NRC Staff Feedback on TerraPower's Type 1 Fuel Pin Qualification Plan White Paper

Note: **[[ ]]** denotes proprietary information.

In general, the U.S. Nuclear Regulatory Commission (NRC) staff observed that the TerraPower, LLC's (TerraPower) Type 1 Fuel Pin Qualification Plan laid out a logical approach to qualify Type 1 fuel pins. In some cases, the NRC staff noted that clarification or additional information would facilitate future licensing actions. Specific observations include:

Overall Comments

1. The NRC staff understands that the intent of Type 1 fuel is to be as similar as possible to fuels used in the Experimental Breeder Reactor-II (EBR-II) and the Fast Flux Test Facility (FFTF). However, newly manufactured fuel may behave differently, whether intentional (e.g., improved manufacturing capability) or unintentional. As part of qualification activities, it will be important to provide thorough comparisons of the newly manufactured and historical fuel, with emphasis on specific areas for which the newly manufactured fuel may exhibit different performance compared to historical fuels.

2. In general, references should be submitted or made available for audit to assist the NRC staff in their review of the submittal. The NRC-approved versions of documents should be cited, if available.

Section 3 – Background

1. This section states, in part, "If significant changes to the fuel design or targeted operating conditions do occur, then the fuel qualification plans would need to be reassessed." The NRC staff notes that "significant changes" is subjective, and objective criteria should be used to screen whether the changes warrant reassessment of fuel qualification plans.

Section 6 – Discussion

1. In the sentence, "A key fuel testing need is to demonstrate the suitability of the established fuel design criteria and limits to prevent damage and/or failure, as well as maintain coolability of the core under all licensing basis events (LBEs)," the NRC staff recommends clarifying that core coolability is maintained during and after all LBEs.

Section 7 – Fuel Design Criteria

1. In general, Tables 7-1 through 7-3 and Tables 9-1 through 9-3 show very similar information, but not all of the wording or entries are consistent between the tables in the two sections (e.g., RAC 4.2-3.5 is not in Table 7-3, but it is in Table 9-3). The NRC staff recommends checking for consistency and/or consolidating the information into a single table to eliminate consistency issues.

2. In some instances, in Tables 7-1 through 7-3 (and the similar Tables 9-1 through 9-3), the identified applicable design basis criteria to satisfy each Regulatory Acceptance Criterion (RAC) appear to be dependent on other factors or criteria. The NRC staff recommends identifying such dependencies where they exist as confirmation that all relevant factors are accounted for. Examples include, but are not limited to:

a. Regarding RAC 4.2-1.1, the fuel system damage criterion of total diametral clad strain should account for fission gas release; allowable cladding wastage due to fretting, corrosion, and fuel-cladding chemical interaction (FCCI); etc.
b. Similarly, the RAC 4.2-1.8 design basis criterion states that fuel pin internal pressure affects cladding strain, but clad wastage also affects strain via increases in localized stress.

3. The NRC staff recommend making the last sentence before Table 7-1 (**[[**

]]) publicly available. It does not appear to be proprietary (the white paper title clarifies that the scope is just fuel pins), and more importantly, **[[**

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4. Regarding the sentence discussed in the previous observation, the NRC staff recognize that **[[** **]]**. However, Section 1 of the paper states that applicable interfaces required to support fuel pin design criteria will be identified. For some RAC, it was not immediately obvious why parts were excluded, and pointers to the interface area may assist a more efficient review in subsequent licensing submittals should they follow the format of this paper. Examples that TerraPower clarified as part of an initial discussion include:
    a. RAC 4.2-1.4 and 4.2-2.5: Erosion is excluded from the applicable design basis criteria because it is covered by the thermal-hydraulic design.
    b. RAC 4.2-1.6: Pin bowing is not included in the acceptance criterion because it is addressed in the fuel assembly qualification plan.
    c. RAC 4.2-2.4 is not included in this paper because it is addressed in the fuel assembly qualification plan.

5. Regarding Table 7-1/9-1, RAC 4.2-1.1, please clarify in a future submittal that no other fuel system components besides cladding need to be considered. If other components are considered, but deemed not to be limiting or important, provide a brief description of that consideration.

6. In Table 7-1 (and 9-1), RAC 4.2-1.6, the acceptance criterion states, in part, that limits on dimensional changes shall be established to ensure that dimensions remain within operational tolerances. The NRC staff note that the operational tolerances should be established such that they preclude fuel and fuel component damage.

7. Regarding Table 7-1, RAC 4.2-1.8: Clad lift-off is a concern with light water reactor fuel due to the difference in fuel pin and system pressures. Please clarify in a future submittal whether clad lift-off could be a concern with metallic sodium fast reactor fuel.

8. Regarding Table 7-2, RAC 4.2-2.1, please clarify in a future submittal whether any other fuel failure modes resulting from cladding overheating besides eutectic liquefication need to be considered. If other failure modes are considered, but deemed not limiting or are addressed elsewhere, provide a brief description of that consideration.

9. Regarding Table 7-2, RAC 4.2-2.3, applicable design basis criteria, please clarify in a future submittal whether any other fuel failure modes besides thermal creep need to be considered. If other failure modes are considered, but deemed not limiting or are addressed elsewhere, provide a brief description of that consideration.

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10. Regarding Table 7-3, RAC 4.2-3.2, future submittals should clarify whether basic material properties are relevant to the available supporting data.

Section 8 – Fuel Design Description

1. Related to Table 8-2, other fuel system information and associated tolerances that may be important to capture in future submittals include fuel smear density/fuel slug outer diameter and rod internal void volume.

2. Table 8-2 lists allowable slug impurities as required fuel system information. Future submittals should clarify if the impurity limit is specific to newly made fuel; whether TerraPower will use recycled or down-blended material; and, if so, whether the existing impurity specification applies.

3. Is historical metallography available for previous EBR-II or FFTF fresh fuel? If so, is there a plan to compare the TerraPower fuel to the historical fuel microstructure? Is fuel performance (e.g., centerline melt, fuel-clad eutectic formation) sensitive to microstructure?

Section 9.3 – Operating Experience

1. **[[**

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2. The NRC staff recommends adding a reference to support the statement **[[**
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3. In addition to the information in Table 9-16, future licensing submittals should specify **[[**
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Section 9.4 – Testing

1. For items identified as Primary Factor of Concern, please clarify in future test plans whether multiple tests over various ranges will be performed (e.g., 4.2.2-1, peaking cladding temperature limit vs. burnup).

2. Table 9-18, “Summary of Future Testing Activities to Predict Fuel Failure,” describes **[[**
]] Please clarify in future licensing submittals how TerraPower will address undercooling transients.

3. Regarding Table 9-20, “Summary of Tests to Address High-Importance Phenomena,” please clarify/consider the following for future licensing submittals:
   a. For fission gas release, does any data exist for transient fission gas release? Could some be obtained from **[[** **]]**?

b. Will **[[** **]]** produce displacements per atom that bound the expected use?

Section 9.5 – Analytical Predictions

1. In Tables 9-21 through 9-24, what are the plans for phenomena/parameters characterized as "partially implemented" or "not yet implemented"? For example, will these eventually be implemented?

2. Table 9-22 addresses transient conditions on peak cladding temperature, but Table 9-21 makes no mention of transient conditions (e.g., transient fission gas release, transient coolant temperature, and pin power histories). Is transient thermal creep addressed? It seems to be captured in peak cladding and fuel temperatures in Table 9-23. **[[**

]] It's not clear why this wouldn't be included in total peak cladding strain (RAC 4.2-3.1, 4.2-3.3, 4.2-3.5).

Section 12 – Post Irradiation Surveillance

1. The last sentence of the paragraph says that five primary concerns were identified, but it appears that only four are listed. Please clarify.

2. Regarding **[[**

]] These factor into reactivity effects which may need to be better understood and documented as part of the analysis in the license application.

3. The NRC supports the use of **[[**

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4. Table 12-1 states, **[[**

"**]]** Please clarify the concern for which regulatory feedback is sought.