U.S. DEPARTMENT OF ENERGY
INTERNATIONAL NUCLEAR ENERGY RESEARCH INITIATIVE
DOE/CEA

ABSTRACT

High Efficiency Hydrogen Production From Nuclear Energy: Laboratory Demonstration of S-I Water-Splitting

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Application of nuclear energy to the efficient and economic production of hydrogen has the potential to revolutionize our use of transportation fuels and provide a path to a more secure energy future. Nuclear hydrogen production would provide an essentially carbon emissions free source of transportation fuels, dramatically reduce dependence on fossil fuels, and open a new area of application for nuclear energy that may eventually exceed the use of nuclear power for electricity. One of the most promising approaches to achieve this goal is the development of high efficiency thermochemical cycles driven by high temperature advanced reactors. These cycles potentially offer the most energy efficient and economically scalable path to the levels of production needed for a future hydrogen economy.

The most promising thermochemical cycle for nuclear application identified in recent studies is the Sulfur-Iodine cycle. The Sulfur-Iodine cycle involves three component chemical reaction systems to achieve thermochemical water-splitting cycle for production of hydrogen. These systems respectively create H_2SO_4 and HI and separate the acids, carry out the reactive distillation decomposition of HI and the concentration/decomposition of H_2SO_4. This current NERI project reviewed the substantial world data base of thermochemical water-splitting reactions, and selected the Sulfur-Iodine cycle as the most promising from an initial compilation of 115 thermochemical hydrogen cycles. This research will provide a detailed flow sheet design of the nuclear - matched Sulfur-Iodine water-splitting cycle and a model of process chemistry and heat and material balances.

The Department of Physico-Chemistry in the Nuclear Energy Directorate of the French Commissariat à l'Énergie Atomique (CEA) has also done a preliminary evaluation of different methods to produce hydrogen from nuclear energy. They have identified the Sulfur-Iodine thermochemical water-splitting process as one of the leading candidates.

The next step in achieving the nuclear hydrogen goal is laboratory demonstration of the Sulfur – Iodine cycle, which is the focus of this INERI proposal. Based on these preliminary evaluations, the French CEA and US DOE teams will collaborate on this next step. The objective is to demonstrate the key technology elements of the Sulfur – Iodine system with sufficient fidelity to allow an engineering and economic assessment of the viability of this approach for nuclear hydrogen production.

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These next steps involve demonstration of the three chemical reaction systems of the S-I cycle. These component reactions are the Prime, or Bunsen, Reaction, the HI Decomposer and the H_2SO_4 Concentrator/Boiler/Decomposer. We propose to design, build and test laboratory-scale demonstrations of these systems. This will demonstrate efficient operation of the Bunsen Reaction that is fundamental to high cycle efficiency, demonstrate successful operation of the HI reactive distillation column that is key to a cost-effective S-I cycle, and will demonstrate the heat exchanger materials technology in the corrosive H_2SO_4 environment that is necessary for high process availability.

The tasks needed to demonstrate the Sulfur- Iodine cycle will be performed in a fully coordinated approach that utilizes the technical capabilities of the CEA and U.S. participants. Sandia National Laboratories will have responsibility for coordination of the effort and will build and test the front-end system that boils and concentrates sulfuric acid to form sulfur dioxide vapor for reaction with iodine. The French team will design and build the prime (Bunsen) reactor and the General Atomics team will design and build the system that decomposes hydroiodic acid vapor (HI) to produce hydrogen. The design of the component reaction sections will be based on an integrated flow sheet analysis that will be developed for a fully integrated, closed loop demonstration system.

The three laboratory-scale units will be sized and designed so that they may subsequently be connected together with other S-I cycle components and integrated into a complete system for integrated, closed-loop testing. Integration of the component reaction sections, and testing and operation of the integrated closed loop demonstration experiments would be the next phase of Sulfur – Iodine demonstration. This closed loop demonstration would require additional resources to complete. A detailed option for accomplishing this closed loop integration step is being developed collaboratively by the US and French partners, and will be available by August 7, 2002. The closed loop demonstration is an essential step in preparation for a full-scale pilot plant demonstration in the future.