TSTF Pre-Submittal Meeting for TSTF-564, "Safety Limit MCPR [Minimum Critical Power Ratio]"

November 1, 2016

Ryan Joyce
Vice-Chair, BWROG Licensing Committee

Introduction

- Today's meeting is to discuss TSTF traveler TSTF-564, "Safety Limit MCPR," which the TSTF plans to submit to the NRC for approval.
- TSTF-564 revises the Safety Limit (SL) value and method of calculation for the Minimum Critical Power Ratio (MCPR), SL 2.1.1.2, for Boiling Water Reactor (BWR) plants using Global Nuclear Fuel or Westinghouse fuel.
- A draft of the traveler was provided to the NRC prior to the meeting.
- The TSTF's goal for this meeting is to ensure that the submittal provides the necessary and sufficient information for the NRC to efficiently review the traveler.

Introduction

- This effort is supported by:
  - The Boiling Water Reactors Owners' Group (BWROG) Licensing Committee
  - The Technical Specifications Task Force
  - The BWROG Reload Analysis and Core Management Committee (RACMC)
  - Global Nuclear Fuel (GNF)
  - Westinghouse Electric

Current Requirements

- Title 10 of the Code of Federal Regulations (10 CFR), Part 50, paragraph 50.36(c)(1)(i)(A), in part, states:

  Safety limits for nuclear reactors are limits upon important process variables that are found to be necessary to reasonably protect the integrity of certain physical barriers that guard against the uncontrolled release of radioactivity.

Current Requirements

- NUREG-1433 and NUREG-1434, the BWR/4 and BWR/6 Standard Technical Specifications (STS), respectively, define Minimum Critical Power Ratio (MCPR) in Section 1.1, "Definitions," as:

  The MCPR shall be the smallest critical power ratio (CPR) that exists in the core [for each class of fuel]. The CPR is that power in the assembly that is calculated by application of the appropriate correlation(s) to cause some point in the assembly to experience boiling transition, divided by the actual assembly operating power.

Current Requirements

- STS Safety Limit 2.1.1.2 states:

  With the reactor steam dome pressure ≥ 785 psig and core flow ≥ 10% rated core flow:

  MCPR shall be ≥ [1.07] for two recirculation loop operation or ≥ [1.08] for single recirculation loop operation.

- The reactor steam dome pressure and core flow limit may vary by plant.
- The two loop operation (TLO) and single loop operation (SLO) Safety Limit MCPR (SLMCPR) values are plant-specific.

Current Requirements

- The SLMCPR value is calculated as the point at which 99.9% of the fuel rods would not be susceptible to boiling transition.
- It is recognized that the onset of transition boiling would not necessarily result in damage to BWR fuel rods, but the critical power at which boiling transition is calculated to occur has been adopted as a convenient limit.

Current Requirements

- STS LCO 3.2.2, "Minimum Critical Power Ratio (MCPR)," states:

  All MCPRs shall be greater than or equal to the MCPR operating limits specified in the COLR [Core Operating Limits Report].

- TS 3.2.2 is applicable when Thermal Power is ≥ 25% RTP (rated thermal power), or a plant-specific thermal power limit.

Current Requirements

- The SLMCPR limit is calculated for each BWR on a cycle-by-cycle basis using NRC approved methodologies.
  - The SLMCPR limit ensures that no fuel damage results during normal operation.
- The Operating Limit MCPR (OLMCPR) values specified in the licensee-controlled COLR are determined using NRC approved methodologies listed in Section 5.6, "Core Operating Limits Report (COLR)," of the TS.
  - The OLMCPR limits ensure that no fuel damage results during anticipated operational occurrences (AOOs) by confirming the SLMCPR is not violated during an AOO.

Need for Change

- **The current method used to determine the SLMCPR value results in frequent, accelerated license amendments that unnecessarily challenge the licensee and the NRC.**

- The cycle-specific core design is dependent on the previous cycle burnup, so the design for the subsequent cycle is typically finalized late in the previous fuel cycle.
- The current SLMCPR value is affected by the cycle-specific design, such as core power distribution, fuel type, and operating power-flow domain.

Need for Change

- If the SLMCPR value for the subsequent cycle is less conservative than the current TS, a TS change is needed.
- Submittals to modify the SLMCPR typically request an accelerated NRC review (i.e., less than one year) to support the scheduled start of the subsequent fuel cycle.
  - The TSTF identified 10 requests to revise the SLMCPR value approved in 2015 and 2016.
  - The average licensee-requested NRC review time was 7 months.
    - 7 of 10 requested a review in 6 months or less.

Need for Change

- **There are methods of determining the SLMCPR that are not cycle-dependent and satisfy the regulations.**

- The equivalent PWR (Babcock & Wilcox, Westinghouse, Combustion Engineering, and AP1000®) safety limit is based on a Departure from Nucleate Boiling Ratio (DNBR) limit, which is similar to the BWR SLMCPR.
- The PWR safety limit is only dependent on the DNBR correlations for the fuel type(s) in the reactor.
- The PWR DNBR safety limit is not cycle dependent and is typically only revised when the fuel type changes.

Proposed Change

- The proposed change revises the SLMCPR methodology for all BWR plants using GNF or Westinghouse fuel.
  - TSTF-564 is not applicable to BWR plants using AREVA fuel.
- The proposed change will substantially reduce the need for cycle-specific changes to the SLMCPR and the need for accelerated NRC review of those changes.

Proposed Change

- For plants adopting the proposed change, Safety Limit 2.1.1.2 is revised to state:

  With the reactor steam dome pressure
  ≥ 785 psig and core flow ≥ 10% rated core flow:

  MCPR shall be ≥ [1.07].

- No changes are proposed to the MCPR definition in TS Section 1.1 or TS 3.2.2, "MCPR."

Proposed Change

- The fuel product-specific Safety Limit MCPR value is determined based on the product's experimentally determined critical power ratio and a statistical analysis that provides a 95% probability at a 95% confidence level (95/95) for the one-sided upper tolerance limit that depends on the number of samples in the critical power database.

Vendor	Fuel Type	Proposed SLMCPR
GNF	GE14	1.06
GNF	GNF2	1.07
Westinghouse	Optima2	1.06
Westinghouse	Optima3	1.06

Proposed Change

- Propose that GNF and Westinghouse send proprietary letters describing how the SLMCPR values are determined based on the proprietary CPR statistics, to be referenced in the traveler.
- For cores loaded with a mix of GNF or Westinghouse fuel products, the SLMCPR is based on the largest (i.e., most limiting) of the SLMCPR values for the fuel products that are fresh or once-burnt at the start of the cycle.
- In the STS, the existing phrase "for two recirculation loop operation or ≥ [1.08] for single recirculation loop operation" will be retained as a plant-specific option (i.e., bracketed) for BWR plants that do not adopt the traveler.

Proposed Change

- The Safety Limit 2.1.1.2 Bases and TS 3.2.2 Bases are revised to reflect the proposed change.
- In the STS, brackets (indicating plant-specific information) and Reviewer's Notes are used to add the new information while retaining the existing description for plants that do not adopt the proposed change.

Basis for Change

- The method of calculation for the SLMCPR is revised from ensuring that 99.9% of the rods would not be susceptible to transition boiling to ensuring that there is a 95% probability at a 95% confidence level that no rods will be susceptible to transition boiling based on the correlation statistics alone.
- This is consistent with the PWR DNBR safety limit, which corresponds to a 95% probability at a 95% confidence level that DNB will not occur based on the correlation statistics alone.
- Both statistical approaches are acceptable.

Basis for Change

- The proposed SLMCPR is based only on the CPR correlation uncertainty determined for the GNF or Westinghouse fuel type(s) in the reactor.
  - This is consistent with the PWR DNBR Safety Limit.
- Plant and cycle-specific uncertainties, including SLO and TLO reactor flow uncertainties, are no longer included in the SLMCPR, so only a single limit is needed.
- The plant and cycle-specific uncertainties, including reactor flow, will continue to be included in the OLMCPR (TS 3.2.2) limit. Therefore, the margin to boiling transition remains unchanged.

Basis for Change

- No changes to the method of determining the OLMCPR (i.e., the LCO 3.2.2 limit) are proposed.
  - The current SLMCPR statistical calculation (i.e.,$MCPR_{99.9\%}$) will continue to be performed using the NRC approved methodology.
  - The OLMCPR COLR limits will continue to be determined by combining the cycle-specific $MCPR_{99.9\%}$ value and the transient ΔCPR component.

Proposed Model Application

- The traveler contains a model application for plant-specific adoption of the proposed change.
- Licensees adopting the traveler using the model application must provide:
  - Verification that the traveler and NRC safety evaluation are applicable.
  - The type of fuel to be in the reactor and the proposed Safety Limit based on the table in the traveler and the Reviewer's Note in the TS Bases.
  - A discussion of any variations from the traveler, such as TS numbering or titles.

Conclusion

- The revised SLMCPR method of calculation for GNF and Westinghouse fuel will continue to meet the regulatory definition of a safety limit and protect the integrity of the fuel rod cladding against the uncontrolled release of radioactivity.

Discussion

Backup Slides

Determination of Proposed SLMCPR value

- The proposed SLMCPR value is designated as $MCPR_{95/95}$
- For each GNF and Westinghouse BWR fuel product (designated i), the $MCPR_{95/95(i)}$ is calculated using that product's experimentally determined critical power statistics as follows:

$$MCPR_{95/95(i)} = \mu_i + \kappa_i * \sigma_i \qquad \text{(Eq. 1)}$$

Where,

μ_i is the mean Experimental Critical Power Ratio (ECPR),

σ_i is the standard deviation of the ECPRs, and

κ_i is a statistical parameter chosen to provide 95% probability at 95% confidence (95/95) for the one-sided upper tolerance limit that depends on the number of samples (N_i) in the critical power database.

i is a fuel product line, such as GE14, GNF2, OPTIMA2, OPTIMA3, etc.

Statistical Treatment of $MCPR_{95/95}$

- The statistical parameter, κ_i, is calculated using formulas attributed to Mary Gibbons Natrella (1963) as recommended by the National Institute of Standards and Technology (NIST) in their Engineering Statistics Handbook (Reference 1). For a 95/95 probability/confidence level, the κ_i values are shown in the table below as a function of database size (N_i).

Statistical Parameter, κ_i, at (95/95)
for the One-Sided Upper Tolerance Limit

Database Size, N_i	κ_i
500	1.7625
750	1.7401
1000	1.7270
1250	1.7181
1500	1.7115
2000	1.7024

Statistical Treatment of $MCPR_{95/95}$

- Assuming a typical critical power database of 1000 data points with no bias (i.e., $\mu_i = 1.0$), the following table illustrates representative $MCPR_{95/95(i)}$ values as a function of the database standard deviation.

Representative $MCPR_{95/95}$ Values for N_i=1000

Standard Deviation, σ_i (%)	$SLMCPR_{95/95}$
2.0	1.03
2.5	1.04
3.0	1.05
3.5	1.06
4.0	1.07
4.5	1.08
5.0	1.09

- The SLMCPR is determined to two digits past the decimal using standard rounding practices.