NRC's Feedback on TerraPower, LLC's Advanced Sodium Fast Reactor
Fuel Assembly Qualification Plan

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

Section 1

- The stated objective of the paper is to confirm that all aspects of the fuel assembly design and fabrication process will provide reliable and safe operation of an advanced Sodium-Cooled Fast Reactor (SFR) where advanced metallic fuel pins will be used. It isn't clear to the staff how this paper does this in its entirety (e.g., conditions beyond normal operations and mechanical upsets). What is the expected objective of this report from a regulatory perspective?

- Along the same lines, the scope of this work should be better defined in Section 1, the introduction. The outline of the work is clear and a reference to the fuel pin qualification plan is provided, but the nature of this report (TerraPower specific?) and where the boundaries of this qualification effort align, overlap, or perhaps are planned in future efforts could be provided.

Section 2

- If the document is intended to have broader applicability beyond TerraPower, provide additional discussion as an intro/example discussion in Section 2. If the document is intended for TerraPower fuel qualification evolutions (beyond a single qualified fuel type), it would be beneficial to provide an explanation to this effect.

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- For the discussion concluding with "Therefore, optimizing dimensions of the CRS and the clearances are very important in order to meet the competing design criteria," staff appreciates the level of detail, but reads this as for context only. These design elements are important from an engineering perspective, but as long as the safety acceptance criteria are met, how an applicant chooses to satisfy them is up to the applicant. Referencing this discussion later in the document (or in a future submittal) to contextualize the final design parameters could be useful.

- Figure 2-3 provides valuable information, but could be augmented for the purposes of this report by highlighting the portions that are pertinent to the scope of this report.

- Control rod insertability and other interactions between the fuel assembly and control rods seem to be within the scope of the report. Would it be possible to add a diagram of how the control rods interface with the core? Are they between assemblies, within an

assembly or have some other unique bundle arrangement (i.e. control elements in a duct)?

Section 3

- The statement "Satisfies relevant design criteria" – we believe covers part, but not all of what is needed to satisfy the design criteria. The report is stated to be applicable to SFR-design criteria (DC)-2, 10, and 35. Based on the staff's reading of the document, we agree with the bulleted application on page10, but each of those represent only a portion of the expected justification for each DC and there would be subsequent information required as part of later submittals. Providing additional context for the applicability of this report could help address questions as part of a set of future submittals.

- For DC 2, we agree with the bullet as scoped only to the seismic analyses for fuel assemblies. The scope of DC 2 goes well beyond just this for the fuel, and beyond that for the reactor as a whole.

- For DC 10, while the set of provided applicable conditions is within the scope of DC 10, it is not clear to the staff how the objectives related to normal operation and anticipated operational occurrences (AOOs) is addressed in entirety.

- For DC 35, we recognize the criteria applies as cited for coolable geometry under severe events; however, this represents a very small portion of the DC 35 justification that would be expected – focusing more on the cooling requirements under a variety of scenarios.

- On page.11, the discussion on DC 35 states "… under severe events that may cause non negligible plastic deformation." It would help to define what constitutes negligible plastic deformation, especially in the context of any related acceptance criteria.

- Regarding the American Society of Mechanical Engineers Boiler and Pressure Vessel Section III Division 5 discussion, the NRC staff agrees with the characterization provided, but highlights that additional information or context could be useful following the staff issuance of the draft regulatory guide (for instance, the use of any code cases).

- Should Title 10 of the *Code of Federal Regulations* (10 CFR) Appendix S be mentioned? The earthquake basis criteria are derived from requirements located in 10 CFR Appendix S.

Section 4

- Service conditions are defined by the frequency ranges set forth in Nuclear Energy Institute (NEI 18-04). While staff does not take any issue with doing so, the NRC notes that doing so involves use of Regulatory Guide 1.233 (which endorses NEI 18-04 Revision 1). Use of this methodology would be subject to an overall review of its implementation beyond just the scope of this topical report.

- For the regulatory acceptance criteria provided:

  - 4.2-1: (fuel assembly damage criteria) would seem to be in line with the scope of the report. Why are dimensional changes due to phenomena not listed (e.g. irradiation, any non-mentioned growth)?
  - 4.2-2: (fuel pin failure criteria) states "merged into 4.2-6", but it is not clear to what extent this criterion will be resolved as part of this document. For instance, are geometric effects internal to the pin (due to internal pressures or irradiation swelling) to be assessed as part of this report or another?
  - 4.2-3: (fuel coolability) regulatory acceptance criteria (RAC) are provided for structural deformation and assembly lift-off, but no provisions appear to be provided for fuel coolability during transient and accident conditions. Is this intended to be part of a separate report or is this a misunderstanding on the part of the staff?
  - 4.2-4: (control rod insertability) we agree with the set for the purposes of this report; for control rod structural performance independent of neighboring assemblies, will that be provided as part of another effort related to the rods themselves?

- In Table 4-1:

  - RAC 4.2-1.2 - the AC is not specific ("significantly less"). At this stage of design, this is not an issue, but staff notes that the standard review plan (SRP) (not necessarily applicable but used as a parallel) provides specific target values for amplitude and number of cycles. The proposed values need not be the same, but a justification for what constitutes "significantly less" should be provided when that determination is reached.
  - RAC 4.2-1.4 – No issue, just an observation – using in-reactor tests to evaluate corrosion products may prove difficult considering the need to evaluate prototypic system conditions (for instance, the effects from any cleanup or cover gas) and duration of operation.
  - When referencing the Reactor Development and Technology, as the document is not in the reference section, providing a brief discussion somewhere in Section 4 regarding the role these play in developing design basis criteria would be helpful (in addition to adding it as a reference).

- In Table 4-2, one criterion is that structural deformation of fuel should not lead to undercooling. Do these combined loads bound expected AOOs and design basis events (DBEs) (is a core disruption event that would produce severe assembly loads classified as beyond DBE)?

- How does the term "design basis earthquake" fit within the safe shutdown earthquake (SSE) and operating basis earthquake (OBE) classifications? Is only elastic deformation assumed for OBEs? In Table 4-3 there is statement that "residual changes should be limited…" which implies OBE plastic deformation. Last row in the Phenomena Identification and Ranking Table (PIRT), Structural and Damage Limit, Additional Comments, states that most of the time inelastic deformation is not permitted. When is deformation permitted for an OBE?

Section 5

- In Section 5.1, it isn't clear to the staff how **[[ ]]** fit within the scope of the regulatory aspects of the report. Staff recognizes how the concept would be important as part of the design phase, but from a regulatory perspective staff expects that applicants will provide a justification for **[[**

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  This conceptual discussion is largely applicable to a number of concepts throughout Section 5 (for instance, in Section 5.2). The NRC staff understands the engineering motivations associated with design decisions and optimizations, but the applicant is responsible for making the decisions. Staff would then review the design bases and acceptance criteria for safety adequacy.

- In general, the NRC staff agrees with the model and method objectives in Section 5.1.

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- For Section 5.2, it is not clear to the staff how the proposed models and method objectives provide for assembly qualification. If TerraPower proposes to directly model the **[[**

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- Section 5.3 focuses on mechanical effects resulting from [assembly drop.] Although staff would not expect such analysis to be provided in the context of this report, staff notes other consequences from this event class (such as criticality or radiological consequences) would need to be evaluated if applicable.

- Section 5.4 implies that **[[**

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- Staff agrees with the general approach set forth in Section 5.4. The acceptance criteria for the method align with the expected needs. Staff notes that compliance with NUREG-0800 (SRP) Chapter 4.2 is not required, though agrees it offers a useful framework

especially when considering relatively technology neutral fuel design aspects such as core seismic response.

- As a general comment, it might be beneficial to provide which condition where some of the parameters are more limiting (e.g. beginning or end or life), as it isn't always clear when parameter changes may influence test conditions.

Section 6

- As general feedback on the PIRT, staff would not evaluate the phenomena influencing parameters and ranking provided as part of a topical report in most circumstances. Instead, staff review at a later stage would focus on the results of these phenomena, along the lines of a failure modes and effects analysis. Accordingly, feedback here is provided as initial thinking on behalf of the NRC staff on what has been provided.

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- Are any control rod parameters aside from insertability and seismic trip requirements within the scope of the report? If so, this should somehow be scoped into Section 5, 6 or 7.

Section 7

- To what extent do the tests described in Chapter 7 fulfill the verification and validation needs outlined in Section 7.1? The report describes the process of acquiring and developing software, and points to Section 7.2, which describes a general scope of mechanical parameters for data to be acquired. Then Section 7.4 states "A

comprehensive plan shall be established to provide the fuel assembly design evaluation results that demonstrate all the design basis criteria described in Section 4 are satisfied." At a high level, this provides an accurate description of the process to be followed, but staff would expect a higher level of specificity in how which tests provide the information needed for the verification and validation activities. This could be the same as the "relevant testing/analysis activities" column in Tables 4-1 and 4-2, that linkage just was not clear in reading the report. Effectively, to fulfill the objective, more specific data should be outlined beyond the mechanical parameters described in Section 7.2 (or these areas should be scoped out of the report and directed elsewhere).

- How are parameters to be refined via testing versus those being evaluated through surveillance? Component tests, single assembly tests, and multiple assembly tests for the purposes outlined in Section 7.2 each make sense, but generally focus on mechanical parameters. Impacts from thermal and irradiation effects appear unclear from testing, save from possibly Section 7.3 (further detailed below). If surveillance parameters are to be used for qualification, how does this factor into the verification and validation discussed in this report? If end-of-life effects are accounted for through assumptions or input conditions in the testing, it would help to provide a statement or footnote to that effect where those effects are accounted for.

- The section, "Historical Operational or Pre-existing Experimental Data Qualification Plan," could use additional specificity. Data points and uncertainties are good starting points, and engineering judgement and PIRT results represent valuable input, but additional factors (such as reproducibility and data quality) should probably factor in qualifying historical data. Further, examples of the types of data to be qualified would provide context.

- Finally, accident and off-normal behavior and impacts on the fuel assembly are not described in Section 7. This may not fall within the intended scope of this document, but that is not clear based on the stated objectives here.