

NRC Feedback on Terra Innovatum White Paper “Design Considerations on Reactor Core (Fuel) at Nominal Conditions”

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Background

- On May 8, 2025, the NRC staff met with Terra Innovatum to discuss a number of forthcoming submittals, including a white paper focused on fuel nominal conditions.
 - Agencywide Documents Access and Management System (ADAMS) Accession No. [ML25126A223](#)
- On June 8, 2025, Terra Innovatum submitted a white paper titled “Design Considerations on Reactor Core (Fuel) at Nominal Conditions.”
 - ADAMS Accession No. [ML25159A010](#)
- The white paper describes how standard pressurized water reactor (PWR) fuel is planned to be integrated in the design of Terra Innovatum’s SOLO 1 megawatt-electric (MWe) gas-cooled reactor and under which conditions it is planned to be operated.

Specific Feedback Requested

Terra Innovatum requested feedback in the following areas:

1. The use of light water reactor (LWR) fuel considering Baseline- and Stretched- Nominal conditions.
2. The possibility of relying on LWR fuel qualification studies.
3. The justifications provided to demonstrate the applicability of LWR fuel pre-existing licensing basis for SOLO implementation.

Notes on NRC Staff Observations & Feedback

- The feedback and observations presented herein are preliminary and subject to change.
- The feedback and observations presented herein are not regulatory findings on any specific licensing matter and are not official agency positions.

1. Using LWR Fuel in SOLO

- The SOLO environment appears to be less challenging than that of a PWR (e.g., lower linear heat generation rate (LHGR) and inert environment), however, the NRC staff would like to discuss:
 - Potentially higher cladding temperatures
 - Potentially harsher fast neutron spectrum leading to higher fast fluence at the same burnups

1. Using LWR Fuel in SOLO

- The proposed use of standard LWR fuel in the SOLO reactor is generally consistent with applicable regulatory frameworks.
- Implementation of this concept and its safety demonstration may warrant additional validation to demonstrate its suitability under the specific operating conditions of the SOLO design.
- The NRC staff has identified several areas related to the use of LWR fuel in SOLO where additional justification may be expected in a future application:
 - Validation of fuel performance models in the SOLO temperature range, particularly mechanical behavior and creep models
 - Potential for gap closures
 - Potential for fuel rod bowing (due to mechanical impingement or differential free growth)
 - Potential for fuel rod growth and differential growth between fuel, cladding, and graphite

2. Reliance on LWR Fuel Qualification Studies

- While many aspects of existing LWR fuel qualification data may be applicable to the SOLO environment, certain areas may not be consistent with the established LWR operational envelope.
- Steady-state fuel temperatures in SOLO are well bounded by those observed in LWRs, suggesting that temperature-dependent fuel qualification data from LWR applications are likely transferable.
- For the cladding, the prolonged residence at elevated temperatures in SOLO, particularly under stretched nominal conditions, have the potential to exceed those typically encountered in LWR service. As such, additional justifications may be warranted.
 - Thermo-mechanical response under irradiation, including creep, dimensional growth, and other time-dependent deformation mechanisms at the relevant temperature and fast neutron fluence levels.

2. Reliance on LWR Fuel Qualification Studies

- The WP primarily addresses normal operating conditions, with no evaluation of transient or accident scenarios. Understanding fuel behavior, including failure modes and thresholds, under such conditions is essential for safety.
- Given that SOLO's transients could differ from those in LWRs, existing licensing bases should be evaluated for applicability, and new design-specific criteria may be needed.
- Future licensing efforts are expected to include safety analyses that accurately capture the relevant physical phenomena and reflect SOLO-specific conditions. Developing specified acceptable fuel design limits (SAFDLs) tailored to SOLO would further support fuel integrity assessments under both normal and off-normal conditions.

3. Applicability of LWR Fuel Licensing Bases

- Certain SAFDLs established for LWRs (such as those related to temperature and strain limits) may be applicable to SOLO.
- Other SAFDLs may not be directly applicable and new SAFDLs may arise due to the differing chemical environment and irradiation conditions.
- A detailed assessment of SAFDLs should be carried out to determine applicability and a path to address each SAFDL.

3. Applicability of LWR Fuel Licensing Bases

- Temperature-dependent fuel qualification data from LWR applications are likely applicable to the SOLO design.
- Deviations in operating conditions from LWRs may impact cladding creep, irradiation-induced growth, and long-term mechanical integrity, which may not be fully bounded by existing LWR qualification data.
 - Therefore, additional validation or targeted demonstration efforts may be necessary, particularly to confirm the cladding's mechanical behavior under SOLO-specific conditions.

General Observations

- The NRC staff noted the following general observations:
 - Deviations from typical LWR operational conditions may have significant influence on cladding performance.
 - The operational envelope of SOLO should be evaluated for potential fuel failure modes not typically observed in LWRs.
 - Prolonged in-reactor time at potentially higher temperatures may require further evaluation of irradiation creep.
 - Additional justification for the assumption that gaps do not close and the evaluation of interactions if gaps were to close would likely be required in a future application.
 - Additional information on material properties, behavior models incorporated, and governing physics considered in modeling and simulation activities would likely be required in a future application.

Discussion