Westinghouse Thermal Design Procedure (WTDP) Pre-Submittal Meeting

August 29, 2024

PaloVerde™
GENERATING STATION

Agenda

- Introduction
- Case for Action
- Background
- DNBR Limit
- Fuel Failure Analysis
- Setpoint Methodology
- Proposed Changes
- Proposed Schedule
- Questions & Feedback

Case for Action

The proposed Palo Verde license amendment adopts advanced Westinghouse methodology to modernize reactor core reload design

- WCAP-18240-P-A, “Westinghouse Thermal Design Procedure (WTDP)” (2020)
  - Applicable to Westinghouse and Combustion Engineering Pressurized Water Reactors (PWRs)
- Palo Verde is lead plant for licensing application
- Submittal will address both Westinghouse and Framatome fuel
  - Westinghouse CE16NGF (2018, ML17319A103 and ML17319A107)
  - Framatome CE16HTP (2020, ML20031C947 and ML20031C968)

Background

WCAP-18240-P-A, "Westinghouse Thermal Design Procedure (WTDP)"

- Methodology for Departure from Nucleate Boiling Ratio (DNBR) Specified Acceptable Fuel Design Limit (SAFDL)
  - ANSI N18.2 Conditions I (normal operation) and II (moderate frequency events)
- Methodology for rods-in-DNB fuel failure analysis
  - ANSI N18.2 Conditions III (infrequent events) and IV (limiting faults), except Loss of Coolant Accidents (LOCAs)
- Methodology for Core Protection Calculator System (CPCS) and Core Operating Limit Supervisory System (COLSS) setpoints

Background

WCAP-18240-P-A, “Westinghouse Thermal Design Procedure (WTDP)”

- Evolutionary change relative to current methods
  - WCAP references Palo Verde Updated Final Safety Analysis Report (UFSAR)
- Leverages improvements in computational resources and automation
  - More efficient core reload analysis process
- Reduces DNBR SAFDLs
- May reduce cycle-specific fuel failure predictions for non-LOCA accidents

DNBR Limit

Current Methodology

- Technical Specification (TS) 5.6.5, “Core Operating Limits Report (COLR)”
  - Combustion Engineering CEN-356(V)-P-A, “Modified Statistical Combination of Uncertainties” (MSCU)
  - Related methodologies
    - Thermal-hydraulic analysis codes
    - Critical heat flux (CHF) correlations
    - Core inlet flow distribution
- NRC Information Notice 2014-01, “Fuel Safety Limit Calculation Inputs Were Inconsistent with NRC-Approved Correlation Limit Values”

DNBR Limit

Current Methodology

- MSCU statistically combines uncertainties associated with system parameters and state parameters to determine CPCS/COLSS setpoints and overall uncertainty factors
  - System parameters – Related to fuel type (for example, fuel rod pitch, fuel rod outside diameter, CHF correlations)
  - State parameters – Related to plant operating conditions (for example, core power distribution, reactor coolant pressure, core inlet flow)

DNBR Limit

Current Methodology

- MSCU involves numerous thermal-hydraulic simulations to evaluate the effects of parameter perturbations
- Statistical analysis yields a DNBR probability density function (pdf) and SAFDL
  - DNBR pdf – Probability of fuel failure vs. DNBR
  - DNBR SAFDL – At least a 95% probability, at a 95% confidence level, that the hot fuel rod in the core does not experience DNBR during normal operation or Anticipated Operational Occurrences (AOOs)

DNBR Limit

Current Methodology

- First use of MSCU was Palo Verde Unit 1 Cycle 2 (1987, ML021690079)
  - Number of simulations constrained by computational resources and costs
  - Proprietary conservative biases reduced the number of required simulations
- Fuel type analytical limits
  - CE16STD: DNBR SAFDL = 1.34
    - TORC with CE-1 (2001, ML010880411)
  - CE16NGF: DNBR SAFDL = 1.25
    - VIPRE with WSSV and ABB-NV (2018, ML17319A103 and ML17319A107)
  - CE16HTP: DNBR SAFDL = 1.27
    - VIPRE with BHTP (2020, ML20031C947 and ML20031C968)

DNBR Limit

WTDP Methodology

- Removes conservative biases from current MSCU methodology
  - CE16NGF: New DNBR SAFDL = 1.20
  - CE16HTP: New DNBR SAFDL = 1.20
  - DNBR pdf differs between the two fuel types
- CE16STD DNBR SAFDL of 1.34 will remain in CPCS/COLSS
  - Same approach used when licensing CE16NGF and CE16HTP for Palo Verde
  - Plant hardware limitations mentioned in TS Bases 2.1.1, "Reactor Core Safety Limits (SLs)"
  - Setpoint methodology establishes relationship between plant hardware and cycle-specific core reload design

Fuel Failure Analysis

Current Methodology

- TS 5.6.5, “Core Operating Limits Report (COLR)”
  - Combustion Engineering CENPD-183-A, “C-E Methods for Loss of Flow Analysis” (statistical convolution technique)
    - Fuel rod power census
    - DNBR pdf
- MSCU methodology for derivation of the DNBR pdf is analogous to that used for the SAFDL, but considers Condition III and Condition IV accident scenarios with a coincident Loss of Offsite Power (LOP)
  - Lower reactor coolant flow rates
  - Lower DNBRs

Fuel Failure Analysis

WTDP Methodology

- Statistical convolution technique analogous to CENPD-183-A
- More computationally efficient than current MSCU methodology when performing Palo Verde cycle-specific analyses
  - Fewer thermal-hydraulic simulations required
  - One DNBR pdf may be used for both DNBR SAFDL verification and fuel failure predictions

Fuel Failure Analysis

WTDP Methodology Example

- Limiting infrequent event (UFSAR Appendix 15E)
  - Composite event assumes an initiating occurrence degrades thermal margin and brings the reactor core to the DNBR SAFDL
  - While at the DNBR SAFDL, a LOP causes a coincident loss of forced reactor coolant flow
  - Acceptance criterion is a small fraction (10%) of 10 CFR Part 100 limits
- WTDP methodology reduces cycle-specific fuel failure predictions
  - Cycle-specific core reload analyses typically predict several thousand fuel rod failures for the postulated limiting infrequent event
  - CE16NGF: Unit 1 Cycle 24 fuel failure reduced by ~100 fuel rods
  - CE16HTP: Unit 2 Cycle 25 fuel failure reduced by ~200 fuel rods

Setpoint Methodology

Current Methodology

- TS 5.6.5, "Core Operating Limits Report (COLR)"
  - Westinghouse WCAP-16500-P-A, Revision 0, "CE 16x16 Next Generation Fuel Core Reference Report"
    - COLR includes Supplement 1, "Application of CE Setpoint Methodology for CE 16x16 Next Generation Fuel (NGF)"
- Setpoint methodology application at Palo Verde addressed in previous license amendments
  - Westinghouse CE16NGF (2018, ML17319A103 and ML17319A107)
  - Framatome CE16HTP (2020, ML20031C947 and ML20031C968)

Setpoint Methodology

Current Methodology

- Addresses use of MSCU where the CHF correlation within the CPCS and COLSS differs from the CHF correlations that are applicable to a specific fuel type
- Addresses the potential for different fuel types to introduce undesirable biases
  - Temperature-dependent
  - Pressure-dependent
  - Flow-dependent
  - Axial Shape Index (ASI)-dependent

Setpoint Methodology

WTDP Methodology

- Limitation/condition in NRC Safety Evaluation for WCAP-18240-P-A
  - The use of an approved subchannel code (e.g., VIPRE-W) in lieu of CETOP-D must be consistent with the CE-NSSS setpoint methodology as defined in WCAP-16500-P-A, Supplement 1, "Application of CE Setpoint Methodology for CE 16x16 Next Generation Fuel," Revision 1
- Palo Verde may choose to utilize this option in the future for selected analysis work
  - Palo Verde TS 5.6.5 includes WCAP-16500-P-A, VIPRE-W, and VIPRE-01
  - The faster CETOP-D code is desirable for time-critical circumstances

Proposed Changes

- Revise TS 5.6.5, “Core Operating Limits Report (COLR),” to add WCAP-18240-P-A
- Revise TS Bases 2.1.1, “Reactor Core Safety Limits (SLs)”
  - Reduce CE16NGF DNBR SAFDL to 1.20
  - Reduce CE16HTP DNBR SAFDL to 1.20
- Conforming changes to UFSAR
  - New topical report
  - Revised DNBR SAFDLs
  - Use of CETOP-D or VIPRE in setpoint methodology

Proposed Changes

5.6.5 CORE OPERATING LIMITS REPORT (COLR)

b. The analytical methods used to determine the core operating limits shall be those previously reviewed and approved by the NRC, specifically those described in the following documents:

-------------------------------NOTE------------------------------

The COLR will contain the complete identification for each of the Technical Specification referenced topical reports used to prepare the COLR (i.e., report number, title, revision, date, and any supplements).

----

30. BAW-10241(P)(A), "BHTP DNB Correlation Applied with LYNXT." [Methodology for Specification 3.2.4, DNBR]

31. EPRI-NP-2511-CCM-A, "VIPRE-01: A Thermal-Hydraulic Analysis Code for Reactor Cores." [Methodology for Specification 3.2.4, DNBR]

32. WCAP-18240-P-A, "Westinghouse Thermal Design Procedure (WTDP)." [Methodology for Specifications 2.1.1, Reactor Core SLs; 3.2.4, DNBR; and 3.2.5, Axial Shape Index]

Proposed Changes

B 2.0 SAFETY LIMITS (SLs)

B 2.1.1 Reactor Core SLs

SAFETY LIMITS

SL 2.1.1.1

The minimum value of the DNBR during normal operation and design basis AOOs is based on a statistical combination of the applicable CHF correlation and engineering factor uncertainties, and is established as an SL. Additional factors such as rod bow and spacer grid size and placement will determine the limiting safety system settings required to ensure that the SL is maintained.

The minimum value of the DNBR during normal operation and design basis AOOs is dependent on the fuel types present in the reactor core, and which fuel type had been irradiated prior to the current operating cycle. The fuel types include Westinghouse supplied Standard (i.e., CE16STD) fuel, Westinghouse supplied Next Generation Fuel (i.e., CE16NGF) fuel, and Framatome supplied High Thermal Performance (i.e., CE16HTP) fuel.

1. For a core where CE16STD fuel is limiting, the DNBR analytical limit is 1.34 using the CE-1 or ABB-NV CHF correlation~~.~~ with MSCU methodology.
2. For a core where CE16NGF fuel is limiting, the DNBR analytical limit is 1.25 using the WSSV and ABB-NV CHF correlations~~.~~ with MSCU methodology, and 1.20 using the WSSV and ABB-NV CHF correlations with WTDP methodology.
3. For a core where CE16HTP fuel is limiting, the DNBR analytical limit is 1.27 using the BHTP CHF correlation~~.~~ with MSCU methodology, and 1.20 using the BHTP CHF correlation with WTDP methodology.
4. For a mixed core where multiple types are limiting, the most conservative DNBR analytical limit will be used in conjunction with the CHF correlation for each limiting fuel type.

As noted in the preceding discussion, the WSSV, ABB-NV and BHTP CHF correlations may be used in safety and setpoint analyses. However, because of existing hardware limitations, the CPC algorithm will retain the CE-1 correlation and the DNBR-Low trip setpoint and Allowable Value of 1.34.

Proposed Schedule

- October 2024: License Amendment Request (LAR) submittal
- October 2025: Request completion of NRC review
- 2025-2026: Palo Verde implementation

Questions & Feedback