
Stationary Liquid Fuel Fast Reactor (SLFFR) Concept for TRU Burning

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ABSTRACT

The objective of this study is to develop a transformational advanced reactor concept that can effectively burn the hazardous transuranic (TRU) elements of used nuclear fuel. This reactor concept, named Stationary Liquid Fuel Fast Reactor (SLFFR), is based on stationary molten metallic fuel with a co-located reprocessing system for ease of used fuel cleanup and recycling. The overall simplified concept is to use non-flowing liquid metallic alloy fuel of TRU in a closed fuel container. The fuel will enter the reactor as a solid form and will then be heated to molten temperatures in a small melting pot. The fuel will be contained within a closed, thick container with penetrating coolant channels, and thus will neither be mixed with coolant nor flow through the primary heat transfer circuit. The fuel container plays the role of conventional fuel cladding, and thus the defense-in-depth principle is retained as opposed to other flowing fluid fuel concepts. The makeup fuel is semi-continuously added to the system, and thus a very small excess reactivity is required. Gaseous fission products will also be removed continuously, and a fraction of the fuel will be periodically drawn off from the fuel container to a processing facility where mixed fission products and other impurities will be removed and then the cleaned fuel will be recycled into the fuel container.

Liquid metallic alloy fuels have several advantages over solid fuels such as the large negative feedback due to thermal expansion, release of the bulk of gaseous fission products, simplified fuel handling and low fabrication costs, increased resistance to irradiation damage and dimensional changes, and on-line refueling and fission product removal. The large negative reactivity feedback allows the use of a uranium-free fuel that yields a zero TRU conversion ratio, and results in inherent safety characteristics. The molten fuel which is already in its most reactive state would also eliminate the concern about the potential for a hypothetical core disruptive accident. The stationary molten fuel will eliminate the principal problems of flowing fuel systems such as the core and primary coolant system contaminated with fuel materials and fission products, fuel pumping, phase separation, and loss of delayed neutrons, while maintaining the advantages of liquid fuels. The continuous addition of makeup fuel and removal of gaseous fission products will compensate for the reactivity loss due to fuel depletion, making the reactivity control requirements minimal. The thick fuel container and continuous fission gas removal will eliminate the traditional concern of fuel cladding integrity due to irradiation and fission gas pressure buildup, and thus will allow a very high burnup. Simple-geometry fuel container and minimal reactivity control requirements will result in a very simple reactor core system. This system can also be operated at a high power density and temperature; the high power density would lead to a compact core system, and the high operating temperature would yield a high thermal efficiency. Combination of these characteristics will provide a large potential to drastically reduce the capital cost per unit energy produced.