

**MODEL SAFETY EVALUATION FOR PLANT-SPECIFIC ADOPTION OF
TECHNICAL SPECIFICATIONS TASK FORCE TRAVELER TSTF-535,
REVISION 0, "REVISE SHUTDOWN MARGIN DEFINITION TO ADDRESS
ADVANCED FUEL DESIGNS," USING THE CONSOLIDATED LINE ITEM
IMPROVEMENT PROCESS**

1.0 INTRODUCTION

By letter dated [DATE], [LICENSEE] (the licensee) proposed changes to the Technical Specifications (TS) for the [PLANT]. Specifically, the licensee requested to adopt U.S. Nuclear Regulatory Commission (NRC)-approved Technical Specifications Task Force (TSTF) Standard Technical Specifications (STS) Change Traveler TSTF-535, "Revise Shutdown Margin Definition to Address Advanced Fuel Designs" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML112200436), dated August 8, 2011.

The proposed change would revise the TS definition of shutdown margin (SDM) to require calculation of SDM at the reactor moderator temperature corresponding to the most reactive state throughout the operating cycle (68 °F or higher). The purpose is to address newer boiling water reactor fuel designs, which may be more reactive at shutdown temperatures above 68 °F.

The licensee stated that the license amendment request is consistent with NRC-approved TSTF Traveler TSTF-535. The availability of this TS improvement was announced in the *Federal Register* on [Date] ([] FR []) as part of the consolidated line item improvement process.

2.0 REGULATORY EVALUATION

2.1 Background

In water-moderated reactors, water is used to slow down, or moderate, high energy fast neutrons to low energy thermal neutrons through multiple scattering interactions. The low energy thermal neutrons are much more likely to cause fission when absorbed by the fuel. However, not all of the thermal neutrons are absorbed by the fuel; a portion of them are instead absorbed by the water moderator. The amount of moderator and fuel that is present in the core heavily influences the fractions of thermal neutrons that are absorbed in each.

Water-moderated reactors are designed such that they tend to operate in what is known as an under-moderated condition. In this condition, the ratio of the moderator-to-fuel in the core is small enough that the overall effectiveness of water as a moderator decreases with increasing temperature; fewer neutrons are absorbed in the moderator due to the decrease in its density, but this is overshadowed by the reduction in the number of neutrons that moderate from high fission energy to the lower energy level needed to cause fission. The result is a decrease in power and temperature: a negative reactivity feedback effect where the reactor becomes self-regulating. However, if the amount of moderator becomes too large with respect to the amount of fuel, the reactor can enter an over-moderated condition. In this condition, the overall effectiveness of water as a moderator increases with increasing temperature; the reduction in the number of neutrons absorbed in the moderator outweighs the loss in neutrons reaching lower energies. This causes an increase in power that leads to a further increase in temperature creating a potentially dangerous positive reactivity feedback cycle.

As practical examples in support of the proposed changes to the definition of SDM, TSTF-535 discussed SDM with regards to GE14 and GNF2 fuels. TSTF-535 indicated that for historical fuel products through GE14, the maximum reactivity condition for SDM always occurred at a moderator temperature of 68 °F because these fuel products were designed so that the core is always under-moderated when all control rods are inserted, except for the single most reactive rod. In cores with GNF2 fuel, TSTF-535 stated that it is expected that the maximum reactivity condition at beginning of cycle will remain at 68 °F, but that later in cycle the most limiting SDM may occur at a temperature greater than this, indicating that with this fuel design the core could potentially achieve an over-moderated condition.

2.2 Technical Specification Changes

[LICENSEE] adoption of TSTF-535 for [PLANT] proposes to revise the TS definition of SDM to require calculation of SDM at the reactor moderator temperature corresponding to the most reactive state throughout the operating cycle (68 °F or higher).

The current definition of SDM in Section 1.1, "Definitions," of the [PLANT] TS is:

SDM shall be the amount of reactivity by which the reactor is subcritical or would be subcritical assuming that:

- a. The reactor is xenon free
- b. The moderator temperature is 68 °F, and
- c. All control rods are fully inserted except for the single control rod of the highest reactivity worth, which is assumed to be fully withdrawn. With control rods not capable of being fully inserted, the reactivity worth of these control rods must be accounted for in the determination of SDM.

The licensee proposes the following changes (shown in bold) to the definition of SDM in accordance with TSTF-535:

SDM shall be the amount of reactivity by which the reactor is subcritical or would be subcritical **throughout the operating cycle** assuming that:

- a. The reactor is xenon free
- b. The moderator temperature is $\geq 68^{\circ}\text{F}$, **corresponding to the most reactive state**; and
- c. All control rods are fully inserted except for the single control rod of the highest reactivity worth, which is assumed to be fully withdrawn. With control rods not capable of being fully inserted, the reactivity worth of these

control rods must be accounted for in the determination of SDM.

2.3 Regulatory Review

Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, Appendix A, General Design Criteria (GDC) 26, "Reactivity control system redundancy and capability," and GDC 27, "Combined reactivity control systems capability," respectively require that reactivity within the core be controllable to ensure subcriticality is achievable and maintainable under cold conditions, with appropriate margin for stuck rods; and that reactivity within the core be controllable to assure that under postulated accident conditions and with appropriate margin for stuck rods the capability to cool the core is maintained.

Among other things, 10 CFR 50.36(c)(2)(ii) requires the establishment of a limiting condition for operation (LCO) for a process variable, design feature, or operating restriction that is an initial condition of a design-basis accident or transient analysis that either assumes the failure of or presents a challenge to the integrity of a fission product barrier. The TS definition of SDM and the LCOs placed on SDM serve, in part, to satisfy GDCs 26 and 27 by ensuring there is always sufficient negative reactivity worth available to offset the positive reactivity worth of changes in moderator and fuel temperature, the decay of fission product poisons, the failure of a control rod to insert, and reactivity insertion accidents. Given this margin, the core can be held subcritical for conditions of normal operation, including anticipated operational occurrences.

{NOTE: After Traveler TSTF-535 was submitted for review, it was agreed upon that future model license amendment requests would include language to account for plants that were licensed before the promulgation of the GDC. The model application for TSTF-535 does not include this language. However, plants licensed before the promulgation of the GDC are to address their plant-specific licensing basis in the license amendment request to adopt TSTF-535, per letter dated July 4, 2012 (ADAMS Accession No. ML12187A184). Language similar to the paragraph below (Item 2 in the July 4, 2012, letter) should have been included in the license amendment request.

The Traveler and model Safety Evaluation discuss the applicable regulatory requirements and guidance, including the 10 CFR 50, Appendix A, General Design Criteria (GDC). [PLANT] was not licensed to the 10 CFR 50, Appendix A, GDC. The [PLANT] equivalent of the referenced GDC are [REFERENCE INCLUDING UFSAR [updated final safety analysis report] LOCATION, IF APPLICABLE]. [DISCUSS THE EQUIVALENCE OF THE REFERENCED PLANT-SPECIFIC REQUIREMENTS TO THE APPENDIX A GDC AS RELATED TO THE PROPOSED CHANGE.] This difference does not alter the conclusion that the proposed change is applicable to [PLANT].

The NRC staff model SE is written for plants licensed to the GDC. The NRC staff should revise the model SE accordingly to explain the current licensing basis with regards to GDCs 26 and 27 (or plant-specific equivalent) from the plant-specific information in the Final Safety Analysis Report or alternative license document, as submitted by the licensee in its license amendment request.}

The NRC's guidance for the format and content of licensee TSs can be found in [NUREG-1433, "Standard Technical Specifications General Electric Plants BWR/4"] [NUREG-1434, "Standard Technical Specifications General Electric Plants, BWR/6"].

Revision 3 of NUREG-0800, "Standard Review Plan [(SRP)] for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Section 4.3, "Nuclear Design," dated March 2007 (ADAMS Accession Number ML070740003), provides the procedures concerning the review of control systems and SDM to help ensure compliance with GDCs 26 and 27.

3.0 TECHNICAL EVALUATION

3.1 Current Definition of Shutdown Margin

In BWR plants, the control rods are used to hold the reactor core subcritical under cold conditions. The control rod negative reactivity worth must be sufficient to ensure the core is subcritical by a margin known as the SDM. It is the additional amount of negative reactivity worth needed to maintain the core subcritical by offsetting the positive reactivity worth that can occur during the operating cycle due to changes in moderator and fuel temperature, the decay of fission product poisons, the failure of a control rod to insert, and reactivity insertion accidents. Specifically, Section 1.1, "Definitions," of the STS defines SDM as the amount of reactivity by which the reactor is subcritical or would be subcritical assuming that the reactor is (1) xenon free, (2) the moderator is 68 °F, and (3) all control rods are fully inserted except for the rod of highest worth, which is assumed to be fully withdrawn.

The three criteria provided in the definition help exemplify what has traditionally been the most reactive design condition for a reactor core. Xenon is a neutron poison produced by fission product decay and its presence in the core adds negative reactivity worth. Assuming the core is xenon free removes a positive reactivity offset and is representative of fresh fuel at the BOC. The minimum temperature the reactor moderator is anticipated to experience is 68 °F, making it the point at which the moderator will be at its densest and therefore capable of providing the highest positive reactivity worth. By assuming the highest worth rod is fully withdrawn, the core can be designed with adequate shutdown margin to ensure it remains safely shutdown even in the event of a stuck control rod, as required by GDC 26 and 27.

Determination of the SDM under the aforementioned conditions yields a conservative result that, along with the requirements set forth in Section [3.1.1] of the TS, helps ensure:

- a. the reactor can be made subcritical from all operating conditions and transients and design basis events,
- b. the reactivity transients associated with postulated accident conditions are controllable within acceptable limits, and
- c. the reactor will be maintained sufficiently subcritical to preclude inadvertent criticality in the shutdown condition,

3.2 Proposed Definition of Shutdown Margin

The specified moderator temperature of 68 °F facilitates the maximum reactivity condition only if the core exists in an under-moderated condition. In addition to burnable poisons, many modern fuel designs also incorporate partial length rods for increased neutron economy which are employed in order to extend the operating cycle. Both of these affect the ratio of moderator to fuel. The strong local absorption effects of the burnable poisons in fresh fuel make the core under-moderated. As burnable poisons are depleted during the fuel cycle, the core becomes less under-moderated, potentially leading to a slightly over-moderated condition wherein the core will be more reactive at a moderator temperature higher than the 68 °F specified in the SDM definition. Thus, the maximum core reactivity condition and the most limiting SDM may occur later in the fuel cycle at a temperature greater than 68 °F. Consequently, calculation of the SDM at the currently defined moderator temperature of 68 °F may not accurately determine the available margin.

TSTF-535 therefore proposed a change to the definition of SDM to enable calculation of the SDM at a reactor moderator temperature of 68 °F or a higher temperature corresponding to the most reactive state throughout the operating cycle. SDM would be calculated using the appropriate limiting conditions for all fuel types at any time in core life.

In support of the proposed change, TSTF-535 cited the requirements for SDM as specified in Topical Report NEDO-24011-A, Revision 18, "General Electric Standard Application for Reactor Fuel (GESTAR II)," dated April 2011 (ADAMS Package Accession Number ML111120038). Section 3.2.4.1 of GESTAR II states:

The core must be capable of being made subcritical, with margin, in the most reactive condition throughout the operating cycle with the most reactive control rod fully withdrawn and all other rods fully inserted.

The Traveler also cited SRP Section 4.3, which states the following concerning the review of control systems and SDM:

The adequacy of the control systems to assure that the reactor can be returned to and maintained in the cold shutdown condition at any time during operation. The applicant shall discuss shutdown margins (SDM). Shutdown margins need to be demonstrated by the applicant throughout the fuel cycle.

Although the licensing basis requirements for SDM in GESTAR II are only applicable for cores licensed with Global Nuclear Fuels methods, they are consistent with the review procedures set forth in the SRP, which are provided to help ensure compliance with GDCs 26 and 27. TSTF-535 stated that while the SRP does not prescribe the temperature at which the minimum SDM should be determined, the requirement of shutting down the reactor and maintaining it in a shutdown condition "at any time during operation" suggests that considering a range of thermal and exposure conditions would be appropriate in the determination of the minimum SDM. Because newer fuel designs employ elements such as partial length rods and burnable absorbers, which may cause the maximum core reactivity conditions and the most limiting SDM to occur later in the fuel cycle at a temperature greater than 68 °F, the NRC staff agrees with the

TSTF-535 assessment in this regard. Additionally, the NRC staff finds that allowing calculation of the SDM at the most limiting core reactivity condition is prudent with respect to ensuring compliance with GDCs 26 and 27 and concludes that the proposed changes to the TSs are acceptable.

The impetus for TSTF-535 was to provide for a more broadly applicable SDM definition in recognition of modern fuel designs, for which the core may not be in its most reactive condition at 68 °F. The proposed language would require the licensee to consider all temperatures equal to or exceeding 68 °F, and all times in the operating cycle. This change places an additional responsibility on any implementing licensee to identify the most limiting time-in-cycle and temperature, a change that is effectively more restrictive than the current definition. Therefore, the change can be considered acceptable for any facility that currently, and appropriately so, adheres to the current definition of SDM that is contained in the STS. Based on these considerations, the NRC staff concludes that the change is applicable to any BWR, regardless of its fuel design. The NRC staff also finds that the revised definition is consistent with the 10 CFR 50.36 requirements pertaining to LCOs, because it ensures that the LCOs for SDM consider a broadly conservative range of potential initial conditions in the anticipated operational occurrence analyses.

3.3 SUMMARY

The NRC staff has reviewed the licensee's implementation of TSTF-535 proposed revisions to the definition of SDM. Based on the considerations discussed above, the NRC staff concludes that the proposed revisions are acceptable and will provide a conservative and improved approach to the calculation of SDM that ensures use of the appropriate limiting conditions for all fuel types at any time in the life of the core. The NRC staff finds the proposed revisions serve to satisfy the requirements set forth in GDC 26 and GDC 27, as discussed in NUREG-0800, Chapter 4.3, "Nuclear Design." Additionally, the NRC staff concludes the proposed changes to the definition of SDM would require the licensee to calculate SDM in consideration of the most limiting conditions in the core. Therefore, the revised SDM definition is acceptable for BWR facilities using any current fuel design.

4.0 STATE CONSULTATION

{NOTE: Per LIC-101, the PM is responsible for contacting the state official and completing the bracketed information appropriately.}

In accordance with the Commission's regulations, the [Name of State] State official was notified of the proposed issuance of the amendment. The State official had [no] comments. [If comments were provided, they should be addressed here].

5.0 ENVIRONMENTAL CONSIDERATION

{NOTE: Caution per LIC-101: The environmental consideration discussed below is written for a categorical exclusion based on 10 CFR 51.22(c)(9). The PM is responsible to ensure that this is accurate for the specific amendment being issued.}

The amendment changes a requirement with respect to installation or use of a facility component located within the restricted area as defined in 10 CFR Part 20. The NRC staff has

determined that the amendment involves no significant increase in the amounts, and no significant change in the types, of any effluents that may be released offsite, and that there is no significant increase in individual or cumulative occupational radiation exposure. The Commission has previously issued a proposed finding that the amendment involves no significant hazards consideration, and there has been no public comment on such finding [enter *Federal Register* citation (XX FR XXXX) and date]. Accordingly, the amendment meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the issuance of the amendment.

6.0 CONCLUSION

{NOTE: the PM is responsible for ensuring the current LIC-101 wording is used.}

The Commission has concluded, based on the considerations discussed above, that: (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) there is reasonable assurance that such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

7.0 REFERENCES

[Optional section to be prepared by the PM or primary reviewers.]

Principal Contributors: [A. K. Heller]
[R. P. Grover]

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