SAFETY EVALUATION REPORT

DOCKET: 70-1113

LICENSEE: SNM-1097, Global Nuclear Fuel – Americas, LLC
Wilmington, North Carolina

SUBJECT: GLOBAL NUCLEAR FUEL – AMERICAS LLC: REVIEW OF THE MINIMUM MARGIN OF SUBCRITICALITY FOR UP TO 8 WEIGHT PERCENT ENRICHMENT OF URANIUM – 235 AND AMENDMENT 16 (ENTERPRISE PROJECT IDENTIFIER L-2020-LNS-0002)

BACKGROUND

By letter dated October 31, 2019 (Agencywide Documents Access and Management System [ADAMS] Accession No. ML19304B896), and later supplemented by letters dated November 27, 2019 (ADAMS Accession No. ML19331A444), and February 27, 2020 (ADAMS Accession No. ML20058G604), Global Nuclear Fuel – Americas, LLC (GNF-A) requested to amend Special Nuclear Material License 1097 (SNM-1097) to increase the enrichment limit in License Condition 6(a) from 5.0 weight percent (wt.%) to 8.0 wt.% U-235.

NRC staff issued two rounds of requests for supplemental information (RSIs) by letters dated February 6, 2020 (ADAMS Accession No. ML19350B458), and May 6, 2020 (ADAMS Accession No. ML20092G719), to obtain information needed to facilitate a detailed technical review. In response to the RSIs and other interactions with NRC staff, GNF-A determined that more time was needed to generate the requested information. By letter dated June 23, 2020 (ADAMS Accession No. ML20175A206), GNF-A requested to withdraw the license amendment request, and for NRC staff to review its minimum margin of subcriticality (MMS) for use up to 8 wt.% U-235 in support of GNF-A's development of its safety basis at the increased enrichment.

By letter dated July 15, 2020 (ADAMS Accession No. ML20196L660), NRC staff issued a request for additional information to obtain information needed in support of the staff's technical review of GNF-A's MMS. In a letter dated July 28, 2020 (ADAMS Accession No. ML20210M309), GNF-A provided a response to the staff's request.

DISCUSSION

Title 10 of the *Code of Federal Regulations* (10 CFR) Paragraph 70.61(d) requires, in part, that the risk of nuclear criticality accidents be limited by assuring that under normal and credible abnormal conditions, all nuclear processes are subcritical, including use of an approved margin of subcriticality for safety. Because computational methods are subject to multiple sources of uncertainty (e.g., uncertainty related to mathematical approach, errors in cross-section data, etc.), certain penalties are imposed to ensure that systems calculated to be subcritical are actually subcritical. Computational methods are validated against experimental benchmark data to quantify the degree to which the method over-predicts or under-predicts reality in its calculation of a system's ability to self-sustain a fission reaction (k_{eff}), and a direct penalty to k_{eff} is assessed (bias). Additional penalties may be applied, as appropriate, for extensions beyond the method's areas of applicability. Administrative margin, commonly referred to as the minimum margin of subcriticality (MMS), is also applied to bound unknown or difficult to quantify

uncertainties beyond those identified by validation. This administrative margin (i.e., the MMS) represents the "approved margin of subcriticality for safety" as it appears in Paragraph 70.61(d).

The MMS must be justified. Although many different methods exist for justifying the MMS, the appropriateness of the MMS is, in general, largely based on the quality of the validation methodology and whether it provides a level of assurance that the estimated bias is accurate and bounding to its various potential sources. The appropriateness of the MMS may also be based, at least in part, on the subcritical margin provided by conservative practices and other sources of safety margin. In considering the contribution from safety margin to the appropriateness of the MMS, the non-linear response in k_{eff} to changes in safety margin must be considered because, for example, a 2 percent change in moderation does not necessarily correspond to a 2 percent change in k_{eff}. Even still, conservative practices and other sources of safety margin can provide a predictable and dependable amount of conservatism generally corresponding to several percent in k_{eff} and, therefore, may be used as part of the justification of the MMS. There are no specific criteria as to what constitutes an appropriate MMS; however, cross-section data is generally not known more precisely than 1–2 percent. While this does not necessarily correspond to an equivalent impact to k_{eff}, operating experience with criticality code validation suggests that biases and spreads in the data of a few percent can be expected. Consequently, the MMS should generally be large compared to the uncertainty in the bias, and should not be less than 0.02 (NRC, 2015).

AREA OF INTEREST

The operations in which the criticality code is to be used to perform calculations and support the development of the licensee's safety basis make up the area of interest (AOI). As a fuel fabrication facility designed to dry-convert enriched UF_6 to U-oxide pellets and ultimately fuel assemblies, the facility operations and associated considerations for the establishment of the AOI for the GNF-A facility include, but are not limited to, the following:

- enriched uranium hexafluoride (UF_6) cylinder handling and storage;
- UF_6 feed operations including sublimation;
- hydrolysis;
- defluorination/calcination;
- enriched uranium oxide (U-oxide) handling and storage;
- pelleting, and pellet handling and storage;
- fuel pin loading, and fuel pin handling and storage;
- fuel assembly handling and storage; and
- scrap handling and storage.

The staff notes that GNF-A does not have a scrap recovery process.

For the purposes of establishing an effective AOI, the normal and credible abnormal conditions of the above facility processes include, but are not limited to, the following:

- dry low-enriched uranium (LEU) systems;
- moderated homogeneous LEU systems;
    - uranyl fluoride – water mixtures
    - uranium oxide – water mixtures
- moderated heterogeneous LEU systems;
    - uranyl fluoride – water mixtures

- uranium oxide – water mixtures
- reflected/moderated uranyl fluoride systems
- reflected/moderated uranium oxide systems

The staff notes that dry systems do not represent a substantial criticality concern at the GNF-A facility due to the required presence of moderator for criticality to occur.

STAFF REVIEW AND ANALYSIS

As stated in Chapter 5.0 of SNM-1097 (ADAMS Accession No. ML19169A086), GNF-A's current approved MMS is 0.03. However, the approval of this MMS, as documented in "Safety Evaluation Report (SER) for the Renewal of SNM-1097 Global Nuclear Fuel – Americas Wilmington, North Carolina" (ADAMS Accession No. ML091000554), hereafter referred to as the "SER for SNM-1097 renewal," was based on the possession limit of SNM-1097 (≤5 wt.% ^{235}U). The SER for SNM-1097 renewal stated that the product manufacturing operations authorized by SNM-1097 consists of receiving, converting, and processing less than 5 wt.%.

An increase in enrichment from 5 to 8 wt.% not only has the potential to impact the effects of conservative practices and safety margin on subcritical margin, but it also challenges whether the selected benchmarks used for validation provide a level of assurance that the estimated bias is accurate and bounding to its various sources. As such, GNF-A requested that the NRC review its MMS to determine whether it is acceptable for use up to 8 wt. %.

The staff notes that Section 5.4.5.2 of SNM-1097 describes several analytical methods to which the MMS would apply that GNF-A uses to perform nuclear criticality safety analyses (e.g., GEMER, GEKENO, MCNP, etc.). However, in a letter dated July 28, 2020 (ADAMS Accession No. ML20210M309), GNF-A committed to use only SCALE6.1/KENO-VI with the ENDF-VII continuous energy data library to perform NCS analyses involving enrichments >5 wt.%. Therefore, the scope of the NRC staff's review regarding the appropriateness of the MMS for enrichments up to 8 wt.% was limited to SCALE6.1/KENO-VI, ENDF-VII, and the appropriateness of the MMS for other analytical methods remains bound by the NRC staff's previous evaluation as documented in the SER for SNM-1097 renewal.

The staff performed its review in accordance with the guidance provided in NUREG-1520, "Standard Review Plan for Fuel Cycle Facilities License Applications" (ADAMS Accession No. ML15176A258), and NUREG/CR-6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology" (ADAMS Accession No. ML050250061), to determine whether the licensee's MMS is acceptable for use up to 8 wt.%. The staff's review primarily focused on GNF-A's methods for estimating bias and bias uncertainty and establishing and limits on k_{eff} (i.e., upper subcritical limits (USLs)); the quantity and quality of selected benchmarks for each area of applicability (AOA); the similarity of selected benchmarks to GNF-A's processes within each AOA; and the contributions to subcritical margin provided by conservative practices and other sources of safety margin. The staff evaluated these focus areas in aggregate to determine whether the MMS is acceptable for use up to 8 wt.%.

MMS for Use up to 8 wt.%

The staff evaluated the licensee's methods for estimating bias and bias uncertainty and establishing USLs; the quantity and quality of the selected benchmark experiments for each AOA; the similarity of the selected benchmarks to GNF-A's processes within each AOA; and the contributions to subcritical margin provided by conservative practices and other sources of

safety margin. The staff evaluated these areas in aggregate to determine whether the MMS is acceptable for use up to 8 wt.%.

The staff determined that the licensee's methods for estimating bias and bias uncertainty and establishing USLs use technically sound statistical approaches and provide a high degree of confidence that appropriately selected benchmark experiments evaluated under these methods will yield an accurate estimate of the bias and its uncertainty. The staff determined that the selected benchmarks were drawn from multiple, independent series and well-established sources. The staff determined that the selected benchmark experiments appropriately spanned the entire range of specified important parameters without large gaps requiring extrapolation or wide interpolation, and that the specified ranges included appropriate considerations for the potential values of important parameters under all normal and credible abnormal conditions. The staff determined that a sufficient quantity of benchmark experiments to draw a physically and statistically meaningful result is appropriately ensured through the use of statistical techniques. The staff determined that the selected benchmark experiments were sufficiently similar to the normal and credible abnormal conditions presented by the licensee's facility processes, and that they provide an acceptable level of assurance that the estimated bias is accurate and bounding to its various potential sources. The selected experiments were sufficiently similar for key parameters, and the key parameters used for benchmark experiment selection were those with the greatest effect on the bias, including material composition; enrichment; physical form of fissionable material, moderating materials, and reflecting materials; hydrogen to U-235 ratio; presence of absorbers; and energy average lethargy of fission. The staff determined that the licensee's conservative practices provide a predictable and dependable amount of conservatism that generally corresponds to several percent in k_{eff}. The staff determined that the MMS was generally large in comparison to each of the individual bias uncertainty values. In aggregate, the staff determined that the licensee's MMS is acceptable for use up to 8 wt. %.

CONCLUSIONS

Based on the review discussed in this report, the staff concludes that the licensee's MMS (0.03) is acceptable for use up to 8 wt.% for the purposes of performing NCS analyses with the SCALE6.1/KENO-IV, ENDF-VII continuous energy package.

The staff also notes that the evaluation and conclusions discussed in this report are with respect to the licensee's MMS for use up to 8 wt.% only. It does not provide any conclusions regarding the physical possession and/or processing of SNM in excess of current possession limits (i.e., ≤5 wt.%). The conclusions discussed in this report may be used to support the development of a safety basis for facility operations involving SNM enriched up to 8 wt.%, as well as to support a future request to amend the SNM-1097 possession limits. However, it does not (in itself) provide a basis for such a change.

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