ENCLOSURE 2

MFN 07-040 Supplement 2

Assessment of the Applicability of the GESTR-M Model and Associated Application Methodology to the GNF2 Fuel Design

Non-Proprietary Version

IMPORTANT NOTICE

This is a non-proprietary version of Enclosure 1 to MFN 07-040 Supplement 2, which has the proprietary information removed. Portions of Enclosure 1 that have been removed are indicated by an open and closed bracket as shown here [[ ]].

Supplement to MFN 07-040 (Part 21 Notification: Adequacy of GE Thermal-Mechanical Methodology, GESTR-M)

Assessment of the Applicability of the GESTR-M Model and Associated Application Methodology to the GNF2 Fuel Design

Summary

In References 1 and 2, GNF provided assessments of conservatisms in the GESTR-M fuel rod thermal-mechanical model and associated application methodology relative to the calculation of fuel temperature, cladding strain and rod internal pressure. Based upon these assessments, the NRC concluded that the GESTR-M model and associated methodology includes sufficient conservatism to adequately confirm compliance with the fuel temperature, cladding strain and rod internal pressure SAFDLs. This evaluation was performed for the GE14 fuel design at its current Linear Heat Generation Rate (LHGR) limit of 13.4 kW/ft GESTR-M.

The Supplement 2 evaluation extends the Reference 1 and 2 assessments to the GNF2 fuel design. More specifically, this evaluation demonstrates that the GESTR-M code and associated application methodology is adequate for GNF2 fuel licensing and design calculations for the [[

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Based upon the results of the evaluation, GNF concludes that the GESTR-M model and associated application methodology is sufficiently conservative to address NRC concerns regarding application of GESTR-M and its associated application methodology to confirm compliance with the fuel temperature, cladding strain and rod internal pressure SAFDLs for [[
]] for the GNF2 design within the LHGR limits defined in the GNF2 Compliance Report, NEDC-33270P (Reference 3).

Introduction

This evaluation extends the Reference 1 and 2 assessments of conservatisms in the GESTR-M fuel rod thermal-mechanical model and associated application methodology to the [[ ]] of the GNF2 fuel design, and thus refers to and follows References 1 and 2. As noted above, [[

]]. The NRC has expressed concerns about the possible underprediction of fuel temperature and rod internal pressure at high exposures due to the fact that GESTR-M does not explicitly address the exposure dependency of fuel thermal conductivity. These concerns are explicitly addressed in this evaluation.

GESTR-M is intended to be a best estimate code, with uncertainty addressed explicitly in specific thermal-mechanical analyses where GESTR-M is applied. The primary fuel rod response parameters calculated by the GESTR-M model for confirmation of compliance with fuel rod SAFDLs include

Fuel centerline temperature
Cladding strain
Fuel rod internal pressure
Inputs to Loss-of-Coolant Accident (LOCA) analyses

[[ ]] as shown in Figure 3 of Reference 1. [[ ]] Therefore, it is concluded that the transient and stability analyses would be either not affected or conservative and that GESTR-M is adequate for such analyses.

Evaluations of the impact of the GESTR-M model relative to the GNF2 fuel design for each of the primary fuel rod response parameters are provided below.

Fuel Centerline Temperature

The design and licensing limit on fuel temperature is that the maximum fuel centerline temperature cannot exceed the fuel melting temperature during normal operation, including anticipated operational occurrences (AOOs). Although it has been well demonstrated in numerous irradiation experiments that extended operation with significant fuel pellet central melting does not result in damage to the fuel rod cladding, this fuel temperature limit is applied to ensure that sudden shifting of molten fuel in the interior of the fuel rods, and subsequent potential cladding damage, is precluded.

The possible underprediction of fuel rod temperature has a negligible impact on the GNF2 fuel design relative to compliance with design limits since the maximum fuel temperature occurs at the first knee of the specified GNF2 LHGR envelope (e.g., at [[ ]]). Fuel temperatures decline after this limiting point in exposure due to the significant reduction in power resulting from fissile atom depletion. The GESTR-M model provides best estimate predictions of fuel temperatures through and beyond this exposure range and is statistically similar to PRIME predictions (Reference 1). Although GESTR-M does not have an exposure dependent UO_2 thermal conductivity model, the integral GESTR-M code adequately predicts the maximum fuel centerline temperature at the most limiting exposure.

Additionally, Thermal Overpower (TOP) and Mechanical Overpower (MOP) limits have been developed to provide parameters that are easily evaluated in terms of LHGR and that can be used as computational limits during design of a core. [[

]] The TOP and MOP limits for GNF2 are specified to ensure that operation within the GNF2 power-exposure envelope (i.e. local linear heat generation rate as a function of local exposure) will conform to the fuel rod thermal-mechanical design and licensing criteria. [[

]] the GESTR-M application methodology used to specify TOP and MOP limits assures that the GNF2 fuel design has the same margins to fuel melting and cladding strain limits as the GE14 design, with one exception. [[

]] for any fuel design, including the GE14 design. The NRC has expressed concerns about the limited data available to support such melting, particularly at high exposures. [[

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Finally, the TOP and MOP limits for the GNF2 fuel design are [[

]] This provides additional assurance that GESTR-M provides conservative results with adequate protection against fuel centerline melting.

Cladding Strain

The licensing limit on cladding strain is that the calculated cladding plastic strain at the pellet mid-height location cannot exceed 1% during normal operation, including AOOs. This limit is applied to ensure that fuel rod failure due to pellet-cladding mechanical interaction will not occur. As noted above, [[

]] Thus, the GESTR-M based MOP limit is conservative and adequate to ensure that cladding strain does not exceed the licensing limit.

This conclusion is based upon the current GESTAR cladding strain limit. GNF recently proposed a revised cladding strain limit to the NRC (Reference 4). The revised limit is exposure dependent and is based upon the characterized corrosion performance and hydrogen pickup of GNF cladding. The revised cladding strain limit is identical to the current cladding strain limit for peak pellet exposures up to [[
]] is based upon the characterized low corrosion and hydrogen pickup for GNF cladding below [[
]] the revised cladding strain limit is implicitly satisfied and direct application of the revised cladding strain limit is not required.

Because the proposed revised cladding strain limit is based upon cladding corrosion performance and hydrogen pickup, the proposed strain limit also includes proposed limits on cladding corrosion and hydrogen concentration. Although the current GESTR-M methodology does not include explicit cladding corrosion or hydrogen concentration limits, the effects of corrosion are explicitly addressed. The corrosion model used reflects the characterized low corrosion for GNF cladding and is well below the [[
]] Based upon corresponding hydrogen concentration data, hydrogen concentration [[
]] the proposed cladding corrosion and hydrogen concentration limits that are part of the proposed revised cladding strain limit are implicitly satisfied and direct application of these limits is not required.

Loss-of-Coolant Accident (LOCA) Response

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As noted in the evaluation of GESTR-M fuel centerline temperature predictive capabilities, GNF concludes that, although the GESTR-M model does not explicitly address the effect of burnup on fuel thermal conductivity, GESTR-M provides adequate predictions of fuel temperature for exposures [[ ]] Also, the uncertainty in GESTR-M predicted temperature is directly characterized using the GESTR-M experimental qualification results and used to provide stored energy uncertainty for the LOCA calculations.

However, in response to NRC concern about the UO_2 temperature underprediction by GESTR-M for operation on LHGR limits, even at low exposures, relative to models that explicitly address the exposure dependency of fuel thermal conductivity, GNF has used the PRIME model (Reference 5), currently under review by the NRC, to determine the possible GESTR-M underprediction of fuel temperature and stored energy. Comparison of PRIME and GESTR-M results for the GNF2 fuel design indicate [[

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]] Thus, it is concluded that the impact on local oxidation in LOCA evaluations is also negligible.

Fuel Rod Internal Pressure

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As noted above, the NRC has expressed concern that the GESTR-M code underpredicts fuel temperatures at high exposure, which may result in underprediction of fission gas release (FGR) and fuel rod internal pressure at end of life. In Reference 2, GNF provided assessment of the conservatisms in the calculation of the GE14 fuel rod internal pressure design ratio and concluded that the conservatisms are sufficient to address NRC concerns about possible underprediction of rod internal pressure at or near end of life by GESTR-M.

As noted previously, this supplemental GNF2 evaluation is [[

]] are approximately [[ ]] respectively, for the GESTR-M code and approximately [[ ]] respectively, for the PRIME code. The upper 95 rod internal pressure values are significantly less than the lower 95 critical pressures calculated by the GESTR-M and PRIME codes, indicating that liftoff will not occur.

Conclusions

The primary fuel rod response parameters in fuel thermal-mechanical calculations, fuel design analyses and downstream safety analyses that are impacted by fuel temperature are fuel centerline melting, cladding strain, loss-of-coolant accident (LOCA) response, and fuel rod internal pressure. With the exception of fuel rod internal pressure, these licensing parameters are limiting at

exposures below [[ ]] and are hence not impacted by exposure effects on fuel thermal conductivity; GESTR-M is fully adequate for these applications. Although GESTR-M may underpredict fission gas release at high exposure, the use of a limiting LHGR envelope in conjunction with statistical application methodology assures that GESTR-M provides adequate protection to the fuel rod internal pressure limit, as confirmed in Reference 2. As, for this evaluation, the [[ ]] conservatism is significantly increased relative to that in the assessment in Reference 2. Also, as noted above, corrosion and hydrogen pickup is low for GNF cladding [[ ]] minimizing the possibility of any unaddressed corrosion or hydriding effects in the GESTR-M application methodology. [[
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Therefore, GESTR-M and its associated application methodology, which includes specification of exposure dependent LHGR limits, is adequate for GNF2 fuel licensing and design calculations for operation [[
]] within the GNF2 LHGR limits defined in Reference 3.

References

1. MFN 07-040, Jason S. Post (GE) to Document Control Desk (NRC), “Part 21 Notification: Adequacy of GE Thermal-Mechanical Methodology, GSTRM,” January 21, 2007.

2. MFN 07-040 Supplement 1, Dale E. Porter (GE-Hitachi) to Document Control Desk (NRC), “Part 21 Notification: Adequacy of GE Thermal-Mechanical Methodology, GESTR-M – Supplement 1,” January 4, 2008.

3. NEDC-33270P, GNF2 Advantage Generic Compliance with NEDE-24011-P-A (GESTAR II), March 2007.

4. Letter to U.S. Nuclear Regulatory Commission, Docket No. 52-010, Subject: Response to Portion of NRC Request for Additional Information Letter No. 110 - Related to ESBWR Design Certification Application - RAI Numbers 4.2-2 Supplement 3, 4.2-4 Supplement 2 and 4.8-6 Supplement 1, MFN 08-347, May 9,2008.

5. NEDC-33256P, “The PRIME Model for Analysis of Fuel Rod Thermal-Mechanical Performance, Part 1-Technical Basis”, January 2007.