NRC Staff's Questions and Observations on Terrestrial Energy's

Principal Design Criteria White Paper

Note: **[[ ]]** denotes Proprietary Information

General Comments:

1. Terrestrial Energy (TEUSA)appears to claim almost, if not all, of the Integral Molten Salt Reactor (IMSR®) design Principal Design Criteria (PDC) and associated bases are proprietary. What is the basis for claiming this information as proprietary? It isn't clear how PDCs that are copied, or slightly modified, from Regulatory Guide 1.232 are proprietary.
2. In the bases for many PDCs, TEUSA states that the IMSR® design will meet certain **[[**

   ]] The NRC staff feedback on this white paper does not endorse the use of **[**

   ]]. The staff will review any exemption requests from NRC regulations when they are submitted, and the results of those reviews could potentially impact the PDCs.
3. Provide clarification for the use of the term "Primary Coolant Boundary." The NRC staff understands this boundary to contain the fuel salt, which is both the fuel and coolant for the IMSR® design. However, in the white paper there are separate references to the fuel salt, and the primary coolant, even though the staff understands these to be the same.
4. The bases for some PDC state that design details are still being finalized. It should be understood that the staff's feedback is based on the design as described in the white paper. Any future design changes or development could affect the staff's conclusions.
5. There appears to be residual use of the term "sodium" from the original sodium-fast reactor – design criteria (SFR-DCs). Specifically, PDCs **[**

   ]. Please confirm or address, as appropriate.

Potential Missing PDCs

6. On page 18 of 113 in the TEUSA PDC White Paper, the Irradiated Fuel System (IrFS) is discussed. One of the specified main functions is to "**[[**

   ]]." As noted in References 1 and 2 below, molten fluoride salts are susceptible to radiolytic degradation when frozen. This is because the recombination reactions can be slower than the rate of radiolytic degradation when fluoride salts are in a solid state. The radiolytic degradation can be caused by fission products and radionuclides alone. The byproducts of this degradation can be fluorine gas (F_2), and/or uranium hexafluoride gas (UF_6), if the salt is re-heated. F_2 is highly toxic to humans and may pressurize the IrFS storage tanks or cause corrosion, and UF_6 represents a potentially mobile fissile material and source of radiation. Therefore, should the IrFS, or its components, be covered under a separate PDC and/or should the fuel be allowed to solidify?

a. Depending on the composition fuel salt used in the IMSR® design it may be necessary to **[** **]** to prevent radiolytic degradation of the fuel salt. This **[[ ]]** will depend on the salt composition and radiation dose from fission products and radionuclides in the salt. Additionally, when graphite is exposed to F_2 gas it reacts to form CF_4 (Reference 3). Therefore, is re-introduction of a previously frozen salt a concern with regard to damage to the graphite moderator?
b. Additionally, this discussion may be applicable to PDC 61 if **[[ ]]**. See discussion under "PDC 61" below.

7. PDC 61 – Item (4) in the proposed PDC is focused on **[[ ]]**. However, given that molten fluoride salts become susceptible to radiolytic degradation at low temperatures (i.e. below the freezing point of the eutectic), should the PDC be focused on **[[ ]]**? Heat removal is still important, but ensuring the salt isn't overcooled may also be important to **[[ ]]**. Additionally, would it be appropriate to add consideration of the potential creation of **[[ ]]**? These present hazards that may not be covered in the items in PDC 61. Also, it is not clear whether this PDC, or another, **[[ ]]**.
8. PDC 63 – The same comment for PDC 61 regarding **[[ ]]** applies to PDC 63 as well.
9. Is a new PDC necessary to address **[[ ]]**?
10. The staff needs clarification as to what is intended with PDC/ARDC 6-9.
11. Where is PDC 5 addressed?
12. The proposed wording for **[[ ]]**. Additionally, the staff believes that it may be appropriate for TEUSA to consider whether **[[ ]]**. If adequate heat removal is not provided, properties of the fuel salt crucial to retention of radionuclides may be impacted. This includes changes to thermophysical properties. For example, increased temperature may decrease the solubility of radionuclides and fission products in the salt as well as increase their vapor pressures leading to potential releases of radionuclide and fission product species from the fuel salt.

<u>Specified Acceptable Fuel Design Limits (SAFDLs)</u>

13. PDC 10 moves away from the **[[ ]]**.

14. PDC 12 **[**

] PDC 10, 25, 34, and 78.

Emergency Core Cooling System (ECCS)

15. **[[**

]]. The staff notes that the high-level purpose of the traditional ECCS isn't simply to add coolant, but instead to remove heat (the addition of coolant is the means by which heat is removed after a loss of coolant accident). While the IMSR® does not need coolant addition into the fuel salt, it does need to remove heat in the event of a postulated accident (PA). In the event of a PA, the IMSR® relies on the internal reactor vessel auxiliary cooling system (IRVACS) to remove heat. Based on the **[**

]].

Use of Passive Safety Features to Either Meet or Not Adopt DCs

16. PDCs 20-25 – Why are **[[** **]]** For some PDCs it seems that TEUSA plans to **[[**

]].

17. PDC 26 – This PDC **[[**

]] IMSR® is in fact designed with a secondary shutdown mechanism capable of shutting down the reactor. The staff does not feel that **[[**

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PDC Specific Comments:

18. **[[**

]].

19. PDCs 41-43 - Do the **[[**

] Are other systems available to provide containment cleanup outside of the reactor vessel? Cover gas cleanup systems for MSRs are unique systems. Are there requirements to consider that would not be applicable to typical containment cleanup systems? For example, could the **[[** **]]** be required to remove fission products and other impurities in order to maintain proper salt chemistry/composition and not just to limit release of fission products?

20. PDC 55 – **[[**

]]. The staff agrees that the primary loop does not exit the guard vessel; however, the primary loop of IMSR® contains fuel whereas the primary loop of an SFR (or LWR for that matter) only contains coolant. If a leak were to occur in the IMSR® primary heat exchanges (i.e. a single failure of the heat exchanger), fuel salt would **[[**

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21. PDC 64 – Should this describe the **[[** **]]**? It appears the **[[** **]]** provides radionuclide retention functions during operations and not the **[[** **]]** which TEUSA describes as **[[** **]]**.
22. PDC 70 – Similar to the clarification regarding the primary coolant boundary in Question 3, clarify which system is the "intermediate" coolant system.
23. PDC 71 – Should this PDC discuss the **[[** **]]** It appears that the **[[** **]]**. This indicates that the **[[** **]]**.
24. PDC 72 – The proposed PDC states the **[[** **]**. Will the heating system also be designed to keep the salt molten at all times? This is important because for a fluoride salt to be radiolytically and chemically stable it must be kept in a molten state. Therefore, it may be useful to specify that the salt heating system will **[[**

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25. PDC 73 – TEUSA states that **[[** **]]**. However, part of SFR-DC-73 is "Systems from which sodium leakage constitutes a significant safety hazard shall include measures for protection, such as inerted enclosures or guard vessels." Although the IMSR® design does not use a coolant that is highly reactive with air or water, like sodium, leakage of the molten salt fuel can still constitute a significant safety hazard. NUREG-1368, "Preapplication Safety Evaluation Report for the Power Reactor Innovative Small Module (PRISM) Liquid-Metal Reactor," Section 3.2.4.1, "Protection Against Sodium Reaction," notes that a new PDC to monitor sodium leakage is needed for liquid sodium reactor designs. In its rationale, the staff noted that this criterion is needed to limit consequences resulting from a sodium leak including means to detect spills and protect plant equipment and personnel from corrosive and radioactive corrosion products. **[[**

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26. PDC 79 - Should this PDC apply to the **[[** **]]** as well? In the TEUSA basis for PDC 79 it states that the **[[** **]]**. This PDC is **[[**

]].

27. **[[** **]]** on which the staff would need additional clarification in order to provide feedback. SFR-DC 19 specifically calls out the need for prompt hot shutdown capabilities and **[[**

]]. The staff would need additional clarification/justification to be able to provide feedback.

References:

1. M.S. Sohal, et. al., Idaho National Laboratory, INL/EXT-10-18297 “Engineering Database of Liquid Salt Thermophysical and Thermochemical Properties,” March 2010.
2. D.E. Holcomb, et. al., Oak Ridge National Laboratory, ORNL/TM-2020-1576, “MSR Fuel Salt Qualification Methodology,” July 2020.
3. R.B. Briggs, Oak Ridge National Laboratory, ORNL-3708, “Molten-Salt Reactor Program Semiannual Progress Report for Period Ending July 31, 1964,” November 1964.