Current Status of the Advanced High Temperature Reactor

David E. Holcomb, Dan Ilas, A. Lou Qualls, Fred J. Peretz,
Venugopal K. Varma, and Anselmo T. Cisneros

The Advanced High Temperature Reactor (AHTR) is a design concept for a central station-type (1500 MW(e)) Fluoride salt-cooled High-temperature Reactor (FHR) that is currently a research and development area within the U. S. Department of Energy Office of Nuclear Energy's (DOE-NE) Advanced Reactor Concepts program. The overall goal of the AHTR development program is to demonstrate the technical feasibility of FHRs as low-cost, large-size power producers while maintaining full passive safety.

FHRs, by definition, feature low-pressure liquid fluoride salt cooling, coated-particle fuel, a high-temperature power cycle, and fully passive decay heat rejection. The AHTR design concept remains substantially immature with significant design issues unexplored and required technologies not yet available. The present design space exploration, however, indicates that reasonable options exist for the core, primary heat transport path, and fuel cycle provided that materials and systems technologies develop as anticipated.

The AHTR design option exploration is a multidisciplinary design effort that combines core neutronic and fuel configuration evaluation with structural, thermal, and hydraulic analysis to produce a reactor and vessel concept and place it within a notional power generation station. A top-down comparative economic analysis has also been performed that shows that the AHTR has the potential to be a low-cost power producer.

The AHTR primary system is a blend of a pool and a three-loop design. The primary coolant is $2LiF\text{-}BeF_2$ (enriched in ^7Li to 99.995%). Decay heat removal is through natural circulation loops that transfer heat from integral heat exchangers to the ambient air. The reactor vessel is cylindrical (10.5-m diameter; 18-m tall) with a short refueling lobe extension on its upper half. The AHTR design calls for a 50°C coolant temperature rise across the core and a mean upper plenum temperature of 700°C. An intermediate fluoride salt loop ($47KF\text{-}53ZrF_4$ [mole%]) transfers the primary heat to an advanced supercritical water power-cycle to produce a net plant thermal efficiency of 45%. Primary coolant flow is upwards through the core. Return flow is channeled downward around the reactor vessel periphery maintaining the reactor vessel at the cold leg temperature. The reactor vessel, primary piping, and primary-to-intermediate heat exchanger are all fabricated from Alloy N.

The reactor core consists of 252 fuel assemblies supported by upper- and lower-support plates. The fuel assemblies consist of 18 plates, each 6 m in length and 2.6-cm thick, suspended from a central 'Y'-shaped support structure and enclosed by a channel box. Both the support 'Y' and the channel box are formed from carbon-carbon fiber composites. The fuel plates consist of a layered structure of coated-particle fuel with the fuel particles located near the plate surface to maximize cooling. The fuel particles are a 9% enriched uranium oxy-carbide variant of the coated-particle fuel currently being developed under the DOE-NE advanced gas reactor program. Each fuel assembly includes a molybdenum alloy control blade. The nominal refueling cycle calls for half of the core to be replaced in a short duration (2–3 days) outage every 6 months.