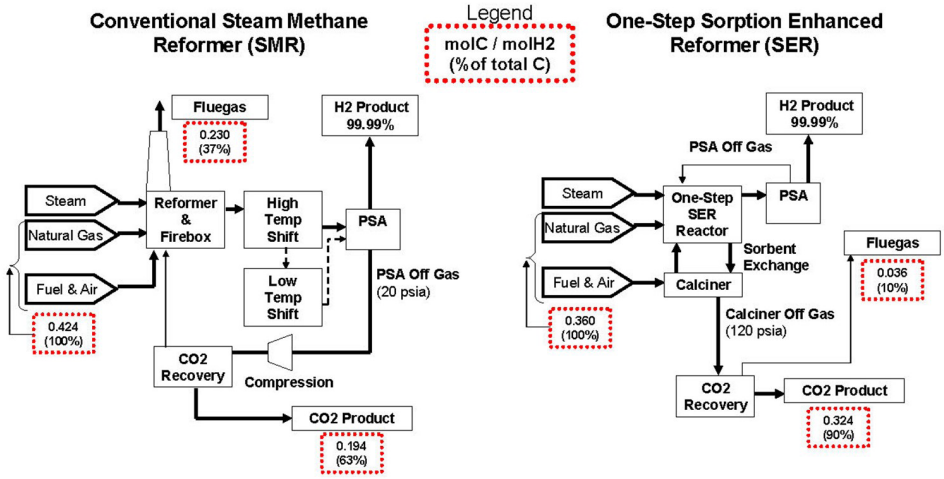
One Step Hydrogen Generation through Sorption Enhanced Reforming

Enabling lower cost hydrogen production

Hydrogen is used extensively in the refining and chemical industries, and has many other current and potential applications. The demand for hydrogen in the United States to support the refining and chemical process industries is projected to exceed 5 trillion standard cubic feet (scf) per year by 2021. The cost and quality of reformed hydrogen is critical to these industries, as well as for the metallurgical industry and emerging hydrogen-based technologies. Steam Methane Reforming (SMR) provides greater than 90% of hydrogen demand today and significant improvements are required in energy productivity, environmental performance, product yield and economic benefits to advance the domestic clean energy economy.

To improve the efficiency of hydrogen production, researchers are developing the One-Step Hydrogen Generation through Sorption Enhanced Reforming (SER) process. In earlier development efforts, a 20,000 scf/day feasibility demonstration unit (FDU) was constructed. The FDU demonstrated >90% hydrogen purity during initial operations totaling 60 hours, with expectations that purity as high as 95% may be achieved when scaled up to commercial size. The key innovation in this one-step process is the fluidized bed reactor, in which calcium oxide sorbent is elutriated through a bubbling fluidized catalyst bed with methane and steam, allowing the reforming, shift and CO_2 absorption reactions to take place in the same vessel.



Comparison of Steam Methane Reforming process and the One-Step Sorption Enhanced Reforming (SER) process. *Schematic courtesy of Gas Technology Institute (formerly Aerojet Rocketdyne)*

The sorbent is separated from the gas stream (with greater than 90% hydrogen purity), calcined to produce a 30% CO_2 stream, and then returned to the reactor. In the One-Step SER system, calcium oxide (CaO) is converted to calcium carbonate in the reforming reactor, separated from the high purity gas stream and then regenerated to CaO in a continuous calcination loop.

Benefits for Our Industry and Our Nation

Improving the efficiency of hydrogen generation has many benefits, including the following:

- Enabling competitively-priced, high-quality hydrogen to expand domestic manufacturing and maintain cost-competitiveness in global markets.
- Lowering capital costs for hydrogen production units, and reducing overall costs by 15-20% for the One-Step SER process compared to the typical SMR process.
- Increasing energy productivity by a projected 75% for the One-Step SER process compared to the typical SMR process.

Applications in Our Nation's Industry

Hydrogen demand is projected to grow at a rate of at least 5% annually, due to expansion in existing industrial uses as well as emerging new clean energy applications. The primary markets that will initially benefit from the technology for bulk hydrogen production are the petroleum refining and chemical industries. Other manufacturing industries that use hydrogen, such as food, glass and metals, can also benefit. The technology also may enable the adoption of calcium looping for pre- and post-combustion carbon capture from fossil fuel power plants; as well as enable pre-combustion carbon capture in integrated gasification combined cycle power plants.

Project Description

The project objective is to update and prepare system models, test equipment and procedures in preparation for further development and commercialization of the One-Step SER process, and demonstrate improved catalyst life. A previously constructed 20,000 scf/day Feasibility Demonstration Unit (FDU) will be recommissioned for further testing, including the evaluation of machinery and equipment to ensure the unit is properly functioning after two years of dormancy.

Barriers

- Successfully recommissioning the dormant FDU facility.
- Improving catalyst life to reduce the frequency of catalyst replacement.
- Achieving acceptable sorbent adhesion rates.

Pathways

Project partners will conduct system analysis updates, including conversion of the system model from ChemCAD to the more widely-used commercial software Aspen Plus. The FDU will be recommissioned; no configuration changes are anticipated other than a minor modification to allow easier extraction of catalyst from the reactor. Existing hardware components will be evaluated and tested as needed to ensure each equipment unit is functioning properly. Previously identified alternate catalyst substrate candidates which reduce or eliminate the use of alumina will be further evaluated before final selection. Once recommissioning is complete, each of the selected substrate candidates will undergo various test conditions to determine their performance in extending catalyst life. All testing will be performed at the Energy and Environmental Research Center (EERC), where the FDU is located.

Milestones

This one year project began in October 2015.

- Complete recommissioning of the FDU (2016).
- Conduct testing of three catalyst substrates in the FDU, with the intent of demonstrating the desired sorbent adhesion rate of less than 5 microns after 12 hours of testing (2016).

Commercialization

At the conclusion of this project, the Gas Technology Institute expects to be ready to further the development of the hydrogen generator. System models will have been updated and the FDU will be ready for additional testing. Later, a commercial demonstration plant (with target size of 2.5 million scf/day) would be designed and subsequently constructed in partnership with interested parties to further validate process results. A preliminary agreement is already in place with a major engineering and construction firm who would be responsible for building and marketing commercial-scale One-Step SER hydrogen plants, which would most likely occur under a revenue-sharing licensing arrangement. Discussions have also already been held with major industrial gas suppliers who have expressed an interest in investing in a commercial One-Step SER demonstration plant, once 200 hours of continuous operation achieving at least 85% hydrogen purity has been demonstrated.

Project Partners

Gas Technology Institute
(formerly Aerojet Rocketdyne)
Canoga Park, CA
Principal Investigator: Jeff Mays
Email: jeff.mays@gastechnology.org

Energy and Environmental Research Center
Grand Forks, ND

For additional information, please contact

Dickson Ozokwelu
U.S. Department of Energy
Advanced Manufacturing Office
Phone: (202) 586-2561
Email: Dickson.Ozokwelu@ee.doe.gov ■