—Summary—

ADVANCED HIGH-TEMPERATURE REACTOR: MOLTEN SALT COOLANT AND GRAPHITE FUEL

Charles W. Forsberg
Oak Ridge National Laboratory*
P.O. Box 2008
Oak Ridge, TN 37831-6179
Tel: (865) 574-6783
E-mail: **forsbergcw@ornl.gov**

Paul S. Pickard
Sandia National Laboratory
P.O. Box 5800
Albuquerque, NM 87185
Tel: (505) 845-3046
E-mail: **pspicka@sandia.gov**

Manuscript Date: June 19, 2001
File Name: MSR.AHTR.Reno2001

Article Prepared for
American Nuclear Society 2001 Winter Meeting
American Nuclear Society
Reno, Nevada
November 11–15, 2001

Limits: 900 words
Actual: 879
Session: 2j Generation IV Nuclear Technologies and Roadmap

---

*Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U.S. Dept. of Energy under contract DE-AC05-00OR22725.

ADVANCED HIGH-TEMPERATURE REACTOR: MOLTEN SALT COOLANT AND GRAPHITE FUEL

Charles W. Forsberg
Oak Ridge National Laboratory
P.O. Box 2008; Oak Ridge, TN 37831–6179
Tel: (865) 574-6783
E-mail: forsbergcw@ornl.gov

Paul S. Pickard
Sandia National Laboratories
P.O. Box 5800; Albuquerque, NM 87185
Tel: (505) 845-3046
E-mail: pspicka@sandia.gov

ABSTRACT

An Advanced High-Temperature Reactor (AHTR) to produce very high temperature heat is proposed for (1) production of hydrogen (H_2) by thermochemical methods and (2) efficient production of electricity by advanced energy conversion technologies. The AHTR uses a coated-particle graphite fuel similar to that planned for use in modular high-temperature gas-cooled reactors (MHTGRs). A molten salt coolant is used to allow for operation at atmospheric-pressure and to increase the operating temperatures. The coolant characteristics provide unique safety and operational advantages when operating at very high temperatures.

I. INTRODUCTION

There is a growing demand for high-temperature heat for efficient production of electricity and H_2. Hydrogen is used in the refining of crude oil to produce gasoline (Forsberg and Peddicord 2001). Because of increasing demand for clean fuels and the need to use more-abundant heavier crude oils, the energy output of the H_2 used to produce chemicals and liquid fuels for the United States is projected to be equivalent to -200 Gw by 2010. If a 50% efficient thermochemical process is used to produce this H_2, the thermal energy requirements would exceed the total thermal energy produced by all existing nuclear plants in the United States. Thermochemical H_2 production methods require heat between 800 and 1000EC. High-efficiency production of electricity requires similar temperatures. A reactor designed to produce heat at these temperatures with improved safety is proposed.

II. REACTOR DESCRIPTION

The AHTR reactor core contains a coated-particle graphite-matrix fuel and core with characteristics similar to that developed for MHTGRs. Such fuels have been demonstrated at temperatures up to 1200EC, allowing outlet temperatures in the range of 1000EC. The ATHTR power can be scaled from 100s to 1000s of MWth. The AHTR fuel cycle would be similar to that for the MHTGR.

The liquid coolant (Cook and Cantor 1968) would be a molten fluoride salt ($2LiF\text{-}BeF_2$). The liquid coolant would transfer heat from the coated-particle graphite-matrix fuel in the reactor core to either (1) a thermochemical H_2-production plant or (2) a high-efficiency electric system. This particular salt has a boiling point of -1400EC and was originally developed for use in molten-salt-fueled fission reactors and as a coolant for fusion reactors. Several other candidate salts exist such as FLiNaK (a eutectic mixture of 46.5 mol % LiF, 11.5 mol % NaF, and 42 mol % KF). Fluoride salts are fully compatible with graphite. (for over a century, the aluminum industry has electrolyzed aluminum fluoride salts in graphite furnaces for to produce aluminum metal.)

The combination of the graphite fuel form and the molten salt coolant makes possible the very high temperatures required. The low-pressure coolant reduces the need for high-temperature, *high-strength* materials in the reactor system, compared with those required in reactors that use high-pressure helium or other high-pressure fluids to transfer heat. The maximum salt outlet temperature can be significantly higher than that for a gas-cooled reactor with the same graphite fuel and same peak fuel-temperature limits. This is a consequence of the better heat-transfer properties of molten salt (which are similar to those for water) compared with helium. The improved heat transfer lowers temperature drops between (1) the fuel and coolant and (2) coolant and energy conversion system (H_2 or electricity). Preliminary engineering estimates indicate that for the same fuel temperature limits, the delivered temperature to the secondary system can be 100 to 200EC hotter than for a reactor cooled with helium.

The low pressures (1) enable use of design options such as pot-type reactors to enhance passive safety, and (2) allow the scaling to different reactor sizes without the constraints of high pressure. Hydrogen production facilities and some advanced power conversion systems operate at low pressures.

III. SAFETY SYSTEMS

The AHTR reactor has some safety systems in common with other reactors, as well as some unique features. Reactor power is limited by the high-temperature Doppler effect within the fuel. The reactor physics are similar to those of gas-cooled graphite-moderated reactors. In an accident, the decay heat would be conducted directly from the reactor core, through the reactor vessel, and then to the environment, providing effective decay-heat cooling.

The molten salt coolant provides enhanced safety margins: (1) the coolant has a high heat capacity to absorb decay heat, (2) the difference (at least 400EC) between the operating temperature and boiling point of the salt provides a large margin before boiling occurs, and (3) the physical properties of the coolant allow its natural circulation to provide decay-heat cooling.

The molten salt coolant provides unique safety benefits under severe conditions: (1) operation at atmospheric pressure eliminates a primary driving force for radionuclide releases, reduces the forces that can destroy the containment or confinement system, and simplifies isolation of the reactor from the environment; and (2) most fission products and actinides dissolve into the coolant.

IV. OTHER CONSIDERATIONS

Some investigations of a similar reactor design have been initiated in Russia (Novikov 1995). The goals are similar: to combine very high safety margins with very high temperatures. The major technical concerns that have been identified are development of materials that can operate for long periods of time at high temperatures and system issues. Unlike many other new reactor concepts, the AHTR is based on two demonstrated technologies: (1) coated-particle fuels and (2) molten salts. This reduces many uncertainties and decreases development costs.

REFERENCES

Novikov, V. M., 1995. “The Results of the Investigations of Russian Research Center—‘Kurchatov Institute’ on Molten Salt Applications to Problems of Nuclear Energy Systems,” Am. Inst. of Physics.

Forsberg, C. W. and K. L. Peddicord, November 11–15, 2001. “Hydrogen Markets and Futures for Nuclear Power,” *American Nuclear Society Annual Meeting, Reno, Nevada*.

Cook, J. W. and S. Cantor, 1968. *Physical Properties of Molten-Salt Reactor Fuel Coolant and Flush Salts*, ORNL/TM-2316.