EXECUTIVE SUMMARY

Currently no large scale, cost-effective, environmentally attractive hydrogen production process is available for commercialization nor has such a process been identified. Hydrogen is a promising energy carrier, which potentially could replace the fossil fuels used in the transportation sector of our economy. Fossil fuels are polluting and carbon dioxide emissions from their combustion are thought to be responsible for global warming.

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. The benefits of this work will include generation of a low-polluting transportable energy feedstock in a highly efficient method that has little or no implication for greenhouse gas emissions from an energy source whose availability and sources are domestically controlled. This will help to ensure energy surety to a future transportation/energy infrastructure that is not influenced/controlled by foreign governments.

This report describes work accomplished during the first year (Phase 1) of a three year project whose objective is to "define an economically feasible concept for production of hydrogen, by nuclear means, using an advanced high temperature nuclear reactor as the energy source." The emphasis of the first phase was to evaluate thermochemical processes which offer the potential for efficient, cost-effective, large-scale production of hydrogen from water, in which the primary energy input is high temperature heat from an advanced nuclear reactor and to select one (or, at most three) for further detailed consideration.

The main elements comprising Phase 1 are:

- A detailed literature search to develop a database of all published thermochemical cycles.
- Develop a rough screening criteria to rate each cycle.
- Perform a first round of screening reducing initial list to 20–30 cycles.
- Report on the results of the first round.
- Perform a second round of screening using refined criteria and reducing the number of cycles under consideration to 3 or less.
- Report on the results of Phase 1.

Ten databases were searched (e.g., Chemical Abstracts, NTIS, etc.), and over 800 literature references were located which pertain to thermochemical production of hydrogen from water. The references were organized in a computerized literature database. Over 100 thermochemical water-splitting cycles were identified. The cycle data was also organized into a computer searchable database.

The first round of screening, using defined screening criteria and quantifiable metrics, yielded 25 cycles for more detailed study. The second round of screening, using refined criteria reduced the 25 to 2.

The two cycles selected for final consideration are the UT-3 cycle and the sulfur-iodine cycle. The UT-3 cycle was invented at the University of Tokyo and much of the early development was done there. This cycle has been studied extensively in Japan by a number of organizations, including Toyo Engineering and Japan Atomic Energy Research Institute (JAERI). After considering several different flowsheets making use of the UT-3 cycle, JAERI selected the so-called Adiabatic UT-3 process for further development. The predicted efficiency of the Adiabatic UT-3 process varies between 35% and 50% depending upon the efficiency of membrane separators, which are under development, and whether electricity is co-generated along with the hydrogen. A 10% overall efficiency increase is projected if co-generation is employed. Much of the type of work we contemplated, such as pilot plant operation, materials studies, and flow sheet development has already been performed for this cycle in Japan.

The sulfur-iodine cycle remains the cycle with the highest reported efficiency, based on an integrated flowsheet. Various researchers have pointed out improvements that should increase the already high efficiency (52%) of this cycle and, in addition, lower the capital cost. In Phases 2 and 3 we will investigate the improvements that have been proposed to the sulfur-iodine cycle and will generate an integrated flowsheet describing a thermochemical hydrogen production plant powered by a high-temperature nuclear reactor. The detailed flowsheet will allow us to size the process equipment and calculate the hydrogen production efficiency. We will finish by calculating the capital cost of the equipment and estimate the cost of the hydrogen produced as a function of nuclear power costs.

It would be advantageous, but not essential, if some form of joint collaboration can be established with the Japanese. In particular, we would like access to their latest experimental results on the chemistry of the sulfur-iodine cycle. Although we will concentrate our effort on the sulfur-iodine cycle, we retain an interest in the UT-3 cycle. The work we have proposed, and which we will carry out for the sulfur-iodine cycle has, to a large part, already been performed in Japan for the Adiabatic UT-3 process. We would encourage the Japanese to perform the required non-steady-state analysis of the

Adiabatic UT-3 process. After the Japanese and we have completed our respective tasks, we will have two processes from which to select a means of producing hydrogen using nuclear power.