Molten Salt Cooling for Advanced High-Temperature Reactors

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

David F. Williams
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6170
Tel: (865) 574-5769
E-mail: williamsdf2@ornl.gov

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—ABSTRACT—

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C. W. Forsberg
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6165
Tel: (865) 574-6783
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P. F. Peterson
University of California
4153 Etcheverry
Berkeley, CA 94720-1730
Tel: (510) 643-7749
peterson@nuc.berkeley.edu

D. F. Williams
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6170
Tel: (865) 574-5769
williamsdf2@ornl.gov

The Advanced High-Temperature Reactor (AHTR) is a new reactor concept that combines four existing technologies in a new way: (1) coated-particle graphite-matrix nuclear fuels (traditionally used for helium-cooled reactors), (2) high-temperature Brayton power cycles, (3) passive safety systems and plant designs from liquid-metal-cooled fast reactors, and (4) low-pressure molten-salt coolants with boiling points far above the maximum coolant temperature. The new combination of technologies enables the design of a large [2400- to 4000-MW(t)] high-temperature reactor, with reactor-coolant exit temperatures between 700 and 1000EC (depending upon goals) and passive safety systems for economic production of electricity or hydrogen.

In many ways, the AHTR is similar to gas-cooled reactors, with similar coated-particle fuels, passive cooling systems, and power cycles. The primary difference is that the AHTR uses a liquid coolant: a mixture of clean transparent molten fluoride salts with physical properties similar to those of water but with boiling points in excess of 1200°C. The use of a liquid coolant, rather than helium, reduces peak reactor fuel and coolant temperatures 100 to 200°C relative to those of a gas-cooled reactor for heat delivered at the same temperatures to the power cycle or hydrogen production facility. Liquids are better heat transfer fluids than gases and thus reduce temperature losses in the system associated with (1) heat transfer from the fuel to the reactor coolant, (2) temperature rise across the reactor core, and (3) heat transfer across the heat exchangers between the reactor and any hydrogen production plant.

Several closely related highly-stable fluoride salts are being evaluated for use as the coolant. Molten salts were extensively investigated and used in two experimental molten salt reactors (MSRs). In an MSR, the fuel and fission products are dissolved in the salt. The AHTR uses a clean salt and a solid fuel. Experimental test loops have operated for a total of several hundred thousand hours on such salts as part of the MSR development program. The use of a clean salt in the AHTR (without dissolved uranium and fission products) enables higher operating temperatures and a wider selection of metals of construction for heat exchangers, piping, and other components. Previous experience has shown that graphite and graphite fuels are fully compatible with such salts. The paper (1) describes the AHTR, (2) examines the considerations for the selection of a preferred molten salt and associated materials of construction, and (3) addresses related issues associated with molten-salt power-cycle heat exchangers.