—ABSTRACT—

Maximizing Temperatures of Delivered Heat from the Advanced High-Temperature Reactor

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The advanced high-temperature reactor (AHTR) is a new reactor concept that uses a high-temperature coated-particle fuel for which significant fuel failure does not occur until the temperature exceeds 1600EC. This is the same basic fuel used in modular high-temperature gas-cooled reactors (MHTGRs). However, the AHTR coolant is a fluoride molten salt with a boiling point near 1400EC. The reactor operates at atmospheric pressure as a pot-type reactor. For power production, the reactor is coupled to a helium Brayton cycle. The electrical efficiency is projected to be 48% with a molten salt reactor exit temperature of 750EC. The reactor is designed to have the same level of passive safety as an MHTGR. The reactor vessel is located within a silo with a passive decay heat cooling system similar to that of the General Electric S-PRISM sodium-cooled fast reactor. In an accident, the molten salt couples the decay heat from the reactor core with that of the vessel wall. Decay heat from the reactor vessel then radiates to a guard vessel, which is cooled by natural circulation of air. In this configuration, the AHTR can use passive safety systems with nominal power levels projected to be in excess of 2000 MW(t).

An evaluation examined raising the temperature to 1000EC. This would increase electrical efficiency (exceeding 55%) or allow coupling to multiple hydrogen production systems. The higher temperatures allow for higher nominal reactor power levels or a smaller reactor vessel and primary system because the performance of the decay heat removal system improves with temperature. The decay heat removal rates are partly dependent upon radiation of heat from the vessel, a process that depends upon temperature to the fourth power. At a nominal 2400 MW(t), the AHTR already has a net electrical output (1100 to 1300 MW(e) depending upon thermodynamic efficiency) in the same class as modern LWRs.

The critical technologies for such high temperatures are the material of construction for the reactor vessel and the intermediate heat exchangers. Because of the unique importance of the reactor vessel to reactor safety, its requirements are the most demanding. Two classes of high-temperature materials are being investigated: high-temperature nickel-based alloys and carbon–carbon composites. These different materials options are described.

This paper considers the issues, implications, and potential improvements (capital costs, etc.) in the AHTR as the peak exit coolant temperature is raised.