HIGH EFFICIENCY GENERATION OF HYDROGEN FUELS USING NUCLEAR POWER

**for the period
May 1 through July 31, 2002**

**by
L.C. BROWN**

**Prepared under
Nuclear Energy Research Initiative (NERI)
Program. DE-FG03-99SF21888
for the U.S. Department of Energy**

DATE PUBLISHED: SEPTEMBER 2002

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

HIGH EFFICIENCY GENERATION OF HYDROGEN FUELS USING NUCLEAR POWER

**for the period
May 1 through July 31, 2002**

**by
L.C. BROWN**

**Prepared under
Nuclear Energy Research Initiative (NERI)
Program. DE-FG03-99SF21888
for the U.S. Department of Energy**

**GENERAL ATOMICS PROJECT 30047
DATE PUBLISHED: SEPTEMBER 2002**

High Efficiency Generation of Hydrogen Fuels Using Nuclear Power

Nuclear Energy Research Initiative (NERI)
Program DE-FG03-99SF21888
Technical Progress Report
May 1 through July 31, 2002

HIGHLIGHTS

- The sulfuric acid processing portion of the flowsheet is completed.

INTRODUCTION

Future nuclear reactors will operate at higher efficiencies and, therefore, at higher temperature than current reactors. High temperatures present the potential for generating hydrogen at high efficiency using a thermochemical process. Thermochemical cycles for the generation of hydrogen from water were extensively studied in the 1970s and early 1980s both in the U.S. and abroad. Since that time, thermochemical water-splitting has not been pursued in the U.S. at any significant level. In Phase 1, we reviewed and analyzed all available data to determine the process best suited to hydrogen production from the advanced nuclear reactors expected to be available in the next 20 to 30 years. The Sulfur-Iodine Cycle was selected for detailed study in Phases 2 and 3. In Phase 2, we investigated means of adapting this cycle to the heat output characteristics of an advanced high temperature nuclear reactor. In Phase 3, we are integrating the cycle and reactor into a unified hydrogen production plant.

OVERALL ASSESSMENT

The three participants: General Atomics (GA), Sandia National Laboratories (SNL) and the University of Kentucky (UK) are working on Phase 2 tasks. Table 1 indicates the scheduled completion date of each task and actual completion date for completed tasks. Each organization participates, and to some extent in every task, but the lead organization is indicated on the task schedule, Fig. 1. The overall project is behind schedule. A no-cost extension has been granted. The new end date is September 30, 2002.

STATUS, ISSUES AND CONCERNS

Phase 3

Develop Concepts for Auxiliary Systems (WBS Element 3.1)

The thermal matching system has been modeled in Mathcad. The MATHCAD model actually consists of three separate models: (1) a hydrogen production reactor system (no electricity generation); (2) an electrical production reactor system (no hydrogen production); and (3) a hybrid hydrogen production/electricity generation system (Fig. 2). The three models permit comparison of both versions of the hydrogen plant with the standard electric plant.

Table 1
Summary of NERI Tasks — Phases 1–3

Identification Number	Milestone/ Task Description	Planned Completion Date	Actual Completion Date	Comments
1.1	Literature survey of new processes	Fri 2/25/00	Fri 2/25/00	Completed on schedule
1.2	Develop screening criteria	Fri 10/1/99	Fri 10/1/99	Completed on schedule
1.3	Carry out first round screening	Fri 3/10/00	Fri 3/10/00	Completed on schedule
1.4	Short report on conclusions	Fri 3/31/00	Fri 3/31/00	Completed on schedule
1.5	Carry Out Second Round Screening	Fri 6/2/00	Tue 5/9/00	Completed ahead of schedule
1.6	Write Phase 1 report	Fri 6/30/00	Fri 6/30/00	Completed on schedule
2.1	Carry out detailed evaluation of few processes to select one	Fri 1/26/01	Fri 1/26/01	Completed on schedule
2.2	Define reactor thermal interface	Fri 3/2/01	Tue 7/31/00	Completed behind schedule
2.3	Preliminary engineering design of selected process	Fri 3/2/01	Tue 7/31/00	Completed behind schedule
2.4	Develop flowsheet	Fri 6/29/01	Tue 7/31/00	Completed behind schedule
2.5	Conceptual equipment specifications	Fri 6/29/01	N/A	Work postponed to Phase 3 as task 3.3
2.6	Write Phase 2 Report	Fri 8/31/01		Work in progress
3.1	Develop concepts for auxiliary systems	Fri 6/28/02		Work not begun
3.2	Refine flowsheet	Fri 6/28/02		Work in progress
3.3	Conceptual equipment specifications	Fri 6/28/02		Work not begun
3.4	Size/cost process equipment	Fri 7/12/02		Work not begun
3.5	Evaluate process status	Wed 7/31/02		Work not begun
3.6	Write Final Report	Wed 7/31/02		Work not begun

Fig. 1. Project schedule.

Refine Flowsheet (WBS Element 3.2)

The flowsheet for the sulfuric acid processing section was completed at UK. The flowsheet is matched assuming that the high temperature heat will be optimally used within the section. The heat requirement for sulfuric acid decomposition provides an upper bound on the overall hydrogen production efficiency of 66%. The heat required for hydrogen iodide processing will reduce this value.

The hydrogen iodide processing was calculated assuming that the phosphoric acid process is used and the thermal energy to remove the water from the phosphoric acid comes from the reject heat from a Brayton power cycle. The results indicated that hydrogen and electricity production could be efficiently coupled but that, for high efficiency, the hydrogen production was quite low. The maximum overall efficiency was 52% with 2% of useful energy output as hydrogen. The hydrogen output rose to 14% as the overall efficiency fell to 47%. This may be cost effective, but there will be insufficient hydrogen to support the hydrogen economy from this source

Conceptual Equipment Specifications (WBS Element 3.3)

This task has not started.

Size/Cost Process Equipment (WBS Element 3.4)

The costing methodology is complete and ready for application.

Evaluate Process Status (WBS Element 3.5)

This task has not started.

NEXT QUARTER'S WORK

Work on tasks 3.1, 3.2 and 3.4 will continue.

Fig. 2. Schematic flow diagram of a hybrid H_2 /electricity production system.

Fig. 3. Spending profile.