# Transmittal of Presentation for the Meeting on February 27, 2017 with the NRC to Discuss the FSLOCA Evaluation Model Safety Evaluation (Non-Proprietary)

**February 2017**

 

# FULL SPECTRUM™ LOCA (FSLOCA™) Evaluation Model (EM) Statistical Procedure Error and Resolution

February 27, 2017



Westinghouse

 

# Introduction & Purpose

- FSLOCA EM is in the final stages of approval
  - Final SER is complete
  - ACRS review is complete
  - WCAP-16996-P-A, Revision 1 is complete
  - Final verification letter is pending
    - Westinghouse requested NRC to hold the final verification letter

- An error has been discovered in the FSLOCA EM statistical processing method
  - Affects Section 30.3 of the topical report and the processing of the large break LOCA demonstration analysis results in Sections 31.4 & 31.5

- Purpose of meeting:
  - Explain the issue
  - Explain the resolution
  - Discuss next steps

 

# Agenda

- Introduction & Purpose
- Background
- Issue Description
- Issue Resolution
- Next Steps

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# Background

- Error in statistical processing is the result of [ ]a,c (Wilks[1], Wald[2], Guba[3])

- FSLOCA EM allows for larger sample sizes than previously used in ASTRUM EM
  - Larger sample sizes generate more information, and give more accurate results
  - [ ]a,c
    - The ASTRUM method remains appropriate

- Westinghouse has corrected the processing [ ]a,c

1. Wilks, S. S., 1941, "Determination of Sample Sizes for Setting Tolerance Limits," *The Annals of Mathematical Statistics*, Vol. 12, pp. 91-96.
2. Wald, A., 1943, "An Extension of Wilks' Method for Setting Tolerance Limits," *The Annals of Mathematical Statistics*, Vol. 14, pp. 45-55.
3. Guba, A., et al., 2003, "Statistical Aspects of Best Estimate Method-I," *Reliability Engineering and System Safety*, 80, pp. 217-232.

# Background: Statistical Analysis Objective

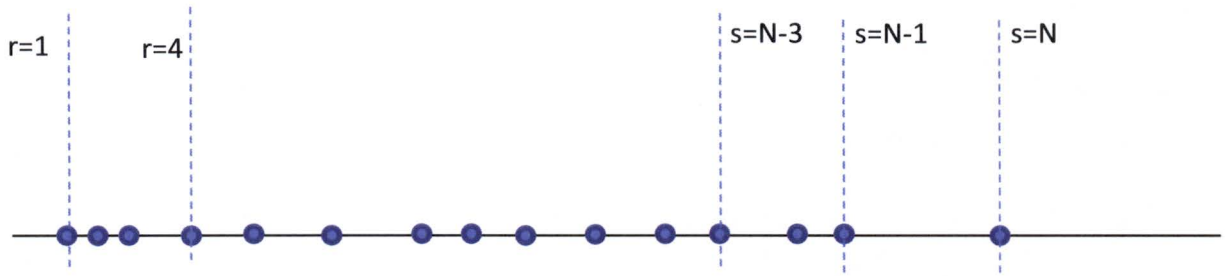
- Characterize the population of LOCA results – peak cladding temperature (PCT), maximum local oxidation (MLO), and core-wide oxidation (CWO) – with joint tolerance limits

- Determine upper tolerance limits that bound 95% of the population of results
  - Meaning: 95% of simulated LOCAs will have PCT, and MLO and CWO less than the tolerance limits
    - A 95% confidence level is expected
  - Success is when the tolerance limits are within 10 CFR 50.46 criteria limits

# Background: Wilks Theorem and Rank Statistics

- Rank the results in a random sample taken from a population. Assign a lower tolerance limit with case 'r' and an upper tolerance limit with case 's'.




- What is the confidence $\beta$ that a fraction of the population $\gamma$ is between tolerance limits defined by r and s, chosen among a sample size N?

$$\beta = 1 - I(\gamma, s - r, N - (s - r) + 1)$$

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# Background: Wald / Guba Multidimensional Tolerance Limits

- For a population with multiple outcomes (each observation in the sample has multiple dimensions), Guba (2003), using Wald (1943), gives:

$$\beta = 1 - I\left(\gamma, s_p - r_p, N - (s_p - r_p) + 1\right)$$

- This compares to the 1-dimensional formulation:

$$\beta = 1 - I(\gamma, s - r, N - (s - r) + 1)$$

- $s_p$ and $r_p$ represent the cases used to bound the last ($p^{th}$) dimension
  - The tolerance limits are defined with an "embedding" ("imbedding") process:
    - Rank the results of a sample based on one of the dimensions
    - Define a tolerance limit based on that dimension
    - Discard all observations at or above the defined tolerance limit
    - Re-rank the remaining observations based on the next dimension
    - Define another tolerance limit based on that next dimension
    - Discard all observations at or above the defined tolerance limit
    - Etc.

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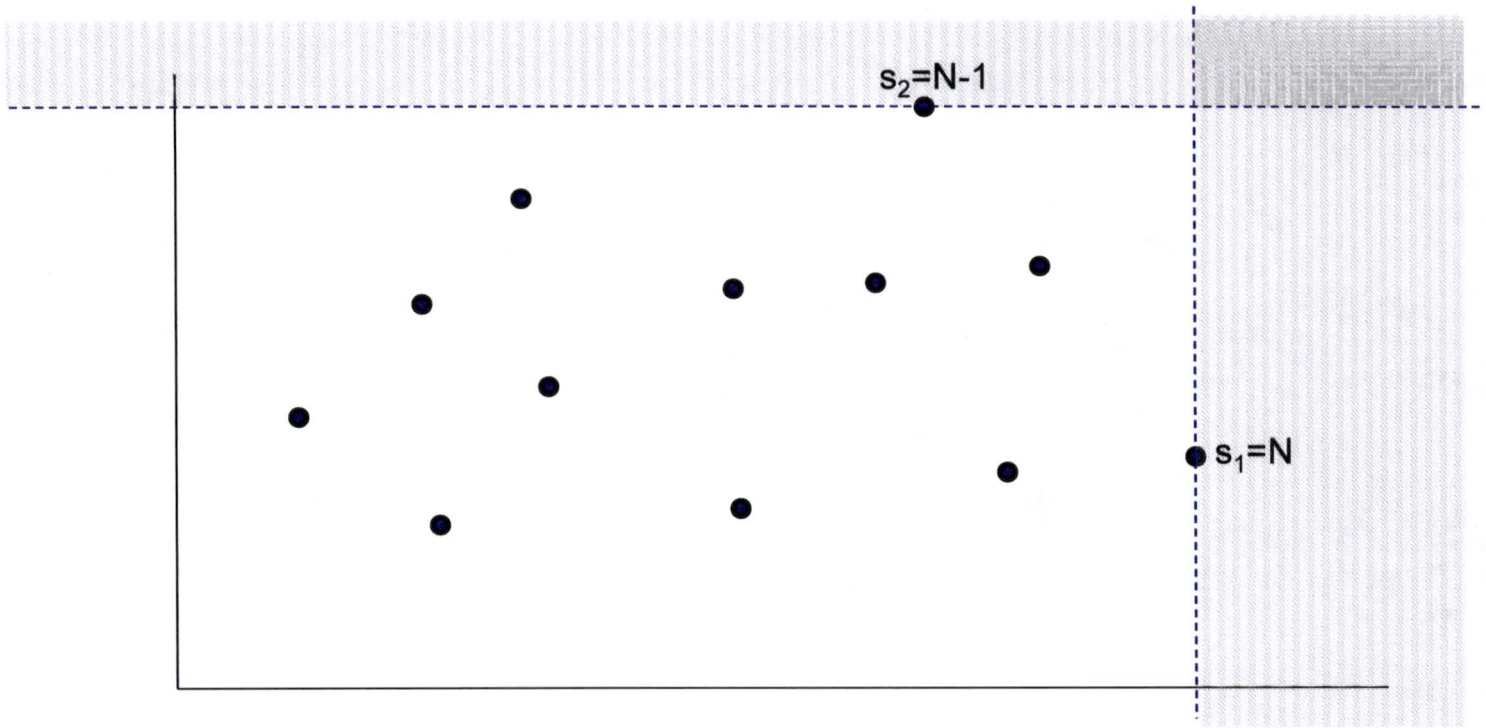
# Background: Embedding Process

- For the LOCA analysis, only define upper tolerance limits: $\beta = 1 - I(\gamma, s_p, N - s_p + 1)$



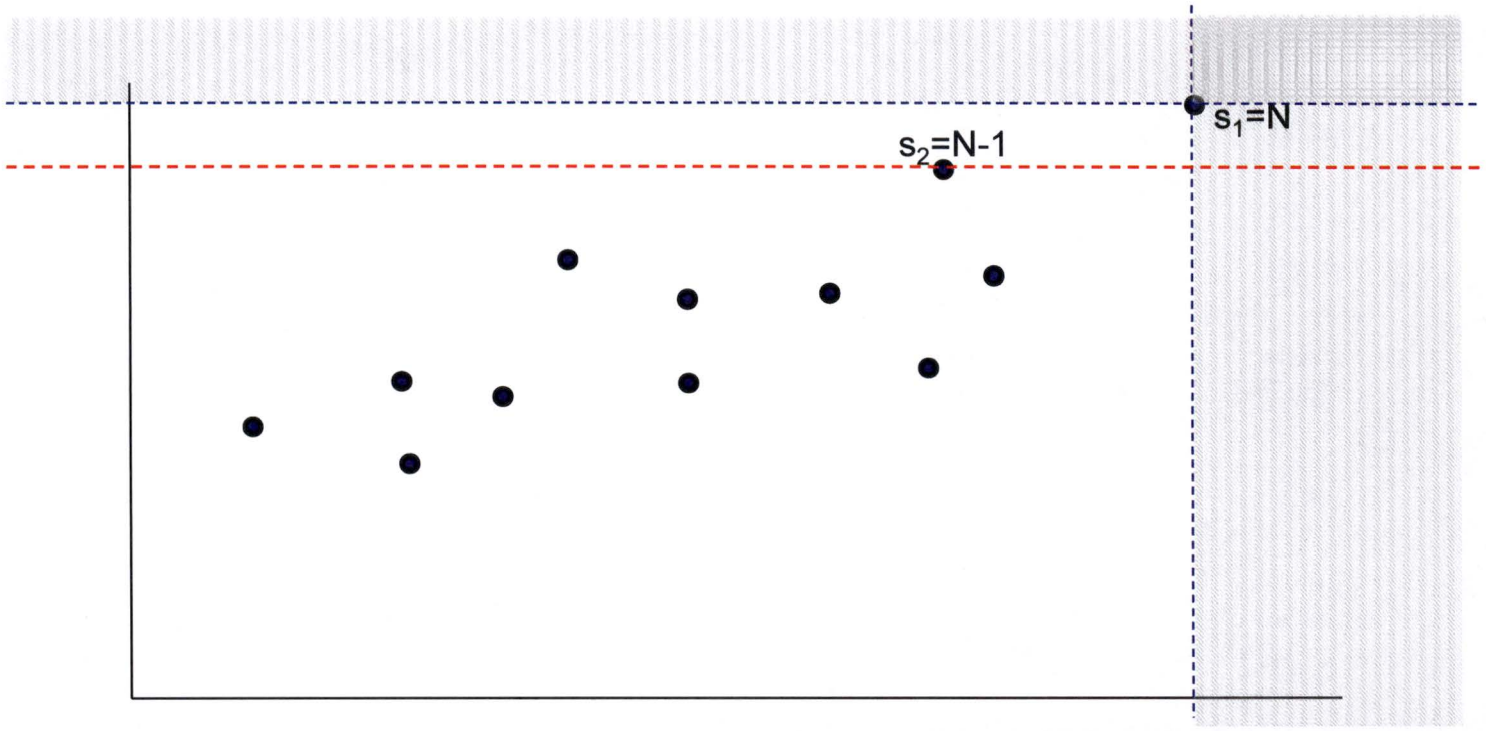

- If most extreme rank is used: $s_p = N - p + 1$

**Guba & Wald statistical proofs assume Embedding**

# Background: Independent Ranking Without Embedding

- Theory supports an embedding process; independent ranking can be conservative




**Independent ranking without embedding [ ]$^{a,c}$ is a simplified and conservative application of the theory**

# Background: Wald / Guba and $s_p$

- Direct application of the established method (Guba, 2003) utilizes only $s_p$

$$\beta = 1 - I(\gamma, s_p, N - s_p + 1)$$

- For a choice of sample size N, a value of $s_p$ exists for 95/95

**Table 1**

[ a,c

[ a,c

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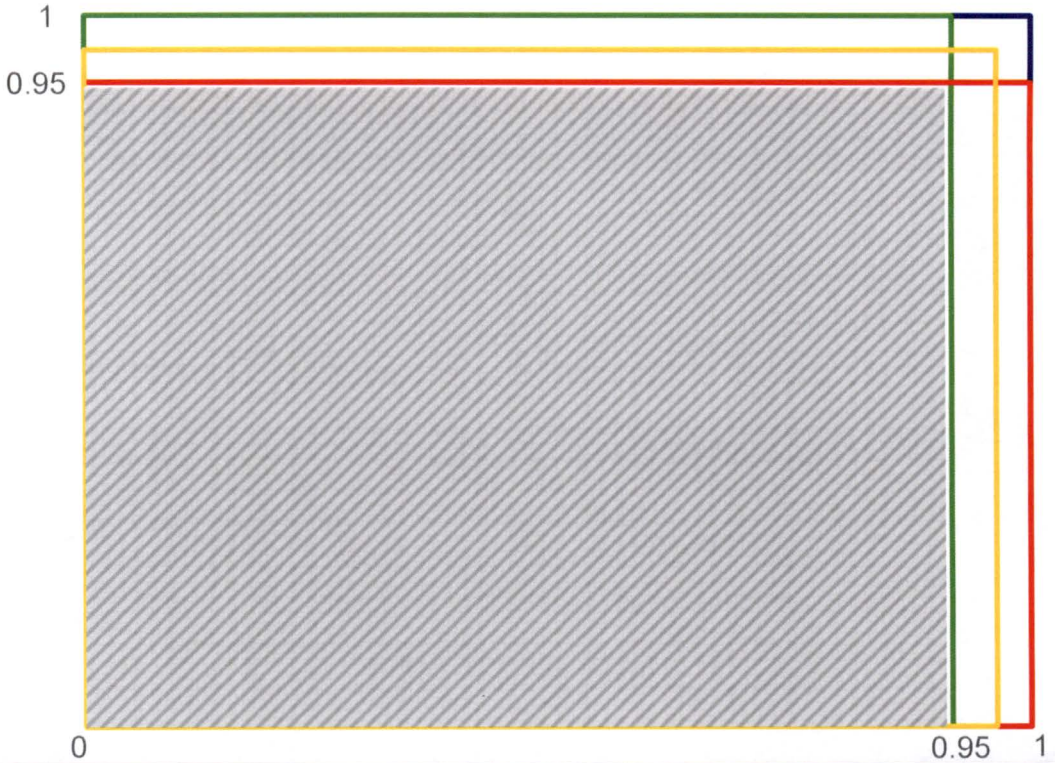
# Background: Embedding Process with Lower Ranks

- Assume [ ]a,c

a,c

# Background: Multidimensional Tolerance Limits




**Multiple solutions exist when defining multidimensional tolerance limits.**

**Minimum tolerance limit for each dimension corresponds to its own 95$^{th}$ quantile.**

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# Issue Description: FSLOCA EM Intended Approach

- FSLOCA EM: Larger sample sizes are used
  - Provides a more accurate representation of the true population
  - [ ]a,c

- [

]a,c

 

# Issue Description:
# FSLOCA EM [ ]a,c

a,c

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# Issue Description:
# FSLOCA EM [ ]a,c

a,c

 

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# Resolution:

[ ]a,c

a,c

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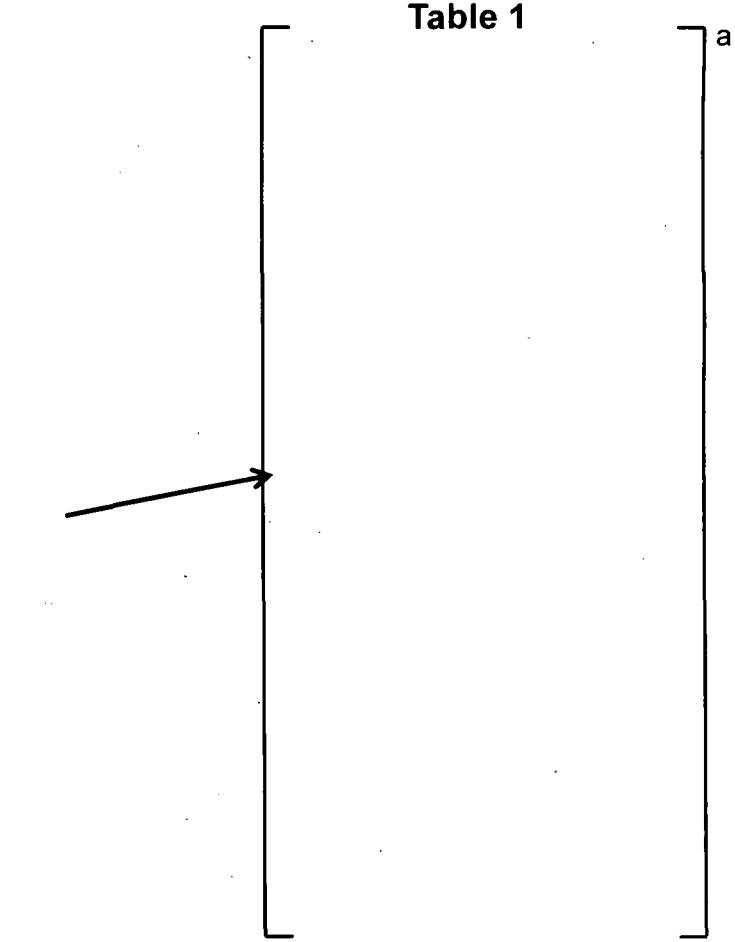
# Resolution: Corrected Method

- [

]a,c

Table 1

a,c



[

]a,c

# Resolution:
# Demonstration Plant Illustration

a,c

# Resolution: Empirical Testing

a,c

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# Next Steps

- [

]a,c

 

# Next Steps

- [

]a,c

- The NRC can take action as appropriate on the supplemental information package

- A licensee can reference the supplemental information package and any NRC action (if needed) in a plant specific application of the FSLOCA EM

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# Nomenclature

- $\beta$ confidence level
- $\gamma$ fraction of the population (probability)
- N sample size = number of observations in the sample
- p number of outcomes (dimensions)
- r rank statistic representing lower tolerance limit (r=1 for lowest)
- s rank statistic representing upper tolerance limit (s=N for highest)
- I incomplete beta function (Guba Equation 17)
- $s_p$ rank statistic representing upper tolerance limit in last ($p^{th}$) dimension
- $r_p$ rank statistic representing lower tolerance limit in last ($p^{th}$) dimension
- k rank for a single outcome (k = 1 for most limiting point)
- [ ]a,c