3-38.3}$$

where max = maximum flow and the transmitter Δp error is:

$\frac{\partial \Delta p_N}{\Delta p_{max}}(100) =$ percent error in Full Scale Δp (% ε FS Δp) Eq. 3-38.4

therefore:

$$\frac{\partial F_N}{F_N} = \frac{\Delta p_{max}\left[\frac{\%\, \varepsilon\, FS\, \Delta p}{100}\right]}{2 \Delta p_{max}\left[\frac{F_N}{F_{max}}\right]^2} = \left[\frac{\%\, \varepsilon\, FS\, \Delta p}{(2)(100)}\right]\left[\frac{F_{max}}{F_N}\right]^2 \qquad \text{Eq. 3-38.5}$$

TABLE 3-38 (continued)
ΔP MEASUREMENTS EXPRESSED IN FLOW UNITS

Error in flow units is:

$$\partial F_N = F_N \left[\frac{\%\,\varepsilon\, FS\, \Delta p}{(2)(100)}\right]\left[\frac{F_{\max}}{F_N}\right]^2 \qquad \text{Eq. 3-38.6}$$

Error in percent nominal flow is:

$$\frac{\partial F_N}{F_N}(100) = \left[\frac{\%\,\varepsilon\, FS\, \Delta p}{2}\right]\left[\frac{F_{\max}}{F_N}\right]^2 \qquad \text{Eq. 3-38.7}$$

Error in percent full span is:

$$\frac{\partial F_N}{F_{\max}}(100) = \left[\frac{F_N}{F_{\max}}\right]\left[\frac{\%\,\varepsilon\, FS\, \Delta p}{(2)(100)}\right]\left[\frac{F_{\max}}{F_N}\right]^2 (100)$$

$$= \left[\frac{\%\,\varepsilon\, FS\, \Delta p}{2}\right]\left[\frac{F_{\max}}{F_N}\right] \qquad \text{Eq. 3-38.8}$$

Eq. 3-38.8 is used to express errors in percent full span in this document.

4.0 APPLICATION OF THE SETPOINT METHODOLOGY

4.1 Uncertainty Calculation Basic Assumptions/Premises

The equations noted in Sections 2 and 3 are based on several basic assumptions about the statistical nature of the calibration accuracy and drift terms for AP1000:

1. The instrument technicians will make reasonable attempts to achieve the "as left" condition for the NTS (process racks) and nominal values (sensor/transmitter), at the start of each surveillance interval, and

2. The process rack and sensor/transmitter calibration accuracy and drift can be approximated by normal distributions.

In support of Item 1) it should be noted that recalibration is required any time the "as found" condition of a device or channel is found outside of the procedural "as left" tolerance. A device or channel may not be left outside the "as left" tolerance without declaring the channel "inoperable" and taking appropriate action. Thus, the "as left" tolerance may be considered an outer limit for the purposes of calibration and instrument uncertainty calculations. An instrument technician may choose to recalibrate the device if it is found near the extremes of the "as left" procedural tolerance, but this is not required. Item 2) may be verified by performing statistical evaluation of "as found" versus "as left" data over several surveillance intervals to confirm that the SCA, SD, RCA, and RD parameter values included in the plant specific uncertainty calculations are satisfied on at least a 95 % probability / 95 % confidence level basis.

4.2 Process Rack Operability Criteria and Application to the Plant Technical Specifications

An approach has been identified to define operability criteria for the digital process racks employed for AP1000. Assuming that the process racks are self-checking, the critical parameter is the ability of the process racks to be calibrated within the RCA. These values will be included in the AP1000 plant calibration procedures as the "as left" calibration accuracy, and must be consistent with the digital card/channel Analog Input Verification Test Criteria. The capability of the racks to be calibrated to within these tolerances defines channel operability. The associated criteria have been included in the plant technical specifications as the AVs, along with the NTS. The channel will be considered inoperable if it cannot be returned to within the RCA regardless of the "as found" value.

4.3 Uncertainty Calculation Assumptions

Since these uncertainty calculations are being performed before the AP1000 I&C system design is finalized, not all of the required input information is available. These unknowns include plant specific sensor types, process scaling calculations, plant specific procedures, process rack design, and others. Consequently, the following general assumptions and function specific assumptions have been established to support these calculations, and should be confirmed/validated and updated as necessary prior to fuel load for a plant specific application.

<u>AP 1000 Setpoint Methodology General Assumptions</u>

1. Process rack uncertainties are based on typical modern digital equipment similar to those being supplied by Westinghouse to other plants. The assumptions for M&TE accuracy are similar to those used for other plant setpoint calculations. The drift values are treated as non-time dependent, which has been Westinghouse experience from review of "as left" / "as found" data.

2. The transmitter uncertainties reflect the use of Westinghouse supplied Barton transmitters. These would be newly supplied and, as such, will not be affected by historical uncertainty issues such as Barton thermal nonrepeatability, long term negative drift, pressure transmitter temperature compensation, etc.

3. Typical insulation resistance (IR) degradation uncertainties of [ ] ^{a,c} (transmitter loops) or [ ] ^{a,c} (temperature loops) are assumed where actuation is required in a harsh environment.

4. M&TE uncertainties for the transmitters assume 1:1 which is readily achievable.

5. The AVs are based on expected equipment performance and are set equal to the rack calibration tolerance. Given the tight calibration tolerance for the digital racks, the AVs may be very close to the NTS. The AVs are displayed to enough decimal places to distinguish them from the NTS.

6. One of the outputs of this effort will be preliminary NTS values. These will be based on the inclusion of approximately [ ] ^{a,c} margin between the NTS and the SAL, when considering instrument uncertainty. The resultant setpoints will be established as rounded, readable values and, in general, have not been reviewed with respect to operability, margin to trip, design transient considerations, etc.

7. For SG Narrow Range (NR) and Wide Range (WR) Level and Pressurizer Level, the differential pressure (DP or Δp) measurements are compensated for process pressure variations. In addition, Pressurizer Level includes compensation for reference leg temperature variations. This approach reduces the process pressure variation and the reference leg heatup PMA uncertainties (Pressurizer Level). For SG Level the pressure compensation is based on steamline pressure and for Pressurizer Level the pressure compensation is based on RCS wide range pressure.

8. For SG Level, the PMA terms are based on engineering judgment and a survey of results for other SG designs that have been recently evaluated in detail. A single PMA allowance addresses all effects documented in the recent Nuclear Safety Advisory Letters (NSALs), with the exception of process pressure effect, which is addressed by separate terms to reflect the compensation system. The PMA terms are treated as bias terms. Detailed SG thermal hydraulic analyses and uncertainty evaluations will be required to support an actual plant license.

9. For the functions that employ RTD temperature measurements, typical sensor uncertainties for Westinghouse supplied instrumentation (RdF, Weed, etc.) are assumed, including use of a cross calibration process to [ ]^{a,c}.

10. Streaming allowances for temperature measurements are established as follows:

    - RCS measurements: For parameters that are not normalized, a hot leg steaming allowance of [ ]^{a,c} random is assumed, which bounds the typical uncertainties associated with the RTD bypass eliminated. For cold leg streaming, a value of [ ]^{a,c} bias is assumed based on the Westinghouse internal information.

    - Other measurements: A nominal streaming allowance of [ ]^{a,c} random is assumed.

11. For DP based level channels (IRWST, hot leg level, spent fuel level, etc.) a nominal [ ]^{a,c} PMA uncertainty is included to account for pressure, temperature, boron, tank tolerance, etc. variations, based on Westinghouse experience with these types of functions. For non-harsh calculations this value is treated as a random uncertainty, and for harsh environments it is treated as a bias.

<u>AP 1000 Function Specific Assumptions</u>

1. For the RCS Loss of Flow, a [ ]^{a,c} PMA uncertainty is assumed to account for the density effect related to pressurizer pressure and Tavg variations as well as hot leg streaming changes. For the PEA an allowance of [ ]^{a,c} is assumed for hot leg elbow hydraulic noise (which is assumed to be similar to the cold leg elbow tap hydraulic noise).

2. For the OTΔT and OPΔT functions, the values of ΔT and Tavg will be normalized to the loop specific indicated values and maintained within the burndown allowances identified in the calculations.

3. For IRWST Level, the allowance between the SAL and the NTS does not support the typical uncertainties for harsh environment. Therefore, a reduced transmitter EA allowance of [ ]^{a,c} was assumed to document positive margin. When a plant specific setpoint calculation is performed, evaluation of a reduced EA or other design changes will need to be considered.

4. For Pressurizer Low Level, a subcooling allowance of [ ] [a,c] has been included, based on engineering judgment.

5. For the Battery Charger Input Voltage function, typical uncertainties are assumed, such as those for ABB UV relays.

6. For Containment Radioactivity and Control Room Air Supply Radiation, uncertainties for typical instrumentation such as General Atomics / Sorrento are assumed.

7. For Core Makeup Tank (CMT) Level, it is assumed that the SALs and the setpoints are located on the cylindrical portion of the tank. In addition, it is assumed that the level measurement taps will be located such that the SAL values (presently 67.5 % volume and 25 % volume) will be no higher than 10 % of the instrument span. This is necessary to limit the magnitude of the PMA process pressure error to the value assumed, since this PMA parameter is level dependent. Alternatives that may be considered for reducing the CMT channel uncertainty include 1) use of a standard DP transmitter (instead of DP switches) to reduce the magnitude of the harsh environment/seismic error from 25 % to 10 %, and 2) use of a different scaling condition, such as elevated temperature and/or reduced pressure, to reduce the magnitude of the PMA.

8. For CMT Level, the qualification of the DP level switches will be extended from the Barton specified limit of 200 °F to the value required by the plant design and analysis (370 °F assumed in this calculation).