—ABSTRACT—

Practical Aspects of Molten-Salt-Cooled Fast-Neutron Reactors

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Molten-salt-cooled fast reactors have been proposed as an alternative to sodium-cooled fast reactors. Sodium-cooled fast-neutron reactors (SFRs) have many attractive features, such as the capability to produce fuel and destroy long-lived radioactive wastes. However, the projected capital costs are significantly greater than those of light-water reactors. Based on technical considerations, molten-salt-cooled fast reactors (MSFRs) may have significantly lower capital costs than SFRs; thus, there is an incentive to examine the feasibility of an MSFR. An exploratory effort has defined some of the characteristics of a MSFR.

Oak Ridge National Laboratory, the University of California at Berkeley, and Sandia National Laboratories are investigating a new thermal-neutron reactor concept, the Advanced High-Temperature Reactor (AHTR). The AHTR combines four existing technologies in a new way: (1) passive safety systems and plant designs from sodium-cooled fast reactors, (2) traditional coated-particle helium-cooled reactor fuel, (3) Brayton power cycles, and (4) low-pressure molten-salt coolants. Preliminary cost estimates indicate that AHTR capital costs are significantly lower than those for sodium-cooled fast reactors, although much of the AHTR facility technology is based on that developed for sodium-cooled fast reactors. These cost differences are a consequence of the differences between sodium and molten salts as coolants.

This work suggests that an MSFR with a traditional fast reactor core with metal or oxide fuel in metal cladding may be significantly more economic than an SFR. Molten salt coolants allow fast-reactor coolant exit temperatures to be increased from 500−550ºC (sodium) to 700−750ºC, with a corresponding increase in plant efficiency from 42 to ~50%. Molten fluoride salts are transparent and have heat transport properties similar to those of water; however, their boiling points exceed 1200ºC. The higher temperatures reduce the size of decay-heat-removal systems and enable the use of nitrogen or helium Brayton power cycles, rather than traditional Rankine steam cycles. The use of inert-gas Brayton power cycles eliminates the potential for sodium−water chemical reactions and the generation of large quantities of hydrogen. The transparent coolant simplifies operations and reactor inspections. The volumetric heat capacity of molten salts is several times that of sodium; thus, the size of piping, valves, and heat exchangers is reduced.

The potential economic advantages provide the incentive to examine the viability of MSFRs. However, molten salt coolants present technical challenges. Only certain cladding materials are compatible with potential molten salts; the neutronics are somewhat different; and the salts have higher melting points than sodium (350 to 500ºC, depending upon the specific salt). The strategic implications, incentives, constraints, and technical uncertainties associated with a potential MSFR are described.