Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, Pennsylvania 16066
USA

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Direct tel: (412) 374-5130
e-mail: Hosackkl@westinghouse.com

LTR-NRC-19-36

July 12, 2019

Subject: Transmittal of Responses to the NRC Request for Additional Information for WCAP-18240-P, "Westinghouse Thermal Design Procedure (WTDP)" (Proprietary / Non-Proprietary)

References: 1. LTR-NRC-18-59 dated August 27, 2018, "Submittal of WCAP-18240-P / WCAP-18240- NP, Revision 0, 'Westinghouse Thermal Design Procedure (WTDP)' (Proprietary / Non-Proprietary)," ADAMS Accession Number ML18242A237 (package)

2. Request for Additional Information RE: Westinghouse Electric Company Topical Report WCAP-18240-P/WCAP-18240-NP, Revision 0, "Westinghouse Thermal Design Procedure (WTDP)," E. Lenning (NRC) to C. Zozula (Westinghouse), dated May 14, 2019 (EPID: L-2018- TOP-0033)

Reference 1 transmitted Proprietary and Non-Proprietary versions of WCAP-18240 to the NRC for review. Reference 2 requested additional information to support the NRC review. Enclosed are Proprietary and Non-Proprietary versions of the responses to the request for additional information (RAI) for WCAP-18240-P, "Westinghouse Thermal Design Procedure (WTDP)."

This submittal contains proprietary information of Westinghouse Electric Company LLC ("Westinghouse"). In conformance with the requirements of 10 CFR Section 2.390, as amended, of the Nuclear Regulatory Commission's ("Commission's") regulations, we are enclosing with this submittal an Affidavit. The Affidavit sets forth the basis on which the information identified as proprietary may be withheld from public disclosure by the Commission.

Correspondence with respect to the proprietary aspects of the this submittal or the Westinghouse Affidavit should reference AW-19-4916 and should be addressed to Camille T. Zozula, Manager, Infrastructure & Facilities Licensing, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 1, Suite 165, Cranberry Township, PA 16066.

Korey L. Hosack, Manager
Product Line Regulatory Support

cc: Ekaterina Lenning (NRC)
Dennis Morey (NRC)

Enclosures:

1. Affidavit AW-19-4916
2. Proprietary Information Notice and Copyright Notice
3. LTR-NRC-19-36 P-Attachment, Responses to the Request for Additional Information for WCAP-18240-P, "Westinghouse Thermal Design Procedure (WTDP)" (Proprietary)
4. LTR-NRC-19-36 NP-Attachment, Responses to the Request for Additional Information for WCAP-18240-NP, "Westinghouse Thermal Design Procedure (WTDP)" (Non-Proprietary)

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

COUNTY OF BUTLER:

(1) I, Korey L. Hosack, have been specifically delegated and authorized to apply for withholding and execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse).

(2) I am requesting the proprietary portions of LTR-NRC-19-36 be withheld from public disclosure under 10 CFR 2.390.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged, or as confidential commercial or financial information.

(4) Pursuant to 10 CFR 2.390, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse and is not customarily disclosed to the public.

(ii) Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar technical evaluation justifications and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

(5) Westinghouse has policies in place to identify proprietary information. Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

AFFIDAVIT

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage (e.g., by optimization or improved marketability).

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

(6) The attached documents are bracketed and marked to indicate the bases for withholding. The justification for withholding is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (5)(a) through (f) of this Affidavit.

AFFIDAVIT

I declare that the averments of fact set forth in this Affidavit are true and correct to the best of my knowledge, information, and belief.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on: 20190220

Korey L. Hosack, Manager
Product Line Regulatory Support

PROPRIETARY INFORMATION NOTICE

Transmitted herewith are the proprietary and non-proprietary versions of a document, furnished to the NRC in connection with the review of WCAP-18240-P / NP, "Westinghouse Thermal Design Procedure (WTDP)."

In order to conform to the requirements of 10 CFR 2.390 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (5)(a) through (5)(f) of the Affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).

COPYRIGHT NOTICE

Responses to the Request for Additional Information for WCAP-18240-NP, "Westinghouse Thermal Design Procedure (WTDP)"

(Non-Proprietary)

July 2019

Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, PA 16066

Response to Request for Additional Information (RAI) on WCAP-18240-P, "Westinghouse Thermal Design Procedure"

1) RAI-WTDP-01

Clarification

Provide the following clarifications:

a) *Section 2*
   a. *Rewrite the equations in a style more consistent with the previous topical reports. The equations should use common mathematical notation and each term in the equation (e.g., variables, functions, indices) should be fully defined and consistent among all of the equations.*
   b. *For random variables that are defined by probability distributions that use the mean and standard deviation or upper and lower bound, discuss how each parameter of the distribution is determined.*
   c. *Clarify the equations to specify what set of inputs are used to generate the nominal case and how that set of inputs is changed to generate the perturbed case (i.e., how the conditions for the second sub-case are determined).*

b) *Section 3*
   a. *Provide additional detail on how the fuel damage probability table (denoted the DNB probability distribution in the topical report) is defined. [*

   ] ^{a,c}
   b. *Provide additional detail on how the fuel census table, the DNBR versus fuel rod power table, and the fuel damage probability table are combined to generate the expected number of rods experiencing fuel damage due to DNB. Provide a sample calculation showing the entire process for one power interval.*

Response to each question of RAI-WTDP-01 is provided below.

a) Section 2
   a. *Rewrite the equations in a style more consistent with the previous topical reports. The equations should use common mathematical notation and each term in the equation (e.g., variables, functions, indices) should be fully defined and consistent among all of the equations.*

Response:

The process of the 95/95 DNBR limit calculation is rewritten below.

Step 1 – Sampling of State Parameters from Uniform Distributions for Core Condition

The state parameters include [ ]a,c The parameter ranges are plant specific and cover normal operation and DNB-limiting conditions in the non-LOCA accident analysis for which the statistical DNBR limit is applied. The state parameters are sampled [ ]a,c from their respective ranges to obtain a reactor core condition:

[ ] a,c

A DNBR is calculated using the sampled core condition and nominal values for the system parameters. The sampled core condition is not used in subsequent calculations if [ ]a,c

Step 2 - Parameter Sampling from Uncertainty Distributions

The system parameters can be [ ]a,c engineering enthalpy rise hot channel factor, fuel rod pitch, fuel rod diameter, engineering heat flux hot channel factor, guide thimble tube diameter and grid spacer loss coefficients. A perturbed either system or state parameter value is obtained by sampling from either a uniform or a normal distribution of its uncertainty.

If it is a uniform distribution, the perturbed value is calculated by sampling a uniformly distributed random number and combining it with the difference between the upper and lower ranges of the parameter as follows:

[ ] a,c

If it is a normal distribution, the perturbed value is calculated by sampling a normally distributed random number and combining it with the mean and the standard deviation for the parameter:

[ ] a,c

[ ] a,c

Based on the DNBR at the reactor core condition with the perturbed parameter values and the DNBR from Step 1, a ΔDNBR for Case "i" is obtained as follows:

[ ] a,c

Equation R-4 is the equivalent of Equations 4.1 and 5.1 of Reference R-1, using explicitly calculated DNBR values in place of response surface DNBR values.

Step 3 - Sampled DNBR

A sampled DNBR value is obtained from a normal distribution based on the CHF correlation statistics that consists of a DNBR mean value and a standard deviation. A sampled CHF DNBR for Case "i" is calculated:

[ ] a,c

Effects of the system parameter uncertainties ($\Delta DNBR_i$, Equation R-4) are combined with the sampled CHF DNBR value (CHF $DNBR_i$, Equation R-5) and the subchannel code uncertainty to obtain a DNBR value for Case "i":

[ ] a,c

Equation R-6 is the equivalent of Equation 5.2 of Reference R-1. The Subchannel Code $Uncertainty_i$ is a sampled multiplicative subchannel code uncertainty factor for case "i",

consistent with the code uncertainties applied in the statistical DNBR calculations (References R-1 and R-2):

[ ]a,c

Step 4 - DNBR Limit Calculation

A DNBR limit calculation is performed based on the distribution of the DNBR values obtained from Equation R-6. The limit is determined as either normal or non-parametric upper 95/95 tolerance limit of the $DNBR_i$ distribution.

Normal DNBR Distribution

The assessment of normality is based on the probability of the D-Prime (D') test statistic (Reference R-3) for a normal distribution. To perform this assessment, probability regions for the D-Prime statistic probability are defined as shown pictorially in Figure R-1. [

]a,c

When the $DNBR_i$ distribution has been determined to be a normal distribution, the following two methods can be used to calculate the 95/95 DNBR limit. Both methods use the mean (μ) and standard deviation (σ) of the DNBR distribution and both must account for the finite number samples in the DNBR distribution:

[ ]a,c

[ ] a,c

The 95/95 DNBR limits from the two methods above are similar. The "raw" DNBR limit is further adjusted to account for any deterministic DNBR penalty not considered in the statistical DNBR limit calculation, such as the rod bow DNBR penalty as illustrated below:

[ ] a,c

Any other deterministic adjustment can be applied in a similar manner.

Non-Normal DNBR Distribution

If the $DNBR_i$ distribution from Equation R-6 cannot be determined to be a normal distribution using the D' test statistic, non-parametric statistics are used to obtain a non-parametric upper 95/95 tolerance limit. As described in Section 2.3.2 of Reference R-2, one-sided 95/95 tolerance limits are calculated by using non-parametric techniques based on order statistics and the binomial probability distribution. The DNBR distribution is first ordered from the smallest to the largest value. The binomial distribution is used to calculate a locator "L" from the ordered DNBR distribution which estimates the one-sided tolerance limit at a 95/95 probability / confidence level. The one-sided upper 95/95 tolerance limit, $UTL_{95/95}$, is obtained by selecting the DNBR value (from the ordered DNBR distribution) corresponding to the locator "L".

A non-parametric "kσ" can be obtained by using the mean of DNBR distribution, the one-sided upper 95/95 tolerance limit, and rearranging the following equation:

[ ] a,c

Similar to Equation R-14, the DNBR limit value is further adjusted to account for any deterministic DNBR penalty, such as the fuel rod bow penalty:

[ ] a,c

Indeterminate DNBR Distribution

If the $DNBR_i$ distribution is indeterminate [ ] a,c both normal and non-parametric 95/95 DNBR limits are calculated using the above methods. The more conservative (larger) of the two 95/95 DNBR limits is then chosen as the 95/95 DNBR limit.

Compliance to Approved CHF Correlation DNBR Limit

As described in Reference R-4, a CHF correlation DNBR limit is typically obtained by the ratios of measured CHF values to predicted CHF values (M/P) using the CHF correlation. The mean and standard deviation of the resulting M/P distribution are calculated based on the CHF database. Using an Owen's k-value for the number of measurements, a 95th percentile at the 95th confidence level of the normal distribution, or the 95/95 DNBR limit of the distribution, can be calculated as a predicted to measured CHF (P/M) or DNBR limit as follows:

$$CHF\ DNBR_{95/95}\ Limit\ = \frac{1}{Mean_{M/P} - (k * Standard\ Deviation_{M/P})} \quad \text{(Eq. R-17)}$$

The approved CHF correlation DNBR limit may include additional conservative adjustments as a bias, so that the resultant limit is more conservative than the value obtained from Equation R-17.

As input to the statistical DNBR limit calculation, the DNBR (P/M) mean and standard deviation values of the CHF correlation must preserve the approved CHF correlation DNBR limit:

$$CHF\ DNBR_{95/95}\ Limit_{Approved}\ = \ CHF\ DNBR\ Mean + 1.645 * CHF\ DNBR\ Sigma \quad \text{(Eq. R-18)}$$

In the above equation, the CHF DNBR Sigma is defined as [

]a,c

[ ]a,c

The CHF DNBR mean value is obtained by subtracting 1.645*(CHF DNBR sigma) from the approved 95/95 correlation DNBR limit:

$$CHF\ DNBR\ Mean = \ CHF\ DNBR_{95/95}\ Limit_{Approved}\ - 1.645 * CHF\ DNBR\ Sigma \quad \text{(Eq. R-20)}$$

Summarizing, CHF DNBR values are sampled from a normal distribution based on the standard deviation and the mean values in Equations R-19 and R-20, respectively.

b. *For random variables that are defined by probability distributions that use the mean and standard deviation or upper and lower bound, discuss how each parameter of the distribution is determined.*

Response:

Uncertainties in the system and state parameters as input to the 95/95 DNBR limit calculation are discussed in Section 2.1 of the topical report. Determination of the parameters and their uncertainties in the sample calculation for the Westinghouse-NSSS plant in Attachment A, including its mean, range, and standard deviation is described in the table below. Additional parameter uncertainties are incorporated in Combustion Engineering CE-NSSS plant applications and their values are plant specific. A one-sided normal distribution was conservatively assumed for some parametric uncertainties. The numerical values in the table below are consistent with those listed in Table A-1.

Parameter	Mean	Uncertainty Distribution	Random Uncertainty Range	Standard Deviation
Engineering Enthalpy Rise Hot Channel Factor ($F^{E}_{\Delta H}$)	1.0			
DNB Correlation	1.031 Adjusted (Eq. R-20)			
Subchannel Code and Modeling	1.0			
Reactor Core Power	1.0			
Reactor Power Radial Peaking Factor ($F^{N}_{\Delta H}$)	1.635			
Reactor Core Inlet Temperature	556.6			
Reactor Core Inlet Flow (Fraction)	1.0			
Reactor Core Bypass Flow (Fraction)	0.924			
Reactor Pressure	2270			

a,c

c. *Clarify the equations to specify what set of inputs are used to generate the nominal case and how that set of inputs is changed to generate the perturbed case (i.e., how the conditions for the second sub-case are determined).*

Response:

The following parameters are sampled from [ ] a,c in plant-specific ranges for generating the nominal case, or the first sub-case in the DNBR limit calculation:

[ ] a,c

The plant-specific ranges cover the plant DNB-limiting accident statepoints for which the DNBR limit is applied.

Uncertainties in the parameters listed in Section 2.1 of the topical report can be sampled from the uncertainty distributions for generating a perturbed case, or the second sub-case, from the nominal case.

Not all the uncertainties in Section 2.1 of the report are incorporated into all the DNBR limit calculations. The uncertainty input is justified on a plant-specific basis. A ΔDNBR is obtained from the DNBR difference between the perturbed case and the nominal case.

b) Section 3

   a. *Provide additional detail on how the fuel damage probability table (denoted the DNB probability distribution in the topical report) is defined. [*

] a,c

Response:

The DNB probability distribution is described below.

The probability of a fuel rod experiencing DNB is calculated as a function of DNBR. The probability density function can be represented by the standard normal (Gaussian) distribution as follows:

$$F(Z) = \frac{1}{\sqrt{2\pi}} e^{-\left(\frac{Z^2}{2}\right)} \quad \text{(Eq. R-21)}$$

where Z = (DNBR - μ)/σ
μ = DNBR mean
σ = Standard deviation.

Integration of the above equation from Z to +∞ gives the probability of a fuel rod experiencing DNB corresponding to Z or DNBR value of the fuel rod. An integrated probability from -∞ to 0 or from 0 to +∞ is 0.5. The DNBR mean (μ) is selected [ ]a,c The DNBR mean is greater than or equal to the value obtained using Equation R-16.

Two different standard deviations were used for conservatively maximizing the number of fuel rods in DNB. [

] a,c

a. The rods-in-DNB calculation in Attachment C is further explained below.

[ ] a,c

a,c

a,c

2) RAI-WTDP-02

Epistemic Uncertainties

What is the impact on the DNBR limit of assuming a [

] a,c

How does Westinghouse ensure that the DNBR SAFDL is satisfied for every statepoint that the reactor operates at during a cycle, and is not simply satisfied based on the initially assumed set of possible conditions?

Response:

Measurement uncertainties of the reactor design parameters should follow normal distributions. For the DNBR limit determination, a uniform distribution of a parameter is assumed [

] a,c As compared to the standard deviation of a normal distribution derived from the uncertainty range, which is typically defined as the absolute value of the uncertainty divided by 2 or 1.96, the standard deviation of the uniform distribution would be the uncertainty divided 1.732 (√3) as input to the DNBR limit calculation. The resultant 95/95 DNBR limit is slightly higher with the uniform distribution of the parameter uncertainties, and therefore is more conservative.

A conservative DNBR SAFDL is satisfied for a domain of the core parameters [

] a,c

3) RAI-WTDP-03

Spatial Sensitivity

Westinghouse's current method for determining the DNBR sensitivity is to use a [

] ^{a,c}

Response:

As described in Section 2 of the topical report and supplemental information in response to RAI-WTDP-01, the DNBR sensitivity is determined from the value of ΔDNBR at each condition sampled from [
]^{a,c} in the plant design domain. The ΔDNBR is applied to a sampled DNBR from [
] ^{a,c} for determining the 95/95 DNBR limit.

A method sensitivity study was performed by selecting 50 cases [
] ^{a,c} where the $DNBR_i$ values were greater than the 95/95 DNBR limit. In each case, additional DNBR calculations were performed to determine the 95/95 DNBR sensitivity based on about 5000 ΔDNBR values from sampling of the parameter uncertainties. The standard deviations of the uncertainties were the same as those in the original calculations in Table A-1, except for some parameters [
] ^{a,c} The resultant 95/95 DNBR values of the sensitivity cases are listed in Table R-2 for comparison with the original values. A comparison of the $DNBR_i$ distributions is shown in Figure R-2.

The comparison shows similar $DNBR_i$ distributions between the 95/95 ΔDNBR sensitivity result and the result from the sample calculation in Attachment A. [
] ^{a,c}

4) RAI-WTDP-04

Criteria for case exclusion

What criteria are used to ensure that code cases which fail to execute or produce an error are reasonable to exclude from the statistical analysis?

Response:

In the statistical analysis using the Westinghouse Thermal Design Procedure (WTDP), the following criteria are used:

- DNBR calculations are performed within the approved parameter range of a CHF correlation. [

  ] a,c

- Any case not converged in the DNBR calculation, if ever occurred, is not used for generating a ΔDNBR for the $DNBR_i$ distribution. [

  ] a,c

References:

R-1 "Statistical Combination of Uncertainties Part 1: Combination of System Parameter Uncertainties in Thermal Margin Analyses for San Onofre Nuclear Units 2 and 3," CEN-283(S)-P Revision 0, Westinghouse Electric Company, LLC, June 1984.

R-2 "Statistical Combination of Uncertainties Part 2: Uncertainty Analysis of Limiting Safety System Settings for San Onofre Nuclear Units 2 and 3," CEN-283(S)-P Revision 0, Westinghouse Electric Company, LLC, October 1984.

R-3 "American National Standard Assessment of the Assumption of Normality (Employing Individual Observed Values)," ANSI N15.15-1974, American National Standard Institute, Inc., October 1973.

R-4 "Fuel Safety Limit Calculation Inputs Were Inconsistent with NRC-Approved Correlation Limit Values," Information Notice 2014-1, the United States Nuclear Regulatory Commission, February 2014.

Table R-1 - Result Summary of Locked Rotor Rods-in-DNB Case in Attachment C

a,c

Fuel Rod Power Interval	Number of Fuel Rods	DNBR	DNB Probability	Number Fuel Rods in DNB

Table R-2 – Comparison of ΔDNBR of Sample Case in Attachment A

a,c

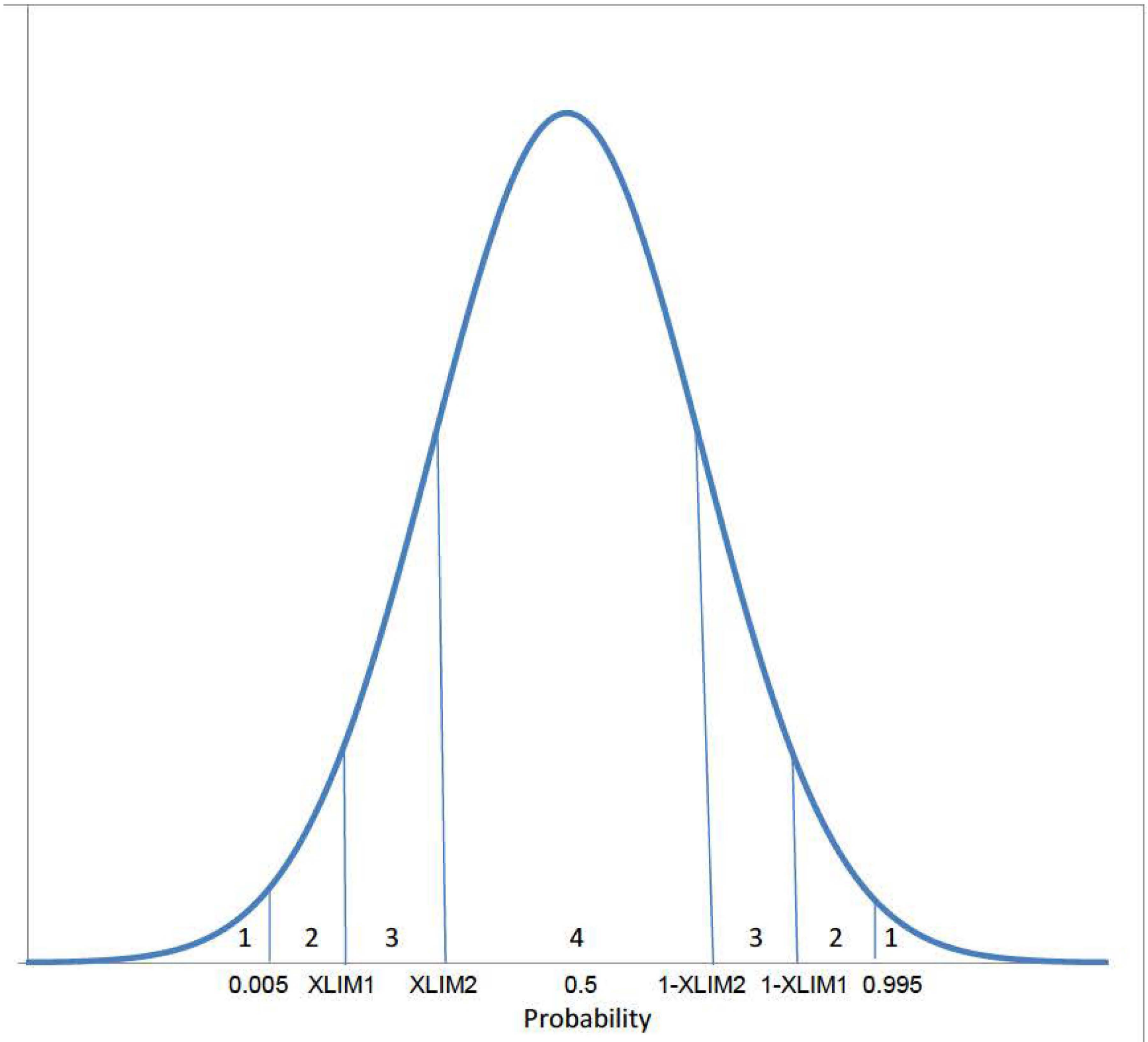
Sampled DNBR from CHF Correlation Statistics	ΔDNBR of Sample Case in Attachment A	DNBRs from Case in Attachment A	95/95 ΔDNBR Of 5000 Sampled Cases of Uncertainties	DNBRs from 95/95 ΔDNBR of 5000 Cases

Table R-2 (continued)

Sampled DNBR from CHF Correlation Statistics	ΔDNBR of Sample Case in Attachment A	DNBRs from Case in Attachment A	95/95 ΔDNBR Of 5000 Sampled Cases of Uncertainties	DNBRs from 95/95 ΔDNBR of 5000 Cases

a,c

Figure R-1 - D-Prime Statistics Probability Regions



[ ]^{a,c}

Figure R-2 – Comparison of $DNBR_i$ Distributions from the Sensitivity Study

a,c