Pre-Submittal Meeting Slides for Topical Report WCAP-18240-P, "Westinghouse Thermal Design Procedure (WTDP)," (Non-Proprietary)

July 18, 2018

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Pre-Submittal Meeting on WTDP (Westinghouse Thermal Design Procedure) Topical Report WCAP-18240-P

July 18, 2018

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AGENDA

- Introductions
- Acronyms
- Problem Statement and Need for Change
- Purpose and Scope
- Technical Overview
- DNBR Limit Calculation – Inputs and Process
- Statistical Rods-in-DNB – Inputs and Process
- Intended Applications
- Sample Results
- Conditions for WTDP Applications
- Topical Report Outline
- Summary

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Technical Acronyms

AO	Axial Offset
ASI	Axial Shape Index (-AO)
CE	Combustion Engineering
CETOP-D	Simplified TORC T/H code in 4-Channel Core Representation
CHF	Critical Heat Flux
COLSS	Core Operating Limit Supervisory System
CPC	Core Protection Calculator
DNB	Departure from Nucleate Boiling
DNBR	Departure from Nucleate Boiling Ratio
$F_{\Delta H}$	Enthalpy Rise Hot Channel Factor
LOCA	Loss of Coolant Accident
NGF	Next Generation Fuel (16x16 CE-NSSS design)
NSSS	Nuclear Steam Supply System
MSCU	Modified SCU (CE-NSSS)
PWR	Pressurized Water Reactor
RTDP	Revised Thermal Design Procedure (Westinghouse-NSSS)
SAL	Safety Analysis Limit
SCU	Statistical Combination of Uncertainties (CE-NSSS)
SER	Safety Evaluation Report
T/H	Thermal-Hydraulic (Design)
$THUNC_{SD}$	Standard deviation of T/H code uncertainties
TORC	T/H Subchannel code used for CE-NSSS
VVER	Water-Water Energetic Reactor (Russian designed PWR)
VIPRE-W	Westinghouse Version of VIPRE-01 T/H Subchannel Code
WTDP	Westinghouse Thermal Design Procedure (Statistical DNB Method)
σ_{GM}	Standard deviation of DNB probability distribution for DNBR $\geq$ mean
σ_{LM}	Standard deviation of DNB probability distribution for DNBR < mean

Problem Statement and Need for Change

- Combustion Engineering (CE) and Westinghouse NSSS plants use different methods for DNBR limit calculations and rods-in-DNB calculations – [ ]a,c

- The NRC approval of the CE-NSSS methods is often documented within individual plant licensing bases, rather than in a generic topical report – [ ]a,c

- Some plant analysis results are overly conservative and reloads/operations are penalized unnecessarily due to [ ]a,c

Purpose and Scope

- One topical report which consolidates existing approved methods for all PWRs would facilitate future analysis work and review activities
  - DNBR limit for Condition I and II events
  - Statistical rods-in-DNB evaluations for non-LOCA Condition III and IV events in support of radiological consequence analyses

- Applicable to all PWR designs (CE-NSSS, Westinghouse-NSSS, VVER, **AP1000**® reactors, APR1400)

- Improved ability to quantify analysis margin:
  - CE-NSSS DNBR limit calculation
  - Westinghouse-NSSS rods-in-DNB for rod ejection and locked rotor

Technical Overview

- WTDP based on existing CE-PWR statistical methods enhanced with VIPRE-W code:
  - 95/95 DNBR Limit
  - Rods-in-DNB convolution method for Condition III / IV events
- Maintains full compliance with current regulatory requirements and guidelines, including
  - NUREG-0800 Rev. 2 Section 4.4 (T/H Design)
  - NRC Information Notice 2014-01, "Fuel Safety Limit Calculation Inputs Were Inconsistent With NRC-Approved Correlation Limit Values"
- Topical report to be submitted for approval of extended applications of existing NRC-approved methods

WTDP DNBR Limit Calculation - Input

- DNB correlation limit as approved by the NRC
- Parameter uncertainties
  - Plant-specific system (fuel-related) parameters
  - Plant-specific state (operating condition and peaking factors) parameters
- Code uncertainty
- Rod bow penalty [ ]a,c
- Design parameter ranges
  - Power
  - Pressure
  - Flow
  - T-in
  - [ ]a,c
  - [ ]a,c

WTDP DNBR Limit Calculation – Process

- Sample reference condition and calculate DNBR, [
  ]a,c
- Additional sampling of [
  ]a,c
- [
  ]a,c
- DNBR distribution generated with minimum of [
  ]a,c

WTDP for Statistical Rods-in-DNB Input and Process

- Based on existing method applied to CE-NSSS plants
  - Credits the fact that there is only 5% probability with 95% confidence that DNB will occur at the 95/95 design DNBR limit
  - No change to conservative assumption of fuel failure when reaching DNB

- DNB probability is determined by integrating the DNBR Limit probability density functions
  - [ ]a,c
  - [ ]a,c
  - [ ]a,c
  - [ ]a,c

- % rods-in-DNB is determined based on probability distribution and following input:
  - [ ]a,c
  - [ ]a,c
  - [ ]a,c

WTDP Intended Applications – Westinghouse-NSSS

- Applications will be on forward-fit basis for plants using RTDP:
  - Monte Carlo sampling for DNBR limit, and/or
  - Rods-in-DNB statistical convolution for Condition IV events

- Implementation requires [ ]^{a,c} including:
  - Approved T/H code and DNB correlations
  - Design interface for reload evaluations

- Flexible input for applications with advanced methods
  - Input of uncertainty in new parameter justified on plant specific basis
  - Can be used with new, approved DNB correlations, transient evaluation methods, etc.
  - *Applicable to new plant designs*

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WTDP Intended Applications – CE-NSSS

- Applications to CE-NSSS currently using SCU/MSCU
  - Simplify DNBR limit calculation process to eliminate response surface as an intermediate step due to TORC code limitations
  - To be implemented with VIPRE-W code

- Support CETOP-D replacement with VIPRE-W under currently NRC-approved setpoint methodology and SER conditions
  - WCAP-16500-P-A, CE-NGF fuel topical report
  - WCAP-16500-P-A Supplement 1 Revision 1
  - [ ]a,c
  - [ ]a,c

Sample Results: WTDP 95/95 DNBR Limit Westinghouse-NSSS 4-Loop / 17x17 Vantage+ Fuel

Method	DNB Correlation	# of Code Runs	95/95 DNBR Limit	Difference in DNBR Limit
RTDP	WRB-2	[ ]a,c	[ ]a,c	
WTDP	WRB-2	[ ]a,c	[ ]a,c	[ ]a,c
		[ ]a,c	[ ]a,c	[ ]a,c

- [ ]a,c

Sample Results: WTDP 95/95 DNBR Limit CE-NSSS System 80 / 16x16 CE16NGF Fuel

Method	DNB Correlation	# of Code Runs	95/95 DNBR Limit	Difference in DNBR Limit
TORC/SCU	WSSV-T	[ ]a,c	[ ]a,c	N/A
VIPRE-W / WTDP	WSSV	[ ]a,c	[ ]a,c	[ ]a,c

- [

]a,c

Sample Results
WTDP Rods-in-DNB Calculations

Event	W-NSSS / Fuel	Rods-in-DNB Deterministic Method	WTDP Rods-in-DNB Statistical Method
Locked Rotor	4-Loop 17x17 V+	[ ]a,c	[ ]a,c

Implementation Prerequisites for WTDP Applications

- WTDP application to a plant, as an alternative to either RTDP or SCU, will be based on the following conditions:
  - WTDP shall be used with an approved subchannel code and DNB correlation;
  - Input of parameter uncertainties to the 95/95 DNBR limit calculation shall be justified on a plant specific basis;
  - Input of DNBR limit to the rods-in-DNB evaluation shall be justified on a plant specific basis;
  - The plant application shall reference this report for the statistical DNBR limit method or rods-in-DNB calculation method;
  - For CE-NSSS plants using the VIPRE-W code in replacement of the CETOP-D code, the WTDP application shall be within the limits and conditions of the CE-NSSS setpoint methodology as defined in WCAP-16500-P-A Supplement 1 Revision 1.

Topical Report Outline

- Report Outline:
  - Introduction & Applicable Regulatory Requirements
  - Method for DNBR Limit Calculation
  - Method for Rods-In-DNB Calculation
  - Intended Applications
    - Westinghouse-NSSS plant DNBR limit
    - CE-NSSS plant DNBR limit
    - Non-LOCA rods-in-DNB events
  - Summary
  - Attachments of sample calculations

Licensee Implementation

- CE-NSSS
  - License amendment required to revise list of COLR Technical Specification references with respect to CETOP-D and TORC
  - Add reference to VIPRE-W (WCAP-14565-P-A), where applicable

- Westinghouse-NSSS
  - License amendment required to change COLR Technical Specification references, where currently listed, from ITDP (WCAP-8567-P-A) or RTDP (WCAP-11397-P-A) to approved version of WTDP (WCAP-18240-P) following approval
  - Add VIPRE-W (WCAP-14565-P-A) to THINC-IV reference citations (e.g., WCAP-7956-A, WCAP-8054-P-A, WCAP-12330-P-A), where applicable

Summary

- Executive summary provided prior to the meeting (LTR-NRC-18-41)
- WTDP consolidates existing statistical DNB methods for all PWR applications into one topical report
  - 95/95 DNBR limit
  - Rods-in-DNB for Conditions III and IV events
- Analysis and review efficiencies
  - Improved ability to quantify analysis margin
  - Unnecessary penalties eliminated
- WTDP compatible with current design interfaces and complementary with Westinghouse advanced technologies
- Topical report to be submitted no later than August 30, 2018 for domestic plant applications

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