the ENERGY lab

PROJECT FACTS

Gasification

Development of Ion Transport Membrane (ITM) Oxygen Technology for Integration in IGCC and Other Advanced Power Generation Systems

Background

Oxygen is among the top five chemicals produced worldwide by volume. In addition to its role in the production of clean power, purified oxygen enables production of ferrous and non-ferrous metals, chemicals, petrochemicals, pulp and paper, glass, and cement, and helps many other processes achieve high production efficiency with low environmental emissions. Oxygen production, second only to nitrogen in scale, is a large part of a global industrial gas industry that generates over $75 billion in annual sales. However, oxygen production by conventional cryogenic processes, which was first practiced in the early 1900s, is capital and energy intensive. Membrane-based electrochemical separation of oxygen from air promises to deliver a step-change reduction in both the capital cost of oxygen production facilities and in the energy required to run them, resulting in reduced costs and increased competitiveness in a wide range of American industries.

The Gasification Technologies Program at the National Energy Technology Laboratory (NETL) supports research and development (R&D) in the area of gasification — a process whereby carbon-based materials (feedstocks) such as coal are converted into synthesis gas (syngas), which is shifted and separated into hydrogen (H_2) and carbon dioxide (CO_2) gas streams. The hydrogen stream can then fuel a combustion turbine-generator to generate clean electricity while preventing the release of CO_2. The focus of the Gasification Technologies Program is to support R&D that offers the potential to substantially improve the cost, efficiency, and environmental performance of gasification systems. Within this R&D portfolio, novel approaches are being investigated for oxygen (O_2), H_2, and CO_2 separation under varying operating conditions.

To accelerate the advancement of these technologies, the Department of Energy (DOE) has awarded American Recovery and Reinvestment Act (ARRA) funding to expand advanced projects that would contribute to the development of industrial carbon capture and storage (ICCS) technologies at large scale. Specifically, this project will accelerate technology development by supporting domestic manufacturing capabilities for the membrane technology while concurrently pursuing a pilot-scale demonstration of the membrane-based separation process. Novel membrane processes offer the potential to reduce costs for separation of gases and to enable more efficient CO_2 management within a fully integrated advanced power generation and carbon capture system.

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PROJECT DURATION

Start Date	End Date
10/01/1998	06/30/2014

COST

DOE/ARRA Funded
Total Project Value
$292,713,069

DOE/Non-DOE Share
$199,421,099 / $93,291,970

AWARD NUMBER

FC26-98FT40343

U.S. DEPARTMENT OF ENERGY

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Project Description

Air Products and Chemicals, Inc., is currently developing ion-transport membrane (ITM) oxygen separation technology for large-scale oxygen production and for integration with advanced power production facilities, including gasification facilities. The ITM Oxygen process uses dense, mixed ion and electron conducting materials that can operate as hot as 900 degrees Celsius (°C). The driving forces for the membrane oxygen separation are determined by the oxygen partial pressure gradient across the membrane. The energy of the hot, pressurized, non-permeate stream is typically recovered by a gas turbine power generation system. The development of the ITM process will support reduced capital cost and parasitic load of air separation systems compared to that of currently available cryogenic air separation technology. Because air separation is a critical component of the gasification process for power production, any reduction in the cost of this process component will in turn reduce the overall costs of gasification, thereby making the process more competitive.

Goals and Objectives

The ITM Oxygen project will develop and scale up a novel, non-cryogenic air separation technology with lower capital cost and energy requirements than conventional cryogenic processes to produce high-temperature/high purity oxygen synergistically with integrated gasification combined cycle (IGCC) and other advanced power generation technologies.

This project has been funded through several phases, with some objectives from previous phases already completed. The initial activities focused on materials and process R&D and the design, construction, and operation of an approximately 0.1 ton per day (TPD) Technology Development Unit (TDU). The TDU test data enabled the establishment of cost and performance targets for stand-alone, tonnage-quantity, commercial ITM Oxygen plants, and integration schemes of ITM Oxygen with IGCC and other advanced power generation systems.

Subsequent activities were focused on testing the performance of full-size ITM Oxygen modules in a 5 TPD Sub-scale Engineering Prototype (SEP) facility specially designed for this purpose. The team fabricated thin, cost-optimized, multi-layer ITM devices that achieved oxygen production rates exceeding commercial performance targets at anticipated commercial operating conditions with significant operating lifetime. ITM Oxygen modules were scaled up to commercial size, built, and tested. Tests conducted in the SEP generated process information for the current activity.

The current objectives include increasing the scale of the engineering test facility from 5 TPD to approximately 100 TPD of oxygen in an Intermediate-Scale Test Unit (ISTU). The ISTU features oxygen production from an ITM coupled with turbo-machinery for power co-production, and will provide data for further scale-up and development. In addition, and to support a larger test facility, expanded efforts in the areas of materials development, engineering development, ceramic processing development, and component testing are being undertaken. The project will also assess the overall reliability of the process relative to the industry standard.

Among this phase's most significant objectives is the development of a dedicated large-scale manufacturing capability (the CerFab), funded under the American Recovery and Reinvestment Act of 2009 (ARRA), needed to support a future 2000 TPD oxygen test facility. Air Products will design, construct, and commission the CerFab and will assess its operating capabilities during a short-term module production campaign. In addition, advanced materials and production techniques will be developed to support the design and operation of the CerFab. The manufacturing capability will be based on ongoing development work in ceramic material and membrane module processing with an emphasis on industrial carbon capture, as well as know-how developed during the earlier part of the program. In addition, assessments of low-carbon industrial applications of ITM technology will be made.

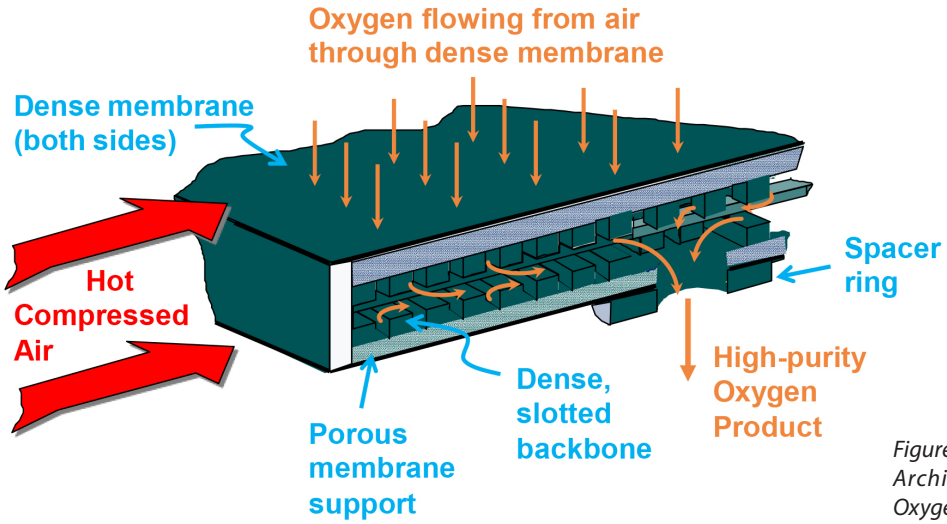

Figure 1. Ion transport Membrane Wafer Architecture to enable separation of Oxygen from Air.

Accomplishments

Air Products and Chemicals, Inc., has realized the following accomplishments during the course of this project:

- Developed a stable, high-flux material and achieved the commercial flux target under anticipated commercial operating conditions.
- Produced commercial-size ITM wafers in large quantities and used them to build commercial-scale modules.
- Completed design and construction of major equipment items for the 5 TPD SEP facility for testing full-size ITM modules.
- Completed reassessment of the status of ITM Oxygen economic evaluations and updated process economics.
- The 5 TPD SEP was operated for over 1,000 days; commercial flux targets were achieved or surpassed, and product purity exceeded 99 percent.
- Implemented patented advanced process control techniques during heating and cooling the SEP facility to improve module reliability.
- Completed design of the 100 TPD ISTU facility and construction is well underway.
- Completed economic assessment of carbon capture power plant cases with ITM Oxygen that feature carbon capture and sequestration technology options.
- Completed conceptual and detailed design engineering, site selection, permitting, and building modification for a Ceramic Membrane Fabrication facility. Began to procure equipment.

Benefits

The project will accelerate commercial manufacture of ITM modules and initiate the development of a 2,000 TPD pre-commercial scale facility ahead of schedule, enabling this technology to enter the marketplace at least two years earlier than previously projected. The ITM technology will produce O_2 at higher efficiencies and at lower capital and operating costs than state-of-the-art cryogenic O_2 production systems, benefitting domestic O_2-intensive industrial processes, such as those involved in the making of aluminum, glass, and steel, in terms of cost, efficiency, and productivity improvements. Successful development of ITM will also lower the cost of oxy-combustion configurations, enabling lower-cost CO_2 capture.

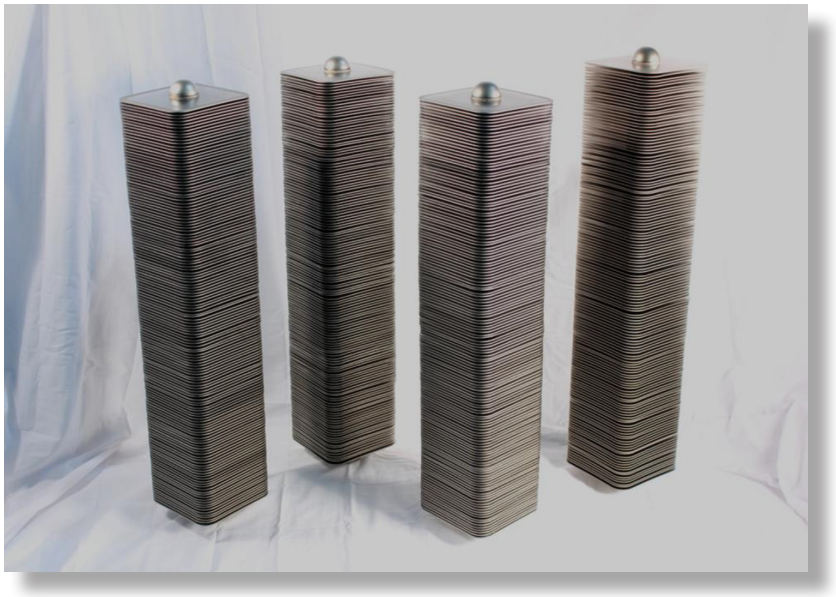

Figure 2. Four ceramic ITM Oxygen modules (each capable of producing 1 TPD oxygen) that are awaiting testing.

Figure 3. The 100-TPD Intermediate-Scale Test Unit (ISTU) under construction in Convent, Louisiana.

Figure 4. The Ceramic Membrane Fabrication Facility (CerFab) site in Tooele, Utah.