—ABSTRACT—

An Advanced Molten Salt Reactor Using High-Temperature Reactor Technology

Charles W. Forsberg
Oak Ridge National Laboratory*
P.O. Box 2008
Oak Ridge, TN 37831-6165
Tel: (865) 574-6783
Fax: (865) 574-0382
E-mail: forsbergcw@ornl.gov

Per F. Peterson
University of California, Berkeley
4153 Etcheverry, Berkeley, CA 94720-1730
Tel: (510) 643-7749
E-mail: peterson@nuc.berkeley.edu

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C. W. Forsberg
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831
Tel: (865) 574-6783
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P. F. Peterson
University of California
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Berkeley, CA 94720-1730
Tel: (510) 643-7749
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Molten salt reactors (MSRs) are liquid-fueled reactors that can be used for actinide burning, production of electricity, production of hydrogen, and production of fissile fuels (breeding). Fissile, fertile, and fission products are dissolved in a high-temperature, molten fluoride salt with a very high boiling temperature (‑1400EC). The molten salt serves as both the reactor fuel and the coolant. The MSR is one of the six advanced reactor concepts identified by the Generation IV International Forum (GIF) as a candidate for cooperative development.

MSRs were originally developed in the 1950s and 1960s. Two test reactors were built and successfully operated. A detailed conceptual engineering design of a 1000-MW(e) reactor was developed. The commercial objective was the development of a breeder reactor that produced more fuel than it consumed. In the United States, the MSR was the backup option for the liquid-metal fast breeder reactor. The program was canceled in the early 1970s when it was decided to concentrate on development of a single breeder reactor. The GIF included the MSR as an advanced reactor because of two sets of considerations: (1) changing goals for reactors such as actinide burning, and (2) new technologies that may radically change the economics of the MSR relative to many other reactors.

A study was initiated to develop a conceptual design of an advanced MSR. Three technologies developed since the 1970s were identified that may dramatically improve the economics and viability of MSRs: Brayton helium power cycles, compact heat exchangers, and carbon–carbon composites. All three technologies are being developed for high-temperature gas-cooled reactors. Replacement of an MSR Rankine steam cycle with a Brayton cycle improves electrical plant efficiency, reduces the potential for tritium migration from the reactor, and avoids chemical reactions between coolant and the power cycle. In an MSR, up to half of the fuel salt is in the heat exchangers, not the reactor core. Compact heat exchangers drastically reduce the inventory of fuel salts in the heat exchangers and thus reduce the fissile fuel inventory of the reactor. This reduces fuel cycle costs, waste volumes, and plant size. Carbon–carbon composite heat exchangers may allow MSRs to operate at 1000EC with major improvements in efficiency. Carbon-based materials have outstanding corrosion resistance in molten salts. The characteristics and impacts of these new technologies are described. Together, they significantly improve the long-term viability and economic competitiveness of MSRs.