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Pebble Fuel Handling and Reactivity Control for Salt-Cooled High Temperature Reactors

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ABSTRACT

This proposed research project will demonstrate the viability of pebble fuel handling and reactivity control for fluoride-salt cooled high temperature reactors (FHRs). The research results will also improve the understanding of pebble motion in helium-cooled reactors, as well as the general, fundamental understanding of low-velocity granular flows. FHRs have unique safety characteristics due to their very large thermal margins to fuel damage (>500 °C), and the absence of sources of stored energy that can create pressure inside the reactor's containment. Successful use of pebble fuels in with salt coolants would allow these safety benefits to be achieved. Pebble fuels also enable on-line refueling and operation with low excess reactivity, and thus simpler reactivity control and improved fuel utilization. Pebble fuels also permit radial zoning in annular cores and use of thorium or graphite pebble blankets to reduce neutron fluences to outer radial reflectors and increase total power production.

The scope of work in this proposal includes a combination of experimental and simulation efforts that will complement each other and serve to inform our understanding of the behavior of pebble-fueled FHR designs. The proposed X-ray Pebble Recirculation Experiment (X-PREX) will demonstrate a novel method to detect and track pebble translation and rotation throughout the entire packed bed, rather than just at transparent walls. This new facility will build upon extensive experience at U.C. Berkeley in scaled pebble experiments for relevant reactor core geometries. The data obtained from the X-PREX facility will be compared to discrete element simulation results for pebble bed dynamics and will provide a strong experimental basis to validate friction models used in these methods.

The experimental work proposed here will be accompanied with an effort to further our understanding of reactivity control in FHRs. The analysis of pebble bed motion will provide a basis to perform accurate neutronics analysis and determine the control element and shutdown rod worth required to provide control due to pebble-motion generated reactivity changes. The knowledge gained from the validation of pebble dynamic simulation methods will inform the stochastic variations in pebble motion in the bed and residence times. These results can be used to populate a neutronics model with physically realistic pebble bed geometry. These results will be compared with results from the conventional hexagonal unit-cell configurations commonly used in modeling pebble cores.