GE Hitachi Nuclear Energy

BWR Operating Units: Discussion of 1-Sided Statistics for Setpoint Margin Calculations

With USNRC and GEH

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September 28, 2010

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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

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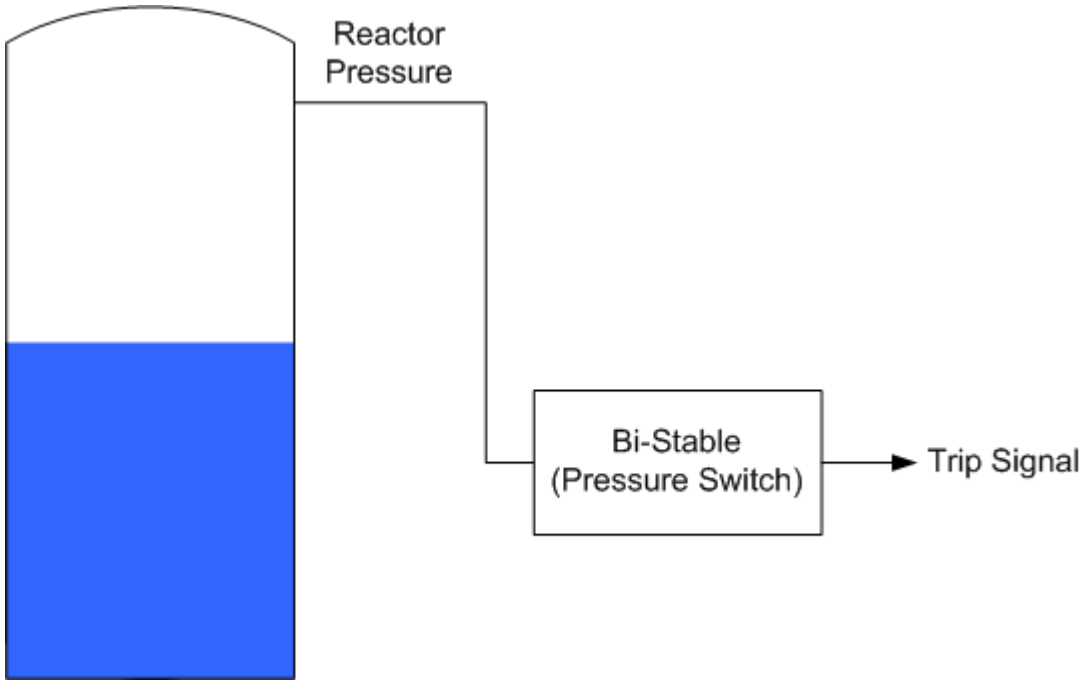
Instrument Loop



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

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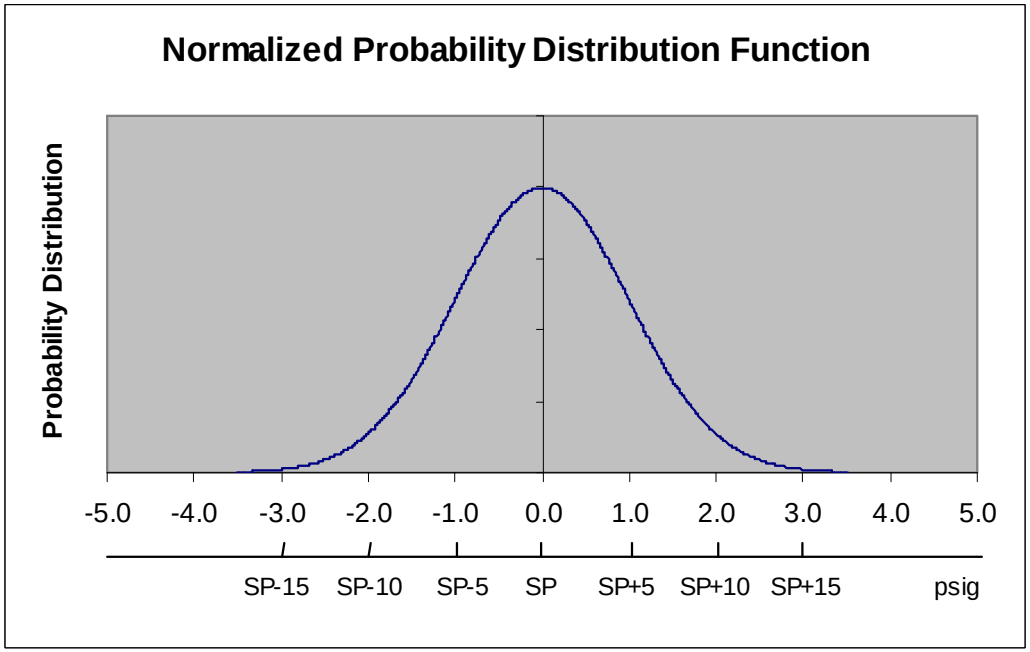
Instrument Errors

- Simplified Problem – One Error Source
- Error Std Dev = ± 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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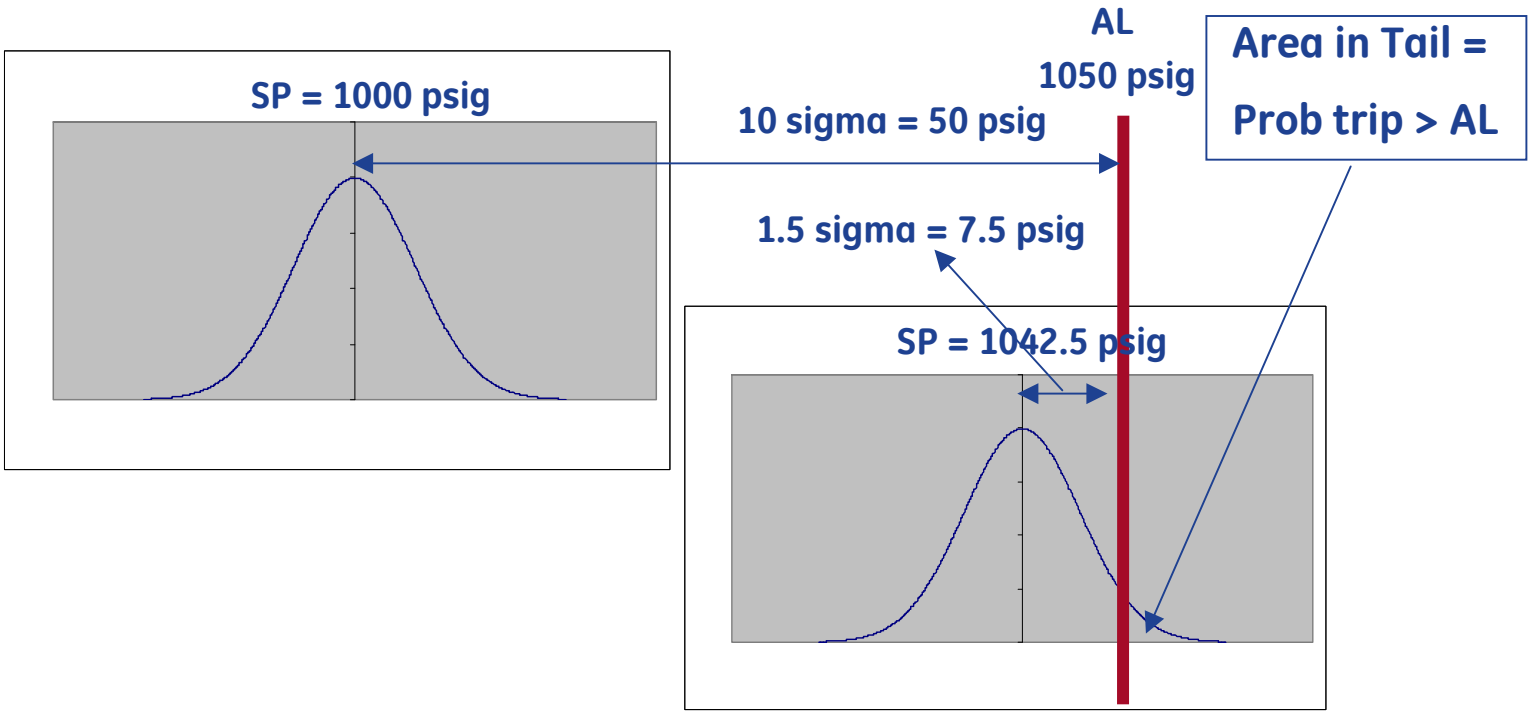
Impact of Instrument Error on Setpoint

- 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 Trip ≤ AL**
  - **5% of errors result in Trip > 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.

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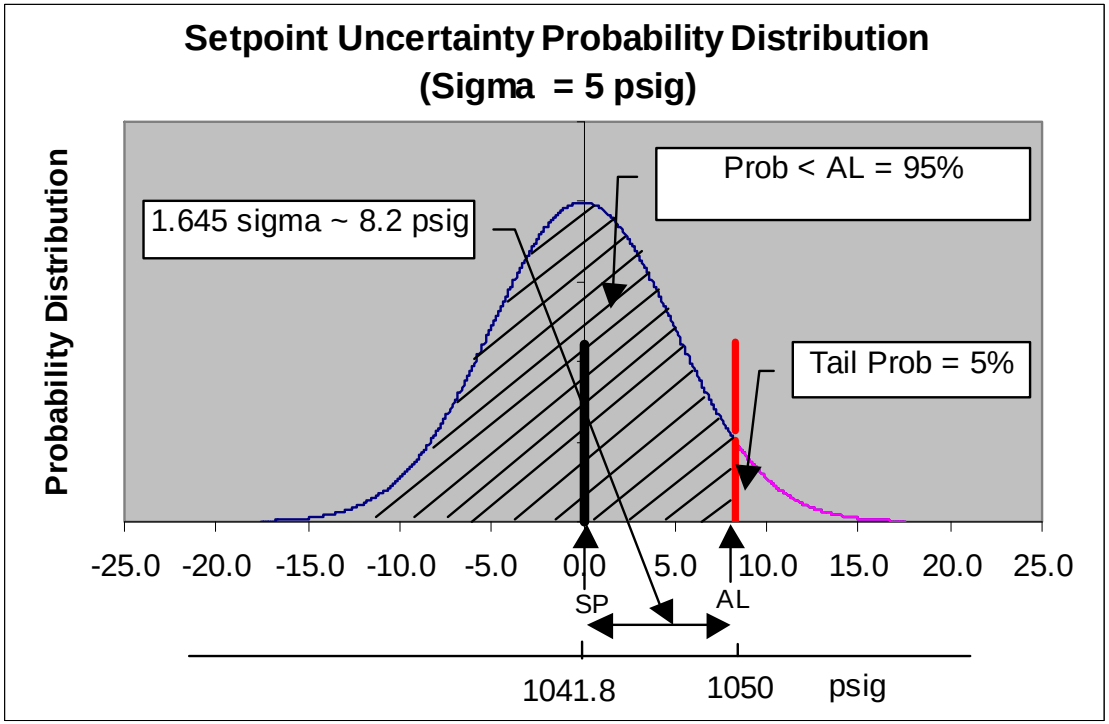
Setpoint Margin to AL

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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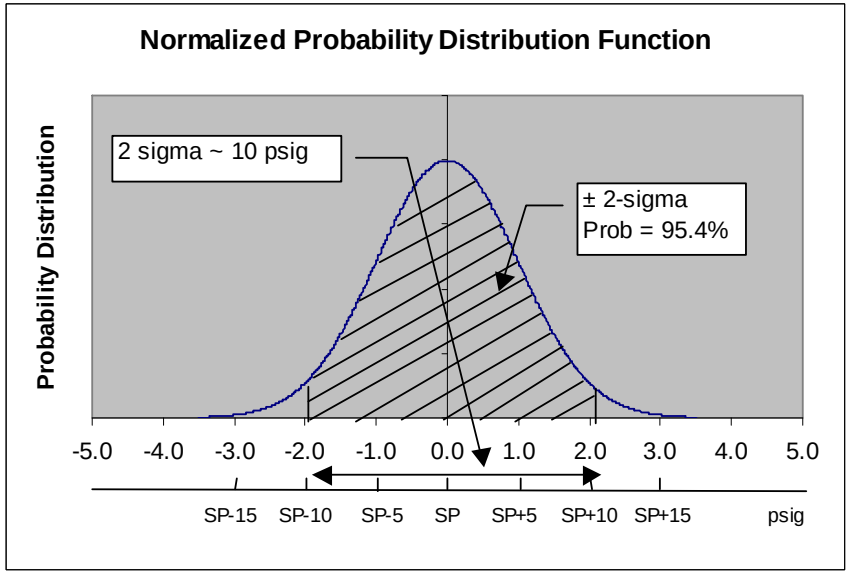
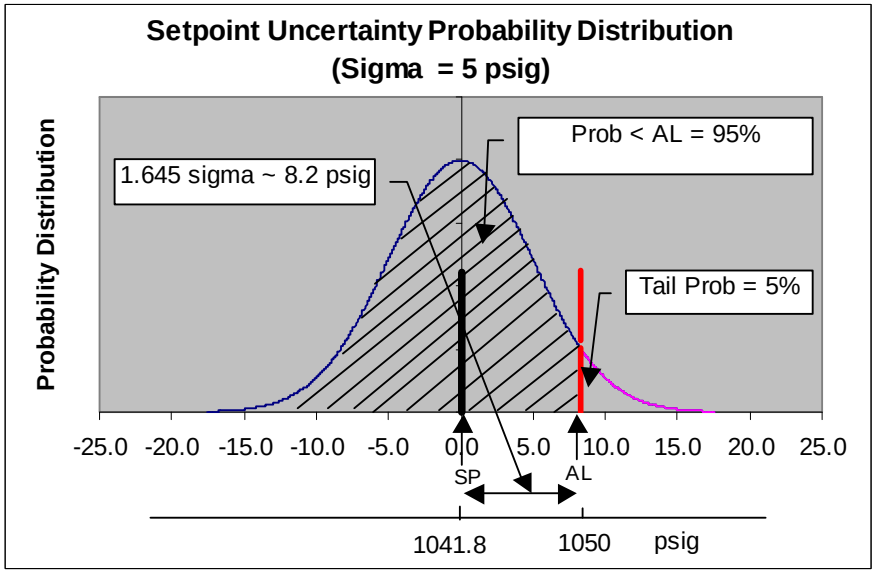
Statistics Summary - Pictorial

- **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 (-∞ to 1.645 Sigma contains 95% of data)**

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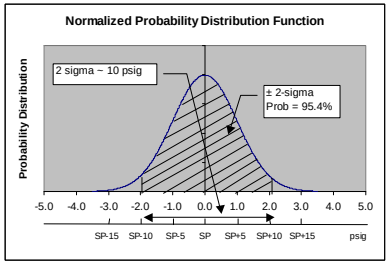
Statistics Summary - Data

- **2-Sided Statistics for Error Distribution**

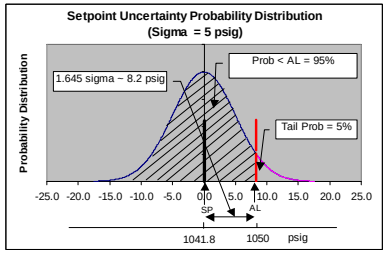
2-sided Statistics for Instrument Errors			
SP = X (arbitrary); Error Sigma = 5 psig			% Data
(± Sigma)	Low (psig)	High (psig)	
1	X - 5	X + 5	68.3
2	X - 10	X + 10	95.4
3	X - 15	X + 15	99.7



(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 ≤ AL when SP/AL Margin is 1.645 Sigma, 95% Prob Trip ≤ AL)

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

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Margin Requirements - Summary

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

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

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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.

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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.**

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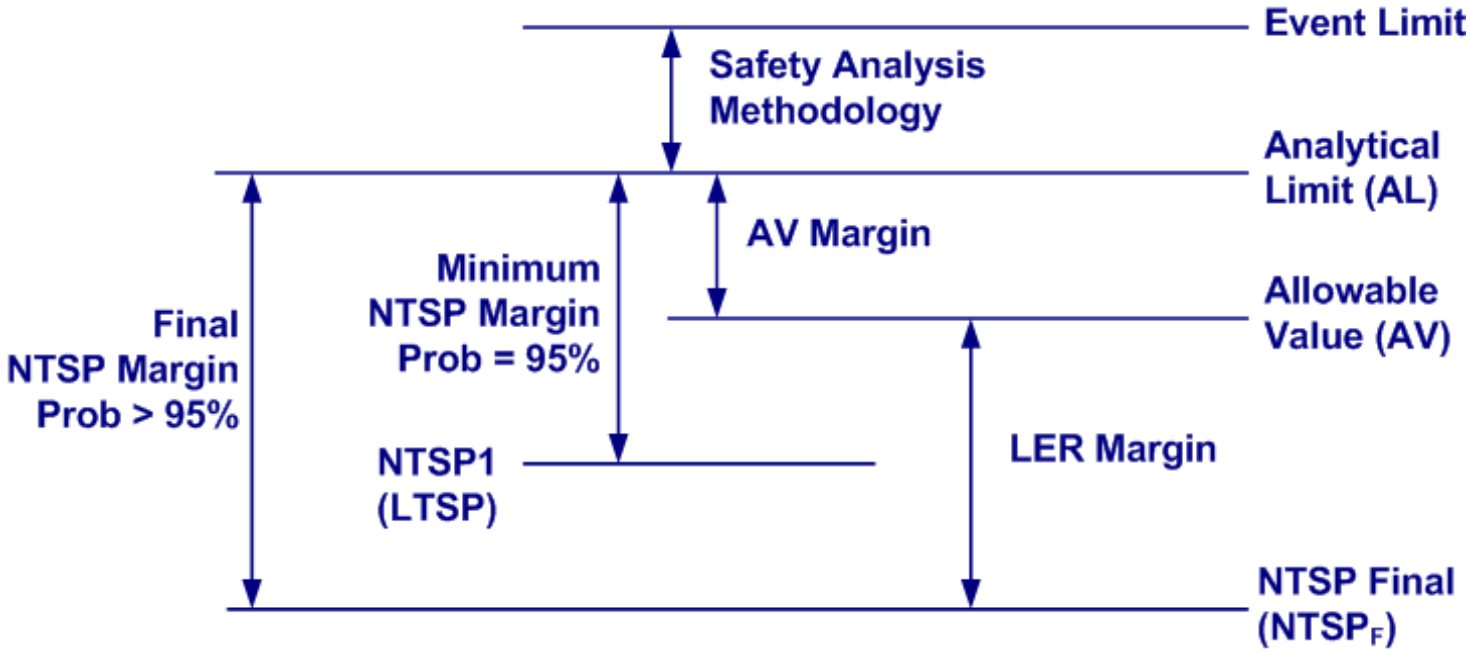
GEH Setpoint Methodology (NRC Approved)



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

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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

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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

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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

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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

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