Enclosure
Attachment 16
PG&E Letter DCL-12-050

Westinghouse Document
"PGE-12-52 NP-Attachment, Westinghouse Input to Diablo Canyon Digital Process Protection System Replacement Uncertainty Calculations Summary LAR"
(Non-Proprietary)

Westinghouse Input to Diablo Canyon Digital Process Protection System Replacement Uncertainty Calculations Summary LAR

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Uncertainty Calculations Summary Evaluation Process

In support of the Diablo Canyon Digital Process Protection System (PPS) License Amendment Request (LAR) commitment to provide representative setpoint and uncertainty calculations to the U.S. Nuclear Regulatory Commission (NRC) staff, a two phased approach is being taken. This input represents the first phase to provide summary evaluations consistent with the current Westinghouse WCAP format for Diablo Canyon as shown in WCAP-11082, Revision 6, "Westinghouse Setpoint Methodology for Protection Systems, Diablo Canyon Units 1 and 2, 24 Month Fuel Cycle Evaluation," and WCAP-11594, Revision 2, "Westinghouse Improved Thermal Design Procedure Instrument Uncertainty Methodology, Diablo Canyon Units 1 & 2, 24 Month Fuel Cycle Evaluation." The second phase of this approach will be the completion of formal documented uncertainty calculation notes to be completed at a later date. For this first phase, Westinghouse performed an engineering judgment evaluation of the acceptability of the current nominal trip setpoint (NTS), initial condition uncertainties, and safety analysis limit (SAL) for those functions affected by the replacement PPS; based on the following process:

- Review of the current Analysis of Record (AOR) uncertainty calculation.
- Review of currently installed plant sensors (transmitters and Resistance Temperature Detector (RTDs)).
- Review of manufacturer's specifications.
- Performed drift evaluations of plant As Left and As Found surveillance data for a sample of transmitters.
- Reviewed current plant surveillance (calibration) procedures.
- Reviewed current plant scaling calculations.
- Reviewed current miscellaneous plant calculations (Insulation Resistance (IR) degradation allowance).
- Reviewed current plant post seismic assessment procedure.
- Used expected bounding replacement PPS rack accuracies (including reference accuracy, temperature effects, and drift) based on the functional design requirement that the new PPS meets or exceeds the current process rack uncertainty allowances.
- Evaluation of uncertainties utilizing WCAP-17504-P methodology (condensed summary noted below).

Westinghouse followed the above process for each of the attached summary tables, and based on engineering judgment, it is believed that the summary tables provide a reasonable representation of the expected uncertainties. It is Westinghouse's expectation that once the formal calculations are completed for phase two, each function will have a total uncertainty that is determined at a two-sided 95% probability and at a 95% confidence level (95/95).

Following the above process, data was reviewed to determine the magnitude and treatment for each uncertainty term provided in the summary tables:

- Process Measurement Accuracy (PMA); based on calculations for the Diablo Canyon plant configuration. For example; for steam generator level the [

]a,c

- Primary Element Accuracy (PEA); this term is reserved for flow metering devices such as orifice plates, elbows and venturi's used specifically for flow functions.

- Sensor Calibration Accuracy (SCA); this term is the As Left Tolerance value for the transmitters and is defined by the As Left Tolerance used in the Diablo Canyon specific surveillance procedures used to calibrate the transmitters.

- Sensor Reference Accuracy (SRA); this term is the basic reference accuracy of the transmitter and is based on transmitter vendor specific information.

- Sensor Measurement and Test Equipment (SMTE); this term is based on a conservative [ ]a,c for uncertainty determination only. Diablo Canyon plant specific procedures require SMTE that is more accurate but for this evaluation the existing allowance was maintained which is conservative for the Channel Statistical Allowance (CSA) calculation.

- Sensor Pressure Effects (SPE); this term is based on the transmitter vendor specific design information along with [ ]a,c.

- Sensor Temperature Effects (STE); this term is based on the transmitter vendor specific design information and the transmitter ambient temperature conditions.

- Sensor Drift (SD); this term is based on a 95/95 statistical evaluation of plant specific As Found minus As Left transmitter data that was evaluated for the 24 month fuel cycle program. A sample of more recent plant data was evaluated for the Reactor Coolant System (RCS) flow and Pressurizer pressure transmitters. This sample confirmed that the previous 24 month fuel cycle drift results remain applicable for these two functions. Therefore, it is reasonable to conclude that for the remaining functions the previous drift values remain valid until formal drift evaluations are completed for the phase two calculations.

- Rack Calibration Accuracy (RCA); this term is based on the replacement PPS functional requirements that the new process racks have an accuracy equal to or better than the existing process racks.

- Rack Measurement and Test Equipment (RMTE); this term is based on the Diablo Canyon specific required RMTE used in the plant surveillance procedures for the process racks.

- Rack Temperature Effects (RTE); this term is based on the replacement PPS functional requirements that the new process racks have an accuracy equal to or better than the existing process racks.

- Rack Drift (RD); this term is a conservative allowance used to bound the expected process rack drift over a 24 month surveillance period. This term is based on the replacement PPS functional requirements that the new process racks have an accuracy equal to or better than the existing process racks.

Summary Evaluation Conclusions:

Using the Westinghouse methodology described below, this uncertainty calculation summary evaluation has concluded that the current plant Reactor Trip System/Engineered Safety Features Actuation System (RTS/ESFAS) NTS and SAL values remain acceptable for the new Digital PPS replacement program. The formal uncertainty calculations, to be completed as part of phase two, will confirm these summary calculations at a 95/95 level.

Westinghouse WCAP-17504-P Uncertainty Methodology

The general uncertainty algorithm used as a basis to determine the overall instrument uncertainty for this summary evaluation is defined in Westinghouse WCAP-17504-P "Westinghouse Generic Setpoint Methodology." WCAP-17504-P provides the basic instrument uncertainty algorithms for the RTS trip functions, ESFAS protection functions, Emergency Operating Procedure (EOP) operator action points, control system functions utilized as initial condition assumptions in the safety analyses, and control board and computer indication of plant parameters utilized by the plant operators to confirm proper operation of the control and protection instrumentation for a Westinghouse Nuclear Steam Supply System (NSSS). These algorithms, when supported by appropriate plant procedures and equipment qualification, are believed to provide total instrument loop uncertainties, CSA, at a 95 % probability and 95 % confidence level; as required by NRC Regulatory Guide (RG) 1.105, Revision 3.

The Westinghouse generalized algorithm (noted below as Eq. 1) was used as the basis to determine the overall instrument uncertainty for an RTS/ESFAS function. This specific algorithm is reflected in WCAP-17504-P and is consistent with American National Standards Institute (ANSI), ANSI/ISA-67.04.01-2006. The basic uncertainty algorithm is the Square-Root-Sum-of-the-Squares (SRSS) of the applicable uncertainty terms, which is endorsed by the International Society of Automation (ISA) standard. All appropriate and applicable uncertainties, as defined by a review of the plant baseline design input documentation, have been included in each RTS/ESFAS function uncertainty calculation. ISA-RP67.04.02-2010 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) 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 believed to be consistent with the guidance contained in Revision 3 on an engineering judgment basis until phase two calculations are completed. It is believed that the total channel uncertainty, CSA, calculations to be completed as part of phase two will represent a 95/95 value as requested in Regulatory Guide 1.105. Variations of the protection function uncertainty algorithm are presented to demonstrate the Westinghouse treatment of uncertainties for control functions and parameter indication.

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 generalized relationship between the uncertainty components and the calculated uncertainty for a protection channel is noted in Eq. 1:

$$CSA_{PROT} = \left\{ \sqrt{\begin{matrix} PMA^2 + PEA^2 + SRA^2 + (SMTE + SD)^2 + (SMTE + SCA)^2 + \\ SPE^2 + STE^2 + (RMTE + RD)^2 + (RMTE + RCA)^2 + RTE^2 \end{matrix}} \right\} + EA + Bias$$

Eq. 1

The generalized relationship between the uncertainty components and the calculated uncertainty for a control channel is noted in Eq. 2 (subscript IND denotes indication):

a,c

[ ]

Eq. 2

The generalized relationship between the uncertainty components and the calculated uncertainty for an indication channel is noted in Eq. 3 (subscript IND denotes indication – control board meter or plant process computer):

a,c

[ ]

Eq. 3

Where:

CSA	=	Channel Statistical Allowance
PMA	=	Process Measurement Accuracy
PEA	=	Primary Element Accuracy
SRA	=	Sensor Reference Accuracy
SMTE	=	Sensor Measurement and Test Equipment Accuracy
SD	=	Sensor Drift
SCA	=	Sensor Calibration Accuracy
SPE	=	Sensor Pressure Effects
STE	=	Sensor Temperature Effects
RMTE	=	Rack Measurement and Test Equipment Accuracy
RD	=	Rack Drift
RCA	=	Rack Calibration Accuracy
RTE	=	Rack Temperature Effects
EA	=	Environmental Allowance
BIAS	=	One directional, known magnitude allowance
CA	=	Controller Accuracy
READOUT	=	Readout Device Accuracy
[		]a,c

The equations are based on the following:

1. Sensor and rack measurement and test equipment uncertainties are treated as dependent parameters with their respective drift and calibration accuracy allowances.

2. [ ]a,c The term is arithmetically summed with 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 arithmetically summed with the SRSS.

4. [ ]a,c

Note: for this summary effort, the Westinghouse evaluation process for calibration and drift data used for the RCS flow and Pressurizer pressure functions follows the approach described in WCAP-17504-P. The previous Westinghouse evaluation of plant drift data for the 24 month fuel cycle program also follows this approach. As a result of this sample evaluation and consistency of the drift process used for the 24 month fuel cycle program with WCAP-17504-P, WCAP-11082 and WCAP-11594, it is reasonable to conclude that the current drift allowances are acceptable for this engineering judgment evaluation. A formal drift evaluation will be performed for all sensors as part of the phase two calculations.

Consistent with the request of Regulatory Guide 1.105 Revision 3, the CSA value from Eq. 1 is believed to be determined at a 95 % probability and at a 95 % confidence level (95/95). The control function CSA value from Eq. 2 is believed to be determined at a 95 % probability and at a 95 % confidence level (95/95), consistent with the requirements of WCAP-11594 Revision 2, "Westinghouse Improved Thermal Design Procedure Instrument Uncertainty Methodology, Diablo Canyon Units 1 & 2, 24 Month Fuel Cycle Evaluation."

Definitions

The following definitions of critical uncertainty terms are provided as follows:

As Found (AFT)

The condition in which a transmitter, process rack module, or process instrument loop is found after a period of operation. For example, after one cycle of operation, a Steam Generator Level transmitter's output at 50 % span was measured to be 12.05 mA. This would be the As Found condition. For the process racks, the As Found Tolerance (AFT) is equal to the process rack As Left Tolerance (ALT), which is equal to the magnitude of the Rack Calibration Accuracy (RCA), i.e., AFT = ALT = RCA. The AFT is a two-sided parameter (+/-) about the calibration points. The AFT for transmitters is defined as the sensor drift magnitude identified in the uncertainty calculations. For transmitters, the AFT is a two-sided parameter (+/-) about the calibration points.

As Left (ALT)

The condition in which a transmitter, process rack module, 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 ± 0.04 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. For the process racks, the ALT is equal to the magnitude of the RCA, i.e., ALT = RCA. The ALT is a two-sided parameter (+/-) about the calibration points. The ALT for transmitters is defined as the two-sided (+/-) sensor calibration accuracy magnitude identified in the uncertainty calculations about the desired calibration points.

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 (PMA), see equations 1, 2 and 3. This parameter is compared with the Total Allowance (TA) for determination of instrument channel margin. The uncertainties and conservatism of the CSA algorithm result in a CSA magnitude that is believed to be determined on a two-sided 95/95 basis.

Margin

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

Margin = TA – CSA
Margin is defined to be a non-negative number, i.e., Margin ≥ 0 % span

Nominal Trip Setpoint (NTS)

The trip setpoint found in plant procedures. This value is the programmed trip value which has been set in the digital PPS. The NTS is based on engineering judgment (to arrive at a Margin ≥ 0 % span), or a historical value, that has been demonstrated over time to result in adequate operational margin. For this effort, the current plant trip setpoints have been used. Based on the requirements of 10 CFR 50.36 (c)(1)(ii)(A), Westinghouse defines the NTS as the Limiting Safety System Setting (LSSS) for the RTS/ESFAS functions.

Rack Calibration Accuracy (RCA)

Rack calibration accuracy is defined as the two-sided (+/-) calibration tolerance about the calibration points of the process racks A/D.

Safety Analysis Limit (SAL)

The parameter value found in the Updated Final Safety Analysis Report (UFSAR) safety analysis or other plant operating limit at which a reactor trip or actuation function is assumed to be initiated. For this effort the current plant safety analysis limits have been used.

Total Allowance (TA)

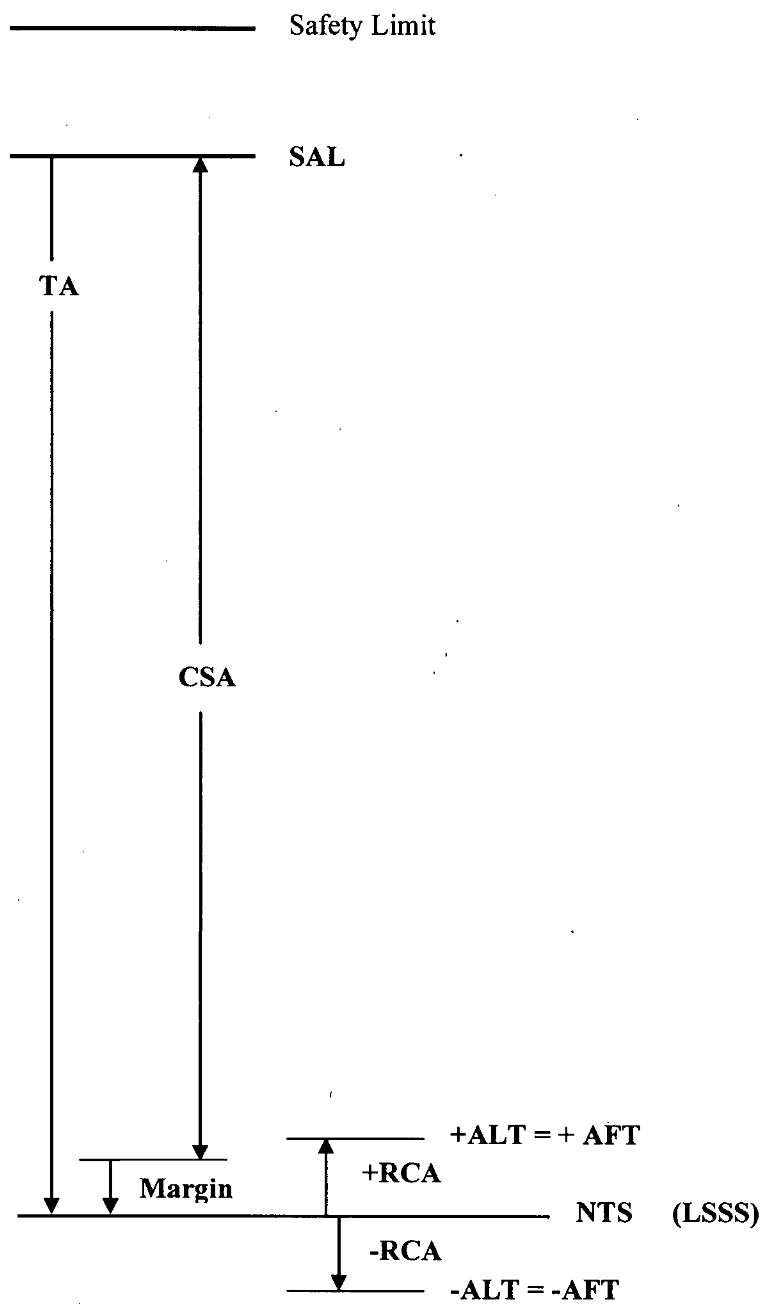
The absolute value of the difference (in % instrument span) between the SAL and the NTS.

$$TA = |SAL - NTS|$$

Instrument Channel Uncertainty Calculations Summary Tables

Provided on each summary table is the function specific uncertainty algorithm which notes the appropriate combination of instrument uncertainties to determine the CSA. Included for the protection function is a listing of the Safety Analysis Limit (SAL), the Nominal Trip Setpoint (NTS), the Total Allowance (TA) (the difference between the SAL and NTS, in % span), Margin and Operability criteria, As Left Tolerance (ALT) and As Found Tolerance (AFT), for both the sensor/transmitter and process racks. The summary Tables report the values in the uncertainty calculations to two decimal places using the technique of rounding down values less than 0.005 % span and rounding up values greater than or equal to 0.005 % span. Parameters reported as "0.0" have been identified as having a value of ≤ 0.01 % span. Parameters reported as "0" have been addressed but are included in other terms, e.g., via a normalization process, and parameters that have been addressed but are not applicable (i.e., have no value) for that channel are listed as "N/A". Parameters that are listed as "N/A" carry a value of "0" in the uncertainty equation.

The following is a diagram of the Setpoint relationships for the Westinghouse Setpoint Methodology.



Setpoint Relationships

RTS/ESFAS Functions

Loss of Flow
Rosemount 1153HD5RC, ALS Process Racks

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

* In % flow span (120.0 % RCS Flow). Percent ΔP span converted to flow span via the following equation, with F_{max} = 120.0 % and F_N = 90 %, Scaling Factor (m) = 1.3

Error in % flow span = $\left[\frac{\%\epsilon FS\Delta P}{2}\right]\left[\frac{F_{max}}{F_N}\right]$

Loss of Flow
Rosemount 1153HD5RC, ALS Process Racks

Channel Statistical Allowance =

$$\{(PMA)^2 + (PEA)^2 + (SMTE + SD)^2 + (SRA)^2 + (SPE)^2 + (STE)^2 + (SMTE + SCA)^2 + (RTE)^2 + (RMTE + RD)^2 + (RMTE + RCA)^2\}^{1/2} + EA + BIAS$$

[ ] a,c

Safety Analysis Limit	=	85 % flow
Nominal Trip Setpoint	=	90 % flow
Instrument Span	=	0 % to 120 % flow / 0 to 432.6"WC / 0.1983 – 0.9914 Vdc = 0.7931 Vdc
Total Allowance	=	[ ] a,c
CSA	=	[ ] a,c
Margin	=	[ ] a,c

[ ] a,c

Transmitter +ALT	=	
Transmitter -ALT	=	
Transmitter +AFT	=	
Transmitter -AFT	=	

[ ] a,c

Process Racks +ALT	=	
Process Racks -ALT	=	
Process Racks +AFT	=	
Process Racks -AFT	=	

Overtemperature ΔT

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

Overtemperature ΔT

Parameter	**Allowance***
Rack Calibration Accuracy	[ ]a,c
[ ]a,c	
[ ]a,c	
[ ]a,c	
[ ]a,c	
[ ]a,c	
[ ]a,c	
Rack Measuring & 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	

* In percent ΔT span (ΔT - 96.6 °F - bounding for both Units)
See attached conversions
N_H = # of hot leg RTDs = 2
N_C = # of cold leg RTDs = 1

Overtemperature ΔT

Channel Statistical Allowance =

$$\{(PMA)^2 + (PEA)^2 +$$

$$[\{\frac{(SMTE_{\Delta T} + SD_{\Delta T})^2 + (SMTE_{\Delta T} + SCA_{\Delta T})^2 + SRA_{\Delta T}{}^2}{N_H} +$$

$$\frac{(SMTE_{\Delta T} + SD_{\Delta T})^2 + (SMTE_{\Delta T} + SCA_{\Delta T})^2 + SRA_{\Delta T}{}^2}{N_C}\}^{1/2}]^2 +$$

$$[\{\frac{(RMTE_{\Delta T} + RD_{\Delta T})^2 + (RMTE_{\Delta T} + RCA_{\Delta T})^2 + (RTE_{\Delta T})^2 + \alpha^2}{N_H} +$$

$$\frac{(RMTE_{\Delta T} + RD_{\Delta T})^2 + (RMTE_{\Delta T} + RCA_{\Delta T})^2 + (RTE_{\Delta T})^2}{N_C}\}^{1/2}]^2 +$$

$$(RMTE_{Tavg} + RD_{Tavg})^2 + (RTE_{Tavg})^2 + (RMTE_{Tavg} + RCA_{Tavg})^2 +$$

$$(SMTE_P + SD_P)^2 + (SRA_P)^2 + (SPE_P)^2 + (STE_P)^2 + (SMTE_P + SCA_P)^2 +$$

$$(RMTE_P + RD_P)^2 + (RTE_P)^2 + (RMTE_P + RCA_P)^2 +$$

$$2(RMTE_{\Delta I} + RD_{\Delta I})^2 + 2(RTE_{\Delta I})^2 + 2(RMTE_{\Delta I} + RCA_{\Delta I})^2 +$$

$$2(RMTE_{NIS} + RD_{NIS})^2 + 2(RTE_{NIS})^2 + 2(RMTE_{NIS} + RCA_{NIS})^2\}^{1/2} + EA + BIAS$$

Channel Statistical Allowance =

a,c

Overtemperature ΔT

Safety Analysis Limit	=	132 % RTP
Nominal Trip Setpoint	=	120 % RTP
Instrument Span	=	ΔT span = 96.6 °F / 4-20 mAdc / 0.1983 – 0.9914 Vdc = 0.7931 Vdc; ΔI span = ±60 % ΔI / 0-10 Vdc; NIS span = ±60 % ΔI / 0-10 Vdc; Pressure span = 1250 psi / 4-20 mAdc / 0.1983 – 0.9914 Vdc = 0.7931 Vdc
Total Allowance	=	[ ] a,c
Channel Statistical Allowance	=	[ ] a,c
Margin	=	[ ] a,c

Overtemperature ΔT

Pressurizer Pressure Input

a,c

Transmitter +ALT =

Transmitter -ALT =

Transmitter +AFT =

Transmitter -AFT =

a,c

Process Racks +ALT =

Process Racks -ALT =

Process Racks +AFT =

Process Racks -AFT =

RTD Input

a,c

RTD +ALT =

RTD -ALT =

RTD +AFT =

RTD -AFT =

a,c

Process Racks +ALT =

Process Racks -ALT =

Process Racks +AFT =

Process Racks -AFT =

NIS Rack

a,c

NIS +ALT =

NIS -ALT =

NIS +AFT =

NIS -AFT =

Overtemperature ΔT

NIS PPS

[ ] a,c

NIS +ALT =

NIS -ALT =

NIS +AFT =

NIS -AFT =

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)	=	1.20 Technical Specification value
K_1 (max)	=	[ ] a,c
K_2	=	0.0182/°F
K_3	=	0.000831/psi
Vessel T_H	=	608.8 °F
Vessel T_C	=	544.4 °F
ΔI gain	=	2.38 % RTP/% ΔI

- Full power ΔT calculation:

ΔT span = [ ] a,c

ΔT span_pwr = 150 % RTP

- Process Measurement Accuracy Calculations:

[ ] a,c

[ ] a,c

[ ] a,c

ΔI - Incore/Excore Mismatch

[ ] a,c

ΔI - Incore Map Delta-I

[ ] a,c

Overtemperature ΔT Calculations

- Pressure Channel Uncertainties

Gain = [ ] a,c

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

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

- NIS Channel Uncertainties

Gain = [ ] a,c

NIS Rack

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

NIS PPS

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

Overpower ΔT

Parameter **Allowance***

[ ][a,c]

Process Measurement Accuracy

[ ][a,c]

[ ][a,c]

[ ][a,c]

[ ][a,c]

[ ][a,c]

[ ][a,c]

Primary Element Accuracy

Sensor Calibration Accuracy

[ ][a,c]

Sensor Reference Accuracy

[ ][a,c]

Sensor Measuring & Test Equipment Accuracy

[ ][a,c]

Sensor Pressure Effects

Sensor Temperature Effects

Sensor Drift

[ ][a,c]

Bias

Environmental Allowance

[ ][a,c]

[ ][a,c]

Rack Calibration Accuracy

[ ][a,c]

Rack Measuring & Test Equipment Accuracy

[ ][a,c]

Overpower ΔT

Parameter	**Allowance***
Rack Temperature Effect	[ ]a,c
[ ]a,c	
Rack Drift	
[ ]a,c	

* In percent ΔT span (ΔT - 96.6 °F - bounding for both Units);
See attached conversions
N_H = # of hot leg RTDs = 2
N_C = # of cold leg RTDS = 1

Channel Statistical Allowance =

$$\{(PMA)^2 + (PEA)^2 +$$

$$[\{\frac{(SMTE_{\Delta T} + SD_{\Delta T})^2 + (SMTE_{\Delta T} + SCA_{\Delta T})^2 + SRA_{\Delta T}{}^2}{N_H} +$$

$$\frac{(SMTE_{\Delta T} + SD_{\Delta T})^2 + (SMTE_{\Delta T} + SCA_{\Delta T})^2 + SRA_{\Delta T}{}^2}{N_C}\}^{1/2}]^2 +$$

$$[\{\frac{(RMTE_{\Delta T} + RD_{\Delta T})^2 + (RTE_{\Delta T})^2 + (RMTE_{\Delta T} + RCA_{\Delta T})^2}{N_H} +$$

$$\frac{(RMTE_{\Delta T} + RD_{\Delta T})^2 + (RTE_{\Delta T})^2 + (RMTE_{\Delta T} + RCA_{\Delta T})^2}{N_C}\}^{1/2}]^2\}^{1/2} +$$

EA + BIAS

[ ]a,c

Overpower ΔT

Safety Analysis Limit	=	114.53 % RTP
Nominal Trip Setpoint	=	107.2 % RTP
Instrument Span	=	ΔT span = 96.6 °F / 4-20 mAdc; / 0.1983 – 0.9914 Vdc = 0.7931 Vdc
Total Allowance	=	[ ] [a,c]
Channel Statistical Allowance	=	[ ] [a,c]
Margin	=	[ ] [a,c]

See Overtemperature ΔT Table for ALT / AFT values

Overpower ΔT Calculations

- The equation for Overpower ΔT:

$$\Delta T \frac{(1+\tau_4 S)}{(1+\tau_5 S)} \leq \Delta T_0 \{K_4 - K_5 \left(\frac{\tau_3 S}{1+\tau_3 S}\right) T - K_6 [T - T''] - f_2 (\Delta I)\}$$

K_4 (nominal)	=	1.072 Technical Specification value
K_4 (max)	=	[ ]^{a,c}
K_5	=	0.0 for decreasing average temperature
K_5	=	0.0174 for increasing average temperature (sec/°F)
K_6	=	0.00145/°F
Vessel T_H	=	608.8 °F
Vessel T_C	=	544.4 °F

- Full power ΔT calculation:

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

- Process Measurement Accuracy Calculations:

[ ]^{a,c}

[ ]^{a,c}

[ ]^{a,c}

RCS Loop ΔT Equivalent to Power

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

* In percent ΔT span (ΔT - 96.6 °F - bounding for both Units)
N_H = # of hot leg RTDs = 2
N_C = # of cold leg RTDs = 1

RCS Loop ΔT Equivalent to Power

Channel Statistical Allowance =

$$
\begin{aligned}
&\{(PMA)^2 + (PEA)^2 + \\
&[\{\frac{(SMTE_{\Delta T} + SD_{\Delta T})^2 + (SMTE_{\Delta T} + SCA_{\Delta T})^2 + SRA_{\Delta T}{}^2}{N_H} \\
&\frac{(SMTE_{\Delta T} + SD_{\Delta T})^2 + (SMTE_{\Delta T} + SCA_{\Delta T})^2 + SRA_{\Delta T}{}^2}{N_C}\}^{1/2}]^2 + \\
&[\{\frac{(RMTE_{\Delta T} + RD_{\Delta T})^2 + (RTE_{\Delta T})^2 + (RMTE_{\Delta T} + RCA_{\Delta T})^2}{N_H} + \\
&\frac{(RMTE_{\Delta T} + RD_{\Delta T})^2 + (RTE_{\Delta T})^2 + (RMTE_{\Delta T} + RCA_{\Delta T})^2}{N_C}\}^{1/2}]^2\}^{1/2} + \\
&EA + BIAS
\end{aligned}
$$

[ ] a,c

Safety Analysis Limit	=	59 % RTP
Nominal Trip Setpoint	=	50 % RTP
Instrument Span	=	ΔT span = 96.6 °F / 4-20 mAdc; / 0.1983 – 0.9914 Vdc = 0.7931 Vdc
Total Allowance	=	[ ] a,c
Channel Statistical Allowance	=	[ ] a,c
Margin	=	[ ] a,c

See Overtemperature ΔT Table for ALT / AFT values

Pressurizer Pressure – Low and High Reactor Trip
Rosemount 1154SH9RC, ALS Process Racks

Parameter	Allowance*
Process Measurement Accuracy	[ ]^{a,c}
Primary Element Accuracy	
Sensor Calibration Accuracy	
Sensor Reference Accuracy	
Sensor Measuring & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift (30 months)	
Bias	
Environmental Allowance	
Rack Calibration Accuracy	
Rack Measuring & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (1250 psi)

Channel Statistical Allowance =

$$\{(PMA)^2 + (PEA)^2 + (SMTE + SD)^2 + (SRA)^2 + (SPE)^2 + (STE)^2 + (SMTE + SCA)^2 + (RMTE + RD)^2 + (RTE)^2 + (RMTE + RCA)^2\}^{1/2} + EA + BIAS$$

[ ]^{a,c}

Pressurizer Pressure – Low and High Reactor Trip
Rosemount 1154SH9RC, ALS Process Racks

Pressurizer Pressure – Low Reactor Trip

Safety Analysis Limit	= 1845 psig
Nominal Trip Setpoint	= 1950 psig
Instrument Span	= 1250 to 2500 psig / 0.1983 – 0.9914 Vdc = 0.7931 Vdc
Total Allowance	= [ ][a,c]
CSA	= [ ][a,c]
Margin	= [ ][a,c]

a,c

Transmitter +ALT =

Transmitter -ALT =

Transmitter +AFT =

Transmitter -AFT =

a,c

Process Racks +ALT =

Process Racks -ALT =

Process Racks +AFT =

Process Racks -AFT =

Pressurizer Pressure – Low and High Reactor Trip
Rosemount 1154SH9RC, ALS Process Racks

Pressurizer Pressure – High Reactor Trip

Safety Analysis Limit	= 2445 psig
Nominal Trip Setpoint	= 2385 psig
Instrument Span	= 1250 to 2500 psig / 0.1983 – 0.9914 Vdc = 0.7931 Vdc
Total Allowance	= [ ]a,c
CSA	= [ ]a,c
Margin	= [ ]a,c

a,c

Transmitter +ALT	=
Transmitter -ALT	=
Transmitter +AFT	=
Transmitter -AFT	=

a,c

Process Racks +ALT	=
Process Racks -ALT	=
Process Racks +AFT	=
Process Racks -AFT	=

Pressurizer Pressure – Low, Safety Injection
Rosemount 1154SH9RC, ALS Process Racks

Parameter	**Allowance***
Process Measurement Accuracy	[ ]a,c
Primary Element Accuracy	
Sensor Calibration Accuracy	
Sensor Reference Accuracy	
Sensor Measuring & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift (30 months)	
Bias	
Environmental Allowance	
[ ]a,c	
[ ]a,c	
Rack Calibration Accuracy	
Rack Measuring & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (1250 psi)

Channel Statistical Allowance =

$$\{(PMA)^2 + (PEA)^2 + (SMTE + SD)^2 + (SRA)^2 + (SPE)^2 + (STE)^2 + (SMTE + SCA)^2 + (RMTE + RD)^2 + (RTE)^2 + (RMTE + RCA)^2\}^{1/2} + EA + BIAS$$

[ ]a,c

Pressurizer Pressure – Low, Safety Injection
Rosemount 1154SH9RC, ALS Process Racks

Pressurizer Pressure – Low, Safety Injection

Safety Analysis Limit	= 1680 psig
Nominal Trip Setpoint	= 1850 psig
Instrument Span	= 1250 to 2500 psig / 0.1983 – 0.9914 Vdc = 0.7931 Vdc
Total Allowance	= [ ][a,c]
CSA	= [ ][a,c]
Margin	= [ ][a,c]

a,c

Transmitter +ALT	=
Transmitter -ALT	=
Transmitter +AFT	=
Transmitter -AFT	=

a,c

Process Racks +ALT	=
Process Racks -ALT	=
Process Racks +AFT	=
Process Racks -AFT	=

Pressurizer Water Level – High
Rosemount 1153HD5, Triconex Racks

Parameter	**Allowance***
Process Measurement Accuracy	[ ]a,c
[ ]a,c	
[ ]a,c	
[ ]a,c	
Primary Element Accuracy	
Sensor Calibration Accuracy	
Sensor Reference Accuracy	
Sensor Measuring & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift/Process Effects (30 months)**	
Bias	
Environmental Allowance	
Rack Calibration Accuracy	
Rack Measuring & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (100 %)

** [ ]a,c

Channel Statistical Allowance =

$$\{(PMA)^2 + (PEA)^2 + (SMTE + SD)^2 + (SRA)^2 + (SPE)^2 + (STE)^2 + (SMTE + SCA)^2 + (RTE)^2 + (RMTE + RD)^2 + (RMTE + RCA)^2\}^{1/2} + EA + BIAS$$

[ ]a,c

Pressurizer Water Level – High
Rosemount 1153HD5, Triconex Racks

Safety Analysis Limit	= Not used in the safety analysis
Nominal Trip Setpoint	= 90 % span
Instrument Span	= 0 - 100 % span / 0.1983 - 0.9914 Vdc = 0.7931 Vdc
Total Allowance	= [ ][a,c]
CSA	= [ ][a,c]
Margin	= [ ][a,c]

a,c

Transmitter +ALT =

Transmitter -ALT =

Transmitter +AFT =

Transmitter -AFT =

a,c

Process Racks +ALT =

Process Racks -ALT =

Process Racks +AFT =

Process Racks -AFT =

Steam Generator Narrow Range Water Level – Low-Low
Rosemount 1154DH5RC, Triconex Racks

Parameter — **Allowance***

Process Measurement Accuracy**

[ ]a,c

Primary Element Accuracy

Sensor Calibration Accuracy

Sensor Reference Accuracy

Sensor Measuring & Test Equipment Accuracy

Sensor Pressure Effects

Sensor Temperature Effects

Sensor Drift (30 months)

Environmental Allowance**

[ ]a,c

Bias**

[ ]a,c

Rack Calibration Accuracy

Rack Measuring & Test Equipment Accuracy

Rack Temperature Effect

Rack Drift

[ ]a,c

* In percent span (100 %)

** [ ]a,c

Steam Generator Narrow Range Water Level – Low-Low
Rosemount 1154DH5RC, Triconex Racks

Channel Statistical Allowance =

$\{(PEA)^2 + (SMTE + SD)^2 + (SRA)^2 + (SPE)^2 + (STE)^2 +$
$(SMTE + SCA)^2 + (RMTE + RD)^2 + (RTE)^2 + (RMTE + RCA)^2\}^{1/2} +$
$BIAS_1 + BIAS_2 + BIAS_3 + EA_1 + EA_2 +$

[ ]a,c

[ ]a,c

Safety Analysis Limit	=	0 % span
Nominal Trip Setpoint	=	15.0 % span
Instrument Span	=	0 - 100 % span / 0.1983 - 0.9914 Vdc = 0.7931 Vdc
Total Allowance	=	[ ]a,c
CSA	=	[ ]a,c
Margin	=	[ ]a,c

Transmitter +ALT	=	[ ]a,c
Transmitter -ALT	=	
Transmitter +AFT	=	
Transmitter -AFT	=	

Process Racks +ALT	=	[ ]a,c
Process Racks -ALT	=	
Process Racks +AFT	=	
Process Racks -AFT	=	

Steam Generator Narrow Range Water Level – High-High
Rosemount 1154DH5RC, Triconex Racks

Parameter	**Allowance***
Process Measurement Accuracy**	[ ]a,c
[ ]a,c	
Primary Element Accuracy	
Sensor Calibration Accuracy	
Sensor Reference Accuracy	
Sensor Measuring & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift (30 months)	
Environmental Allowance**	
Bias**	
[ ]a,c	
Rack Calibration Accuracy	
Rack Measuring & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (100 %)
** [ ]a,c

Steam Generator Narrow Range Water Level – High-High
Rosemount 1154DH5RC, Triconex Racks

Channel Statistical Allowance =
$-\{(PEA)^2 + (SMTE + SD)^2 + (SRA)^2 + (SPE)^2 + (STE)^2$
$+ (SMTE + SCA)^2 + (RMTE + RD)^2 + (RTE)^2 + (RMTE + RCA)^2\}^{1/2} +$
$BIAS_1 + BIAS_2 + EA +$
[ ][a,c]

[ ][a,c]

Note: Negative sign ("-") denotes direction (i.e. indicates lower than actual).

Safety Analysis Limit	= 98.7 % span
Nominal Trip Setpoint	= 90.0 % span
Instrument Span	= 0 - 100 % span / 0.1983 - 0.9914 Vdc = 0.7931 Vdc
Total Allowance	= [ ][a,c]
CSA	= [ ][a,c]
Margin	= [ ][a,c]

Transmitter +ALT	=	[
Transmitter -ALT	=	
Transmitter +AFT	=	
Transmitter -AFT	=	][a,c]

Process Racks +ALT	=	[
Process Racks -ALT	=	
Process Racks +AFT	=	
Process Racks -AFT	=	][a,c]

Containment Pressure – High, High-High
Rosemount 1154DP6RC, ALS Process Racks

Parameter	Allowance*
Process Measurement Accuracy	[ ]a,c
Primary Element Accuracy	
Sensor Calibration Accuracy	
Sensor Reference Accuracy	
Sensor Measuring & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift (30 months)	
Bias	
Environmental Allowance	
Rack Calibration Accuracy	
Rack Measuring & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (60 psi)

Channel Statistical Allowance =

$$\{(PMA)^2 + (PEA)^2 + (SMTE + SD)^2 + (SRA)^2 + (SPE)^2 + (STE)^2 + (SMTE + SCA)^2 + (RMTE + RD)^2 + (RTE)^2 + (RMTE + RCA)^2\}^{1/2} + EA + BIAS$$

[ ]a,c

Containment Pressure – High
Rosemount 1154DP6RC, ALS Process Racks

Safety Analysis Limit	= 5.0 psig
Nominal Trip Setpoint	= 3.0 psig
Instrument Span	= -5 - 55 psig / 0.1983 - 0.9914 Vdc = 0.7931 Vdc
Total Allowance	= [ ]a,c
CSA	= [ ]a,c
Margin	= [ ]a,c

a,c

Transmitter +ALT	=
Transmitter -ALT	=
Transmitter +AFT	=
Transmitter -AFT	=

a,c

Process Racks +ALT	=
Process Racks -ALT	=
Process Racks +AFT	=
Process Racks -AFT	=

Containment Pressure – High-High
Rosemount 1154DP6RC, ALS Process Racks

Safety Analysis Limit	= 24.7 psig
Nominal Trip Setpoint	= 22.0 psig
Instrument Span	= -5 - 55 psig / 0.1983 - 0.9914 Vdc = 0.7931 Vdc
Total Allowance	= [ ][a,c]
CSA	= [ ][a,c]
Margin	= [ ][a,c]

Transmitter +ALT	=	[
Transmitter -ALT	=	
Transmitter +AFT	=	
Transmitter -AFT	=	][a,c]

Process Racks +ALT	=	[
Process Racks -ALT	=	
Process Racks +AFT	=	
Process Racks -AFT	=	][a,c]

Steamline Pressure – Low
Rosemount 1154SH9RC, Triconex Racks

Parameter	**Allowance**
Process Measurement Accuracy	[ ]a,c
Primary Element Accuracy	
Sensor Calibration Accuracy	
Sensor Reference Accuracy	
Sensor Measuring & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift (30 months)	
Bias	
Environmental Allowance	
[ ]a,c	
[ ]a,c	
Rack Calibration Accuracy	
Rack Measuring & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (1200 psi)

Channel Statistical Allowance =

$$\{(PMA)^2 + (PEA)^2 + (SMTE + SD)^2 + (SRA)^2 + (SPE)^2 + (STE)^2 + (SMTE + SCA)^2 + (RMTE + RD)^2 + (RTE)^2 + (RMTE + RCA)^2\}^{1/2} + EA + BIAS$$

[ ]a,c

Steamline Pressure – Low
Rosemount 1154SH9RC, Triconex Racks

Safety Analysis Limit	=	444 psig
Nominal Trip Setpoint	=	600 psig
Instrument Span	=	0 - 1200 psig / 0.1983 - 0.9914 Vdc = 0.7931 Vdc
Total Allowance	=	[ ]a,c
CSA	=	[ ]a,c
Margin	=	[ ]a,c

a,c

Transmitter +ALT	=	[
Transmitter -ALT	=	
Transmitter +AFT	=	
Transmitter -AFT	=	]

a,c

Process Racks +ALT	=	[
Process Racks -ALT	=	
Process Racks +AFT	=	
Process Racks -AFT	=	]

Steamline Pressure – Low
Barton 763, Triconex Racks

Parameter	Allowance
Process Measurement Accuracy	[ ]a,c
Primary Element Accuracy	
Sensor Calibration Accuracy	
Sensor Reference Accuracy	
Sensor Measuring & Test Equipment Accuracy	
Sensor Pressure Effects	
Sensor Temperature Effects	
Sensor Drift (30 months)	
Bias	
Environmental Allowance	
[ ]a,c	
[ ]a,c	
Rack Calibration Accuracy	
Rack Measuring & Test Equipment Accuracy	
Rack Temperature Effect	
Rack Drift	

* In percent span (1200 psi)

Channel Statistical Allowance =

$$\{(PMA)^2 + (PEA)^2 + (SMTE + SD)^2 + (SRA)^2 + (SPE)^2 + (STE)^2 + (SMTE + SCA)^2 + (RMTE + RD)^2 + (RTE)^2 + (RMTE + RCA)^2\}^{1/2} + EA + BIAS$$

[ ]a,c

Steamline Pressure – Low
Barton 763, Triconex Racks

Safety Analysis Limit	= 444 psig
Nominal Trip Setpoint	= 600 psig
Instrument Span	= 0 - 1200 psig / 0.1983 - 0.9914 Vdc = 0.7931 Vdc
Total Allowance	= [ ][a,c]
CSA	= [ ][a,c]
Margin	= [ ][a,c]

[a,c]

Transmitter +ALT	=
Transmitter -ALT	=
Transmitter +AFT	=
Transmitter -AFT	=

[a,c]

Process Racks +ALT	=
Process Racks -ALT	=
Process Racks +AFT	=
Process Racks -AFT	=

Negative Steamline Pressure Rate – High
Rosemount 1154SH9RC, Triconex Racks

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

*In % span (1200 psi)

Channel Statistical Allowance =

$$\{(PMA)^2 + (PEA)^2 + (SCA + SMTE)^2 + (SMTE + SD)^2 + (SPE)^2 + (STE)^2 + (SRA)^2 + (RCA + RMTE)^2 + (RMTE + RD)^2 + (RTE)^2\}^{1/2} + EA + BIAS$$

[ ]a,c

Negative Steamline Pressure Rate – High
Rosemount 1154SH9RC, Triconex Racks

Safety Analysis Limit = Not used in the safety analysis

Nominal Trip Setpoint = 100 psi

Instrument Span = 0 - 1200 psig / 0.1983 - 0.9914 Vdc = 0.7931 Vdc

Total Allowance = [ ][a,c]

CSA = [ ][a,c]

Margin = [ ][a,c]

a,c

Transmitter +ALT =

Transmitter -ALT =

Transmitter +AFT =

Transmitter -AFT =

a,c

Process Racks +ALT =

Process Racks -ALT =

Process Racks +AFT =

Process Racks -AFT =

Improved Thermal Design Procedure Functions

PRESSURIZER PRESSURE CONTROL SYSTEM UNCERTAINTY
Rosemount 1154SH9RC, Indicator

SENSOR/TRANSMITTER

a,c

SRA =
SCA =
SMTE =
STE =
SD =
BIAS =

PROCESS RACKS

CONTROLLER IND

a,c

RCA =
RMTE =
RTE =
RD =
RDOUT =
CA =

All above values in % of instrument span. Span = 1250 psi.

a,c

ELECTRONICS UNCERTAINTY
PLUS

ELECTRONICS UNCERTAINTY
PLUS

CONTROLLER UNCERTAINTY
(3 Indicators Available)

PRESSURIZER PRESSURE CONTROL SYSTEM UNCERTAINTY
Rosemount 1154SH9RC, Indicator

Nominal Control Setpoint (NCS) = 2235 psig

Instrument Span = 1250 to 2500 psig / 0.1983 – 0.9914 Vdc = 0.7931 Vdc

Safety Analysis Initial Condition (indicated higher than actual) = 2175 psig

Total Allowance (indicated higher than actual) = [ ]a,c

CSA (indicated higher than actual) = [ ]a,c

Margin (indicated higher than actual) = [ ]a,c

Safety Analysis Initial Condition (indicated lower than actual) = 2295 psig

Total Allowance (indicated lower than actual) = [ ]a,c

CSA (indicated lower than actual) = [ ]a,c

Margin (indicated lower than actual) = [ ]a,c

a,c

Transmitter +ALT = [

Transmitter -ALT =

Transmitter +AFT =

Transmitter -AFT =]

a,c

Process Racks (analog controller) +ALT = [

Process Racks (analog controller) -ALT =

Process Racks (analog controller) +AFT =

Process Racks (analog controller) -AFT =]

a,c

Process Racks (Indicator) +ALT = [

Process Racks (Indicator) -ALT =

Process Racks (Indicator) +AFT =

Process Racks (Indicator) -AFT =]

TAVG CONTROL SYSTEM UNCERTAINTY
Rosemount 1153GD8RC, ALS / Triconex Process Racks

SENSOR/TRANSMITTER (All values in % span)

	Tavg	Turbine Pressure*
Span	100 °F	615 psig

a,c

PMA =
BETA =
SRA =
SCA =
SMTE =
STE =
SD =
BIAS =
TP_Sen=

PROCESS RACKS (All values in % span)

Tavg	RTD_{Input}	A/D	D/A	INDICATOR	CONTROLLER	TURBINE
Span	300 °F	120 °F	100 °F	100 °F	100 °F	615 psig

a,c

RCA =
RMTE =
RTE =
RD =
RDOUT=
CA =

N_H = # HOT LEG RTDs = 2

N_C = # COLD LEG RTDs = 1

a,c

ELECTRONICS CSA = ° F
ELECTRONICS SIGMA = ° F
CONTROLLER SIGMA = ° F
CONTROLLER BIAS = ° F
= ° F
CONTROLLER CSA = ° F
= ° F

* Based on Rosemount uncertainties for Turbine Pressure. This bounds the results for the Barton transmitters.
** Sensitivity of Tref to Turbine Pressure uncertainties. Based on relationship between turbine pressure and Tref from no load to full power.

TAVG CONTROL SYSTEM UNCERTAINTY
Rosemount 1153GD8RC, ALS / Triconex Process Racks

Tavg uses a closed-loop control system that compares the auctioneered high Tavg from the loops to a reference derived from the First Stage Turbine Impulse Chamber Pressure. Proper operation of the control system is verified through indication. Tavg is the average of the narrow range Thot and Tcold values, and the highest loop Tavg is used in the controller. In conjunction with the move to a 24 month fuel cycle (30 month surveillance interval) the control uncertainties were determined consistent with the Diablo Canyon Units 1 and 2 administrative procedures. Uncertainties are from hot leg and cold leg streaming, the RTDs, the turbine pressure transmitter, and the process racks/indicators. Based on the assumption that 2 Thot and 1 Tcold cross-calibrated RTDs are used to calculate Tavg (assuming one failed Thot RTD per loop) using the equation below, the electronics uncertainty is calculated to be [ ]^{a,c}. Assuming a normal, two sided probability distribution results in an electronics standard deviation (s_1) of [ ]^{a,c}.

a,c

TAVG CONTROL SYSTEM UNCERTAINTY
Rosemount 1153GD8RC, ALS / Triconex Process Racks

a,c

[ ]

However, this does not include the controller deadband of ± 1.5 °F. The controller uncertainty is the combination of the electronics uncertainty and the deadband. The probability distribution for the deadband has been determined to be [uniform, i.e., an equal probability throughout the range of the deadband].[a,c] The variance for the deadband uncertainty is then:

$(s_2)^2$ = [ ][a,c].

Combining the variance for the electronics and the variance for the deadband results in a controller variance of:

$(s_C)^2 = (s_1)^2 + (s_2)^2$ = [ ][a,c]

The controller standard deviation s_C = [ ][a,c] results in a total random uncertainty for a 30 month surveillance interval of [ ][a,c] and a cold leg streaming bias of [ ][a,c].

TAVG CONTROL SYSTEM UNCERTAINTY
Rosemount 1153GD8RC, ALS / Triconex Process Racks

Nominal Control Setpoint (NCS) = 570.5 °F

Instrument Span = 6.5 to 621 psig / 0.1983 – 0.9914 Vdc = 0.7931 Vdc

Safety Analysis Initial Condition (indicated lower than actual) = 575.3 °F

Total Allowance (indicated lower than actual) = [ ]a,c

CSA (indicated lower than actual) = [ ]a,c

Margin (indicated lower than actual) = [ ]a,c

Safety Analysis Initial Condition (indicated higher than actual) = 566.2 °F

Total Allowance (indicated higher than actual) = [ ]a,c

CSA (indicated higher than actual) = [ ]a,c

Margin (indicated higher than actual) = [ ]a,c

Turbine Presssure

a,c

Transmitter +ALT = [

Transmitter -ALT =

Transmitter +AFT =

Transmitter -AFT =]

a,c

Process Racks +ALT = [

Process Racks -ALT =

Process Racks +AFT =

Process Racks -AFT =]

a,c

Process Racks (analog controller) +ALT = [

Process Racks (analog controller) -ALT =

Process Racks (analog controller) +AFT =

Process Racks (analog controller) -AFT =]

TAVG CONTROL SYSTEM UNCERTAINTY
Rosemount 1153GD8RC, ALS / Triconex Process Racks

a,c

Process Racks (Indicator) +ALT =

Process Racks (Indicator) -ALT =

Process Racks (Indicator) +AFT =

Process Racks (Indicator) -AFT =

See Overtemperature ΔT Table for RTD Input and Process Rack ALT / AFT values

DAILY POWER MEASUREMENT INSTRUMENTATION UNCERTAINTIES

(% SPAN)	FW TEMP	FW PRES	FW d/p	STM PRESS*
				a,c
SRA =				
SCA =				
SMTE =				
SPE =				
STE =				
SD =				
BIAS =				
RCA =				
RMTE =				
RTE =				
RD =				
RCA_{comp} =				
$RMTE_{comp}$ =				
RTE_{comp} =				
RD_{comp} =				
NUMBER OF INSTRUMENTS USED				
	1/LOOP	N/A	1/LOOP	1/LOOP
INST SPAN =	400 °F	2000 psi	120%FLOW	1200 psi
	°F	psi	%Δp span	psi
				a,c
INST UNC (RANDOM) =				
INST UNC (BIAS) =				
NOMINAL =	435	981PSIA	100%FLOW	881PSIA

* Uses uncertainties associated with Rosemount transmitters. These values bound the Barton values for the Power Calorimetric function.

All parameters are read by the process computer, except feedwater pressure which is an assumed value.

DAILY POWER MEASUREMENT UNCERTAINTY

COMPONENT	INSTRUMENT ERROR	POWER UNCERTAINTY
		a,c
FEEDWATER FLOW		
Venturi (**FW_Venturi**)		
THERMAL EXPANSION COEFFICIENT		
Temperature (**FWFFAT**)		
Material (**FW_Venturi_Fa**)		
DENSITY		
Temperature (**FWFDT**)		
Pressure (**FWFDP**)		
Delta P (**FWFVDP**)		
FEEDWATER ENTHALPY		
Temperature (**FWET**)		
Pressure (**FWEP**)		
STEAM ENTHALPY		
Pressure (**SEP**)		
Moisture (**SEMS**)		
NET PUMP HEAT ADDITION (**NPHA**)		
SG BLOWDOWN (**SGBD**)		
BIAS VALUES		
Feedwater Venturi (**bias**)		

*, ** INDICATE SETS OF DEPENDENT PARAMETERS

SINGLE LOOP UNCERTAINTY (WITHOUT BIAS VALUES)
4 LOOP UNCERTAINTY (WITHOUT BIAS VALUES)
4 LOOP (**RCS_N**) UNCERTAINTY (WITH POSITIVE BIAS VALUES)

Using the power uncertainty values noted previously, the 4 loop uncertainty (with bias values) equation is as follows:

Power = [ ]a,c

Power = [ ]a,c

Based on four (4) loops and the instrument uncertainties for the four parameters, the uncertainty for the secondary side power calorimetric measurement is:

# of loops	power uncertainty (% RTP)
4	[ ]a,c

COLD LEG ELBOW TAP RCS FLOW INDICATOR UNCERTAINTY
Rosemount 1153HD5RC, ALS Process Racks

INSTRUMENT UNCERTAINTIES

% Δp SPAN* % FLOW

a,c

PMA =
PEA =
SRA =
SCA =
SMTE =
SPE =
STE =
SD =
BIAS =

Process Racks

Input Card

RCA_{Input} =
$RMTE_{Input}$ =
RTE_{Input} =
RD_{Input} =

Output Card

RCA_{Output} =
$RMTE_{Output}$ =
RTE_{Output} =
RD_{Output} =

Control Board Meter

RCA_{IND} =
$RMTE_{IND}$ =
RTE_{IND} =
RD_{IND} =
RDOUT =

FLOW CALORIMETRIC BIAS
FLOW CALORIMETRIC (RCSF)
INSTRUMENT SPAN

* Percent ΔP span converted to percent flow via the following equation, with F_{max} = 120.0 % and F_N = 90 %, Scaling Factor (m) = 1.3 applies to sensor and Process Rack input card.

$$\text{Error in \% flow} = \left[\frac{\%\,\epsilon FS\Delta P}{2}\right]\left[\frac{F_{max}}{F_N}\right]^2$$

COLD LEG ELBOW TAP RCS FLOW INDICATOR UNCERTAINTY
Rosemount 1153HD5RC, ALS Process Racks

Channel Statistical Allowance =

[ ] a,c

[ ] a,c

Number of Taps per loop = 3
Number of loops = 4

COLD LEG ELBOW TAP RCS FLOW INDICATOR UNCERTAINTY
Rosemount 1153HD5RC, ALS Process Racks

a,c

Transmitter +ALT =

Transmitter -ALT =

Transmitter +AFT =

Transmitter -AFT =

a,c

Input Process Racks +ALT =

Input Process Racks -ALT =

Input Process Racks +AFT =

Input Process Racks -AFT =

a,c

Output Process Racks +ALT =

Output Process Racks -ALT =

Output Process Racks +AFT =

Output Process Racks -AFT =

a,c

Process Racks (Indicator) +ALT =

Process Racks (Indicator) -ALT =

Process Racks (Indicator) +AFT =

Process Racks (Indicator) -AFT =