Nuclear Production of Hydrogen Using Thermochemical Water-Splitting Cycles*

L.C. Brown, G.E. Besenbruch, K.R. Schultz†
General Atomics, P. O. Box 85608, San Diego, California 92186-5608
Phone: 858-455-4304, Fax: 858-455-2838, Email: ken.schultz@gat.com

S.K. Showalter , A.C. Marshall , P.S. Pickard
Sandia National Laboratories , PO Box 5800 , Albuquerque, New Mexico 87185
Phone: 505-845-3046, Fax: 505-284-4276, Email: pspicka@sandia.gov

J.F. Funk
University of Kentucky, Lexington, Kentucky 40506
Phone: 859 257-1941, Fax: 859 257-3304, Email: funk@engr.uky.edu

†Author to whom correspondence should be sent

Hydrogen is a promising energy carrier, which could replace the fossil fuels used in the transportation sector of our economy. Current commercial hydrogen production processes use fossil fuels and release carbon dioxide. The purpose of this work is to determine the potential for efficient, cost-effective, large-scale production of hydrogen utilizing high temperature heat from an advanced nuclear power station in a thermochemical water-splitting cycle.

We carried out a detailed literature search to create a searchable database with more than 100 cycles and 800 references. We developed screening criteria to rate each cycle and reduce the list to 25 cycles. We used detailed evaluation to select two cycles that appear most promising, the Adiabatic UT-3 cycle and the Sulfur-Iodine cycle. The UT-3 cycle was invented at the University of Tokyo and selected by JAERI for further development. The predicted efficiency is 35 to 40%. A 10% overall efficiency increase is projected if co-generation of electricity is employed. The Sulfur-Iodine cycle remains the cycle with the highest reported efficiency, 52%, with process improvements suggested that could increase the efficiency and, lower the capital cost. Co-generation could also be possible for still higher total efficiency. We have selected the Sulfur-Iodine thermochemical water-splitting cycle for further development.

We then assessed the suitability of various nuclear reactor types to the production of hydrogen from water using the Sulfur-Iodine cycle. A basic requirement is to deliver heat to the process interface heat exchanger at temperatures up to 900°C. We considered nine categories of reactors: pressurized water-cooled, boiling water-cooled, organic-cooled, alkali metal-cooled, heavy metal-cooled, gas-cooled, molten salt-cooled, liquid-core and gas-core reactors. The physical characteristics of the reactor coolant were major determinants in the evaluation. We developed a set of five requirements and five criteria to carry out the assessment, considering design, safety, operational, economic and development issues. This assessment process led to our choice of the helium gas-cooled reactor for coupling to the sulfur-iodine cycle.

In continuing work, we are investigating the improvements that have been proposed to the Sulfur-Iodine cycle and will generate an integrated flowsheet describing a hydrogen production plant powered by a high-temperature helium gas-cooled nuclear reactor. This will allow us to size process equipment and calculate hydrogen production efficiency and capital cost, and to estimate the cost of the hydrogen produced as a function of nuclear power cost.

*Work supported by U.S. Department of Energy under NERI Grant No. DE-FG03-99SF21888