—Abstract—

Refueling Liquid-Salt-Cooled Very High-Temperature Reactors

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Strategies and approaches to enable rapid and safe refueling of liquid-salt-cooled very high-temperature reactors (LS-VHTRs) are described—including some of the complex trade-offs between fuel design (geometry), reactor core design, fuel fabrication, fuel cycle economics, and refueling. The LS-VHTR, also called the Advanced High-Temperature Reactor, is a new reactor concept that has been under development for several years. It uses a liquid-fluoride-salt coolant with a boiling point near 1400°C and graphite-matrix coated-particle fuel (the same type used in high-temperature gas-cooled reactors). Depending upon goals, the peak coolant operating temperatures are between 700 and 1000°C with reactor outputs between 2400 and 4000 MW(t).

The goal of any refueling system is the rapid and safe replacement of spent nuclear fuel in the reactor core with fresh fuel. There are strong economic incentives for rapid refueling to minimize reactor downtime. For a new reactor concept, such as the LS-VHTR, several refueling considerations are applicable: the refueling strategy, the available technology, and the choice of fuel element design. A reduced number of elements generally implies shorter refueling times.

Several fluoride salts are being evaluated for the LS-VHTR. The salts have melting points between 350 and 500°C, which imply minimum refueling temperatures between 400 and 550°C. The liquid salts are transparent and have physical properties similar to those of water (except for the temperatures).

Several refueling approaches are being considered based on industrial experience. The 14 British Advanced Gas-Cooled Reactors refuel online at high pressure (43.3 bar), with average gas outlet temperatures between 620 and 640ºC and peak temperatures approaching 750ºC. The sodium-cooled Fast-Flux Test Reactor in the United States has refueled off-line at near atmospheric pressure at ~370°C. The prismatic-fuel high-temperature reactors, such as Fort St. Vain, have refueled off-line at atmospheric pressures and low temperatures, while the high-temperature German AVR pebble-bed reactor has refueled online at full pressure and temperatures of 950°C.

The base-case LS-VHTR design uses the same prismatic fuel elements as those used in the Fort St. Vrain power plant with off-line refueling. However, improvements in technology since the 1960s would allow much longer fuel elements with fewer elements in the reactor core. This geometry and other alternative fuel geometries may significantly reduce refueling times. For example, the alternative pebble-bed reactor core allows relatively simple online refueling because the pebble-bed fuel moves through the reactor.