

GE Hitachi Nuclear Energy BWR Operating Units: Discussion of 1-Sided Statistics for Setpoint Margin Calculations

With USNRC and GEH

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Agenda

- Objective
- Simple Example
- Problem Statement
- Instrument Error
- Setpoint Margin
- Probability Requirements
- 2-sided vs. 1-sided Conclusions
- Confidence Level Considerations



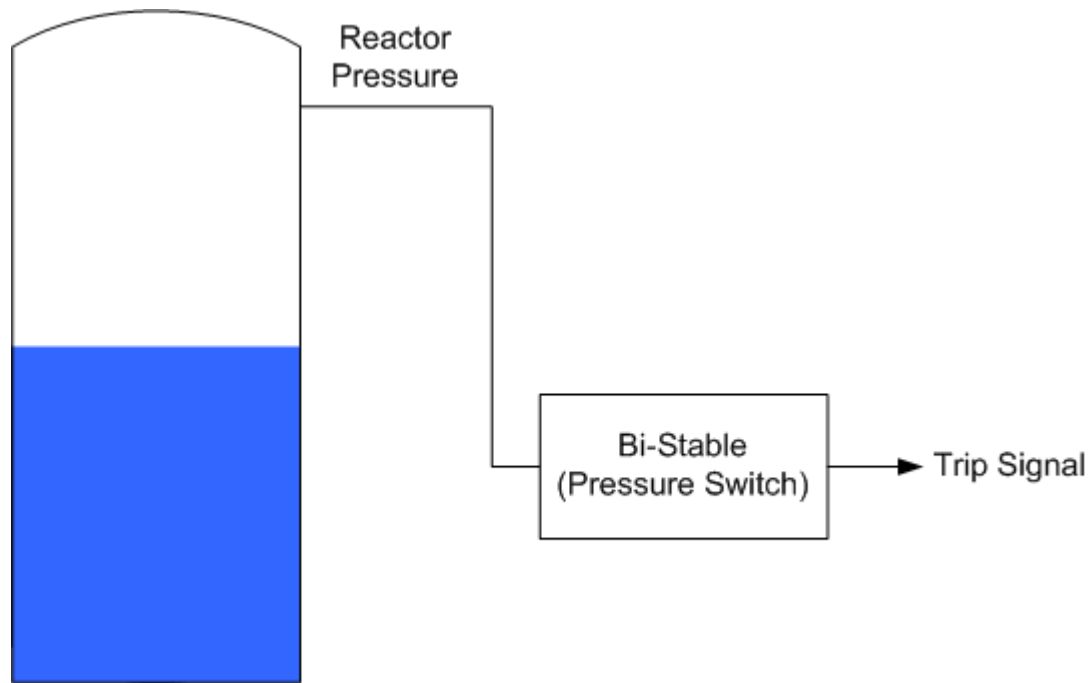
Objective

- **Calculate Setpoint Margin for Setpoints Approached from One Direction for Normal Error Distribution**
 - **Instrument Loop and Setpoint Function definition**
 - **Instrument Error**
 - **Impact of Error on Setpoint Location**
 - **Setpoint Margin Calculation for 95% probability**

Establish Statistical Factor for Setpoint Margin Calculation that Meets Probability Requirements for Setpoints Approached from One Direction



Instrument Loop



Simple Loop (One Instrument) Chosen to Facilitate Statistics Discussion



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Statement of Technical Objective

- **Safety Analyses for Over Pressure Protection Assumes that a Scram is Initiated at 1050 psig. Analysis Results Demonstrate Margin to Event Limits.**
- **Define Analytic Limit (AL) = 1050 psig**
- **Determine Setpoint location relative to the AL so that there is at least 95% probability (per RG 1.105) that the trip will occur before the AL is reached.**

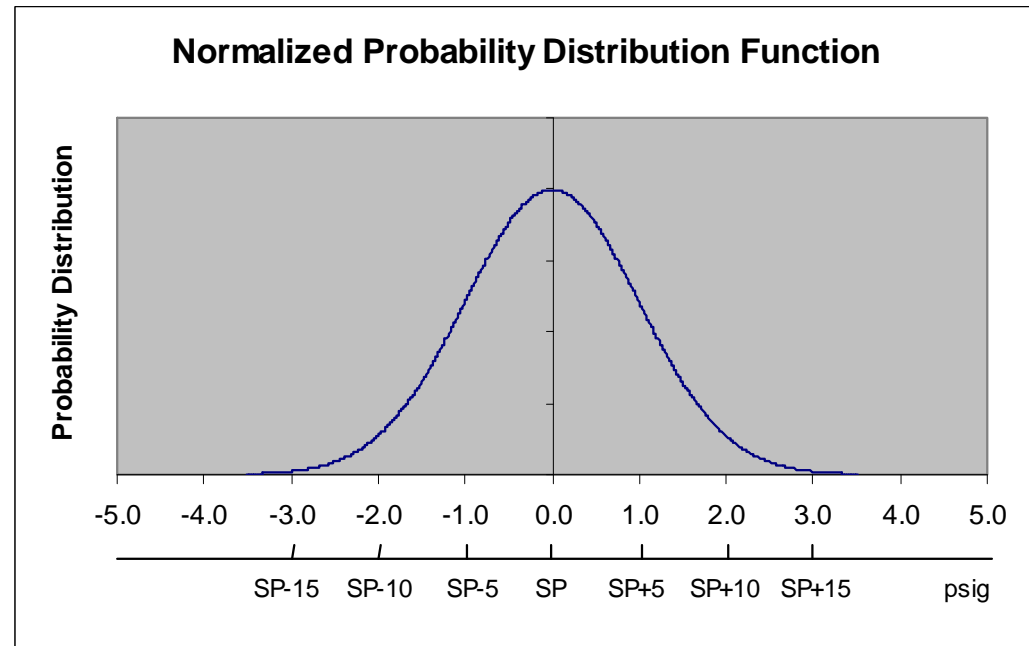
**Overall Technical Objective Important when
Dealing with Setpoint Statistics**



Instrument Errors

- Simplified Problem – One Error Source
- Error Std Dev = $\pm 0.4\%$ of Span
- Span = 1250 psig, Error = ± 5 psig (1 Std Dev or 1 sigma)

Std Dev =
Standard Deviation



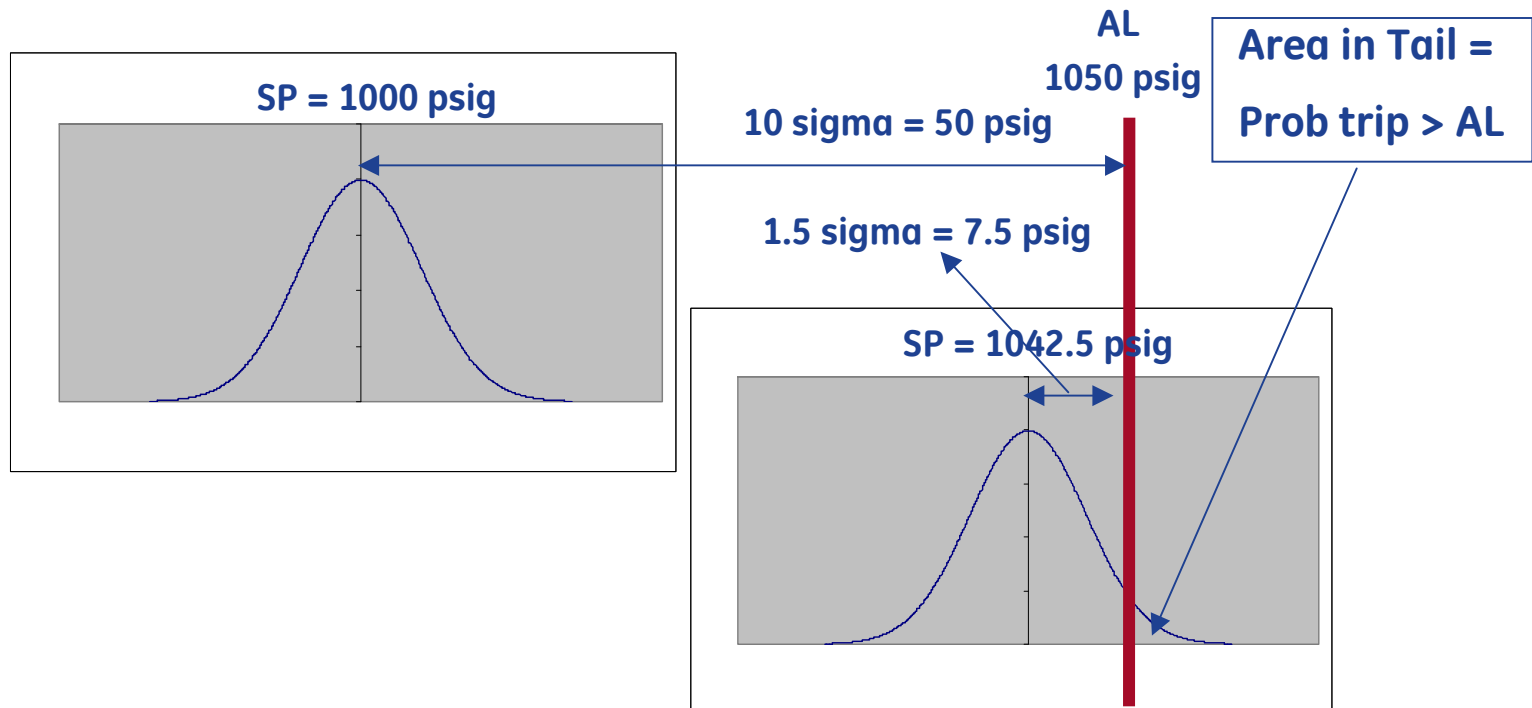
Normal Error Distribution, 2-sided Errors
Positive and Negative Errors Equally Likely



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Impact of Instrument Error on Setpoint

- Analytic Limit (AL) = 1050 psig; AL fixed based on safety analysis
- If Instrument Error = 0, Setpoint (SP) Located at AL = 1050 psig
- Instrument Error Anchored to SP, Independent of SP and AL
- SP Location depends on AL and Trip Probability Requirement



Probability of Exceeding AL Depends on SP Location Relative to AL



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Setpoint Margin for 95% Probability

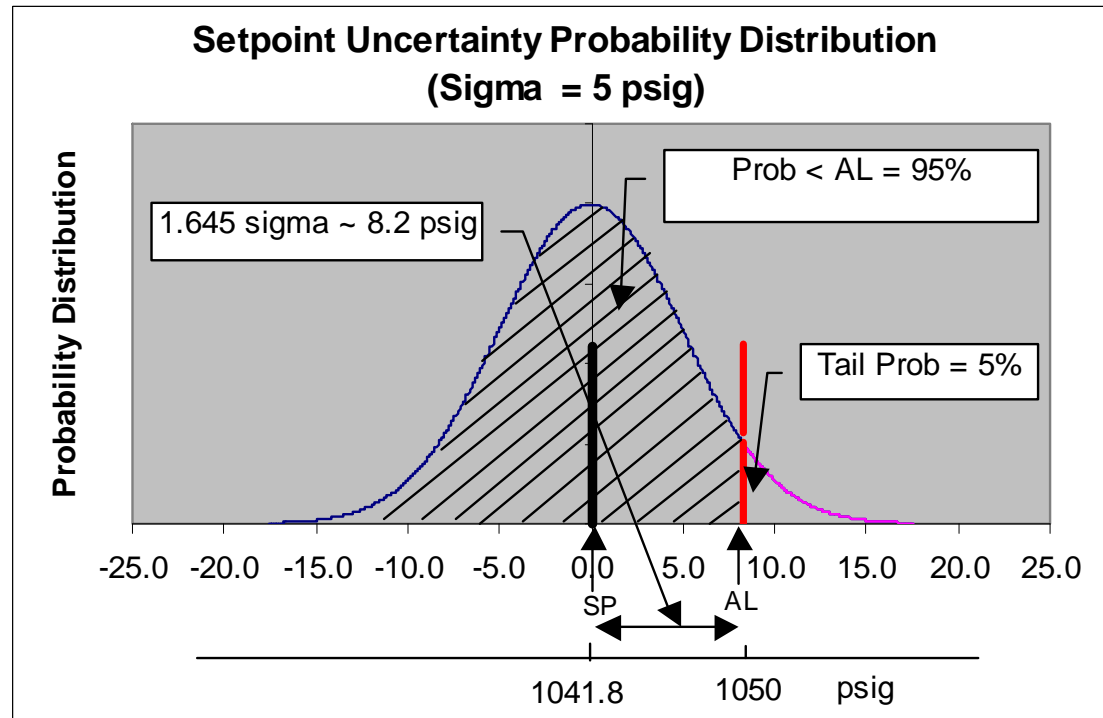
- **SP Approached from One Direction (low pressure side)**
- **Requirement: 95% Probability Trip will occur before AL exceeded**
 - **95% of the errors result in $\text{Trip} \leq \text{AL}$**
 - **5% of errors result in $\text{Trip} > \text{AL}$**
- **Means SP Location Relative to AL is such that**
 - **Probability in Error Distribution Tail above AL is 5%**
 - **Probability in Error Distribution below AL is 95%**
- **For Probability calculation, Errors in both Positive and Negative direction must be considered**

**95% Probability that SP will not Exceed AL. If Event Occurs
95% Probability that Trip will Occur before AL is Reached.**



Setpoint Margin to AL

Based on
Characteristics
of Normal
Distribution



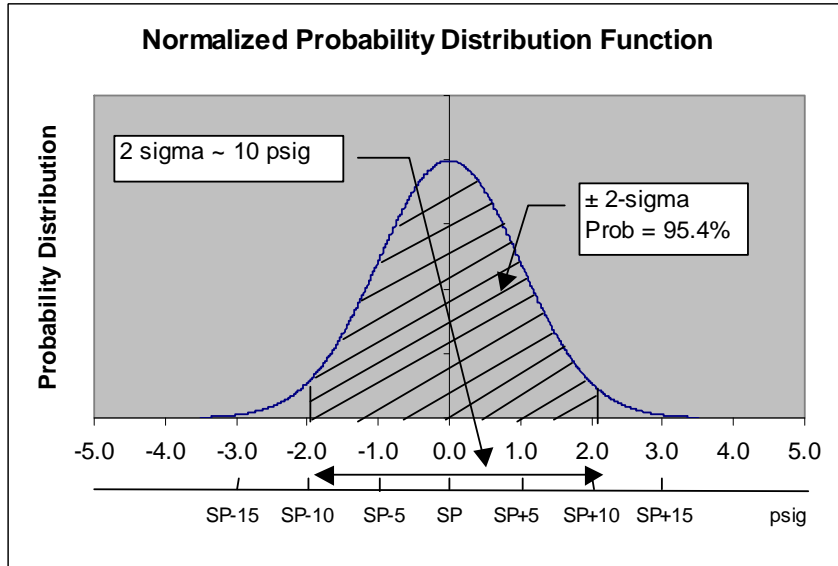
**SP Margin to AL for 95% Probability is 1.645 Std Dev
(1.645 Sigma)**



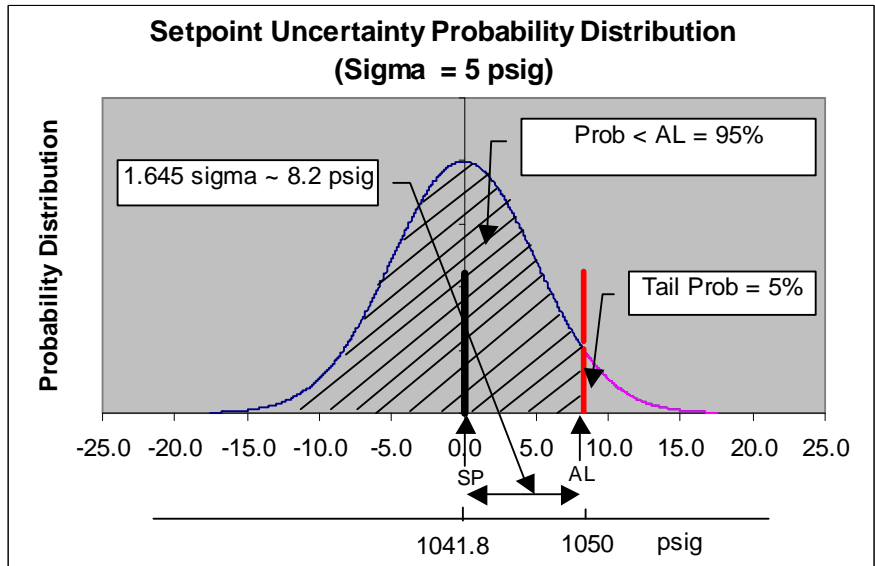
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Statistics Summary - Pictorial

- 2-Sided Statistics for Error Distribution



- 1-Sided Statistics for SP to AL Margin



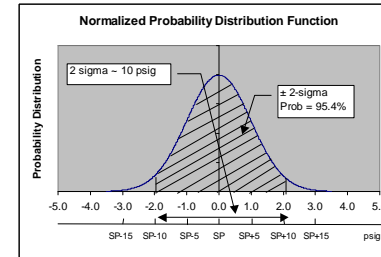
- 2-sided Error Distribution (± 2 Sigma contains 95% of data)
- 1-sided Statistics for SP/AL Margin ($-\infty$ to 1.645 Sigma contains 95% of data)



Statistics Summary - Data

- 2-Sided Statistics for Error Distribution

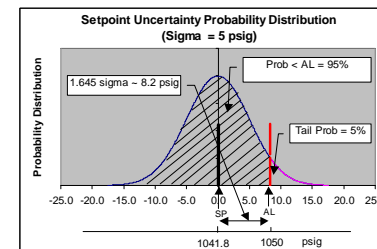
2-sided Statistics for Instrument Errors			
SP = X (arbitrary); Error Sigma = 5 psig			% Data
(\pm Sigma)	Low (psig)	High (psig)	
1	X - 5	X + 5	68.3
2	X - 10	X + 10	95.4
3	X - 15	X + 15	99.7



(95.4% of Error Data is within ± 2 Sigma around the setpoint, independent of SP and AL)

- 1-Sided Statistics for SP to AL Margin

1-sided Statistics for Instrument Margin				
Error Sigma = 5 psig		SP/AL Margin	Prob Trip < AL	Prob Trip > AL
SP (psig)	AL (psig)	(# Sigmas)	(% Data < AL)	(% Data > AL)
1000	1050	10	100.0	0.0
1030	1050	4	100.0	0.0
1035	1050	3	99.9	0.1
1040	1050	2	97.7	2.3
1041.775	1050	1.645	95.0	5.0
1045	1050	1	84.1	15.9
1050	1050	0	50.0	50.0



(95% of Error Data is \leq AL when SP/AL Margin is 1.645 Sigma, 95% Prob Trip \leq AL)

Use of 1-sided Statistics is Technically Correct for Calculating SP Margin to meet Probability Requirement to Trip \leq AL



Margin Requirements - Summary

- Requirement: 95% Probability Trip \leq AL
(95% data \leq AL)
- Required SP/AL Margin (Per RG 1.105)
 - 1.645 sigma Margin -- 95% data \leq AL
- Other SP/AL Margins
 - 2 sigma Margin -- 97.7% data \leq AL
 - 3 sigma Margin -- 99.9 % data \leq AL

- SP/AL Margin = 1.645 Sigma meets 95% Probability Requirements
- Larger Margins Increase Probability but are Not Required

Statistics for Setpoint Margin - Summary

- SP/AL Margin is based on 1-sided statistics for Trip Setpoints approached in 1 direction
- Magnitude of Margin depends on Requirement for not exceeding AL, or Required Probability of Tripping before AL is exceeded
- For 95% Probability Requirement, the Required SP/AL Margin is 1.645 Sigma
- Larger Margins result in probability greater than 95%
 - Example: 2 Sigma margin would result in 97.7% probability.
- Statistically incorrect to use 2-sided statistics and say that a 2 Sigma margin would give 95% probability.



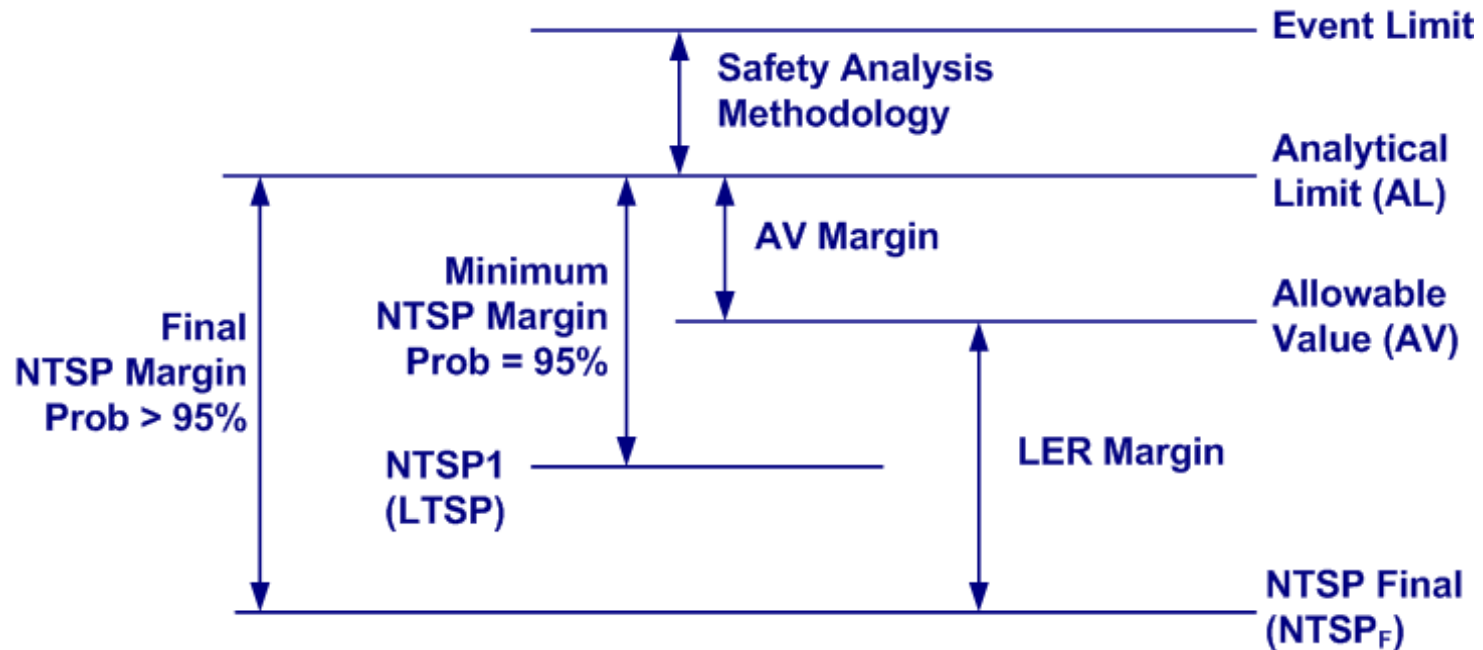
Applicability of 95% Requirement for GEH BWRs

- 95% Probability has historically been used in Safety Analyses that have been licensed
- Significant conservatism in BWR Safety Analyses
- Most Safety Functions use Redundant Trip Channels. Using 95% probability for each channel results in significantly higher probability of tripping before AL for multiple channels.
- GEH Setpoint Methodology is Conservative and provides a final setpoint which is more conservative than required, so margin to AL for each channel provides > 95% probability.

- ❖ Licensed BWR Safety Analyses consistent with use of setpoints developed using 95% Probability Requirement.
- ❖ Final Setpoint Conservatively provides > 95% Probability.



GEH Setpoint Methodology (NRC Approved)



Final NTSP/AL Margin Provides > 95% Probability of Not Exceeding AL



2-Sided vs. 1-Sided Conclusions

- For Normal Error Distribution, the following conclusions, based on statistical principles, are applicable:
 - Margin of the Setpoint to the AL based on single-sided statistical factor
 - Margin of 1.645 Standard Deviations provides 95% probability that the trip will occur before the AL is exceeded.
 - ± 2 Sigma band around the setpoint contains 95% of the error data does not mean that a setpoint margin of 2 Sigma would give 95% probability of not exceeding the AL.

1-sided statistics applicable to setpoint margin calculations for setpoints approached from 1 direction



Confidence Level Considerations

- Confidence level is based only on sample size used to obtain the error standard deviation
- One-sided statistics is applicable for setpoint margin calculations regardless of the confidence level

Use of 1-sided statistics for setpoint margin calculations is applicable regardless of confidence level



Confidence Level Considerations - GEH Setpoint Calculations

- Vendor data used by GEH assures high confidence in setpoint margin calculations
- NRC SER concludes that Approved GEH Methodology (NEDC 31336P-A) using single-sided statistics produces acceptable setpoint margin with high degree of confidence (95%)

Setpoints Calculated with GEH Methodology using the single-sided statistical factor for Setpoint Margin Calculations meet NRC RG 1.105 Requirements



Summary

- Normal Error distribution is 2-sided, positive and negative errors are equally distributed around the setpoint
 - Setpoint margin is based on 1-sided statistics for setpoints approached from 1 direction
 - Margin based on probability requirement for not exceeding AL. For 95% probability the margin is 1.645 standard deviations. (ISA 67.04 Section 7.3, GEH Methodology NEDC-31336P-A)
 - 95% Probability is consistent with licensed GEH Safety Analyses.
 - Conservative GEH Setpoint Methodology provides final setpoint margin typically > 95% Probability with high confidence (95%)
- ❖ Use of 1-sided Statistics is Technically Correct for SP Margin Calculations when Setpoints Approached from 1 Direction
 - ❖ Conservative GEH BWR Methodology Provides Final Setpoint with > 95% Probability of Not Exceeding AL

