Fuel and Core Design Options to Overcome the Heavy Metal Loading Limit and Improve Performance and Safety of Liquid Salt Cooled Reactors

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ABSTRACT

Liquid salt cooled reactors (LCSR) are attractive due to their operation at high temperature that enables high efficiency in electricity production and use in high-temperature (HT) industrial application. Most LSCR designs use fuel based on TRISO particles due to its excellent safety features at HT. However, this attractiveness is challenged by the inherently low heavy metal (HM) loading density of TRISO-type fuel.

The objective of this project is to overcome the neutronic performance limitations resulting from this low HM density, which, within the traditional mindset, makes it impossible to simultaneously achieve the desired power density, discharge burnup and cycle length, while keeping the fuel enrichment in the LEU range This project will therefore devise and examine a broad range of novel and radically novel options for LSCR fuel lattices, fuel assembly designs, and core designs, combined with a range of non-standard refueling options. The latter will range from pseudo-continuous refueling and short (a few months) refueling interval to extended cycle, for a range of LEU enrichments. Use of high conversion Th-^{233}U cycle to alleviate the reactivity swing will be assessed as well. As indicated by our preliminary assessment, this much broader search space, with "dimensions" (i.e, options) not considered before, will not *a priori* exclude options based on "common wisdom", since "common wisdom" may not be correct in this case. This will allow finding and devising new solutions that are feasible and practical. The expected outcome is a range of novel fuel-core-reload options (whether derived from new combinations/approaches, or more likely also incorporating new designs) that will help overcome the LSCR HM loading limitation, while improving the performance and safety parameters.

The scope of the project includes:

- Develop economic model to assess fuel cost with uncertainties
- Perform economic evaluation for a traditional LSCR refueling approach over a wide range of values for enrichment, discharge burnup and cycle length, to uncover non-traditional optimum
- Develop and evaluate novel LSCR fuel design concepts supporting increased HM loading
- Develop and evaluate LSCR fuel burnable absorbers supporting fuel cycle objectives
- Examine broad range of reloading strategies, including frequent refueling to improve fuel utilization
- Devise a pseudo-continuous refueling approach, and develop novel fuel design concept to facilitate such refueling
- Examine use of thorium-bearing fuel optimized for in-situ breed/burn to extend cycle length and reduce reactivity swing

With the over-arching objective:

- Develop novel improved LSCR fuel design concept and reloading strategy