the ENERGY lab

PROJECT FACTS

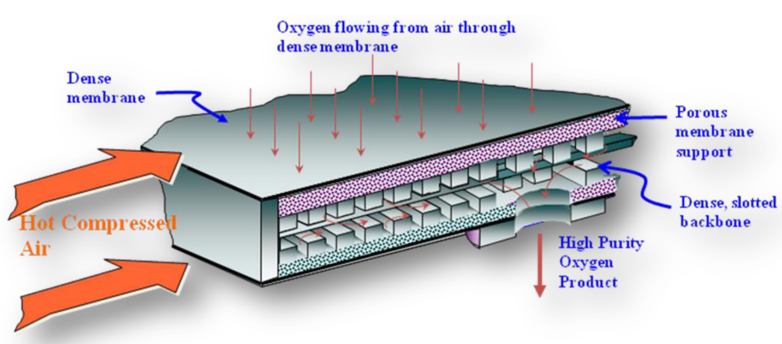
Gasification Technologies

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

Background

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 and uses a combustion turbine-generator as a way 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 funds from the American Recovery and Reinvestment Act (ARRA) 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 lower costs for separating gases and enabling CO_2 management more efficiently with a fully integrated advanced power carbon capture system. Following successful completion, this advanced technology will be ready for scale-up to large-scale systems for clean power, including industrial energy applications.



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

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PROJECT DURATION

Start Date
10/01/1998

End Date
06/30/2014

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. 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 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 IGCC and other advanced power generation technologies.

This project has been funded through several phase, 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 allowed 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 are to increase 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.

Also, the project has additional concurrent planned objectives which include (1) the development of the manufacturing capability needed to support ITM technology commercialization and (2) preliminary design concepts for a 2,000 TPD ITM Oxygen gas production plant.

Accomplishments

Air Products and Chemicals, Inc., has achieved the following accomplishments over the entirety of this project:

- Developed a stable, high-flux material; demonstrated stable operation in the 0.1 TPD TDU.
- Demonstrated the commercial flux target under anticipated commercial operating conditions.
- Devised a planar ITM architecture.
- Scaled-up and produced commercial-size wafers in large quantities.
- Reconfirmed the economic benefits of the technology.
- Built first commercial-scale ITM Oxygen modules.
- Completed detailed design of SEP vessel capable of housing full-size ITM Oxygen modules to produce an estimated 5 TPD of O_2 at full commercial conditions of 200–300 psig and 800–900 °C.
- Completed construction of major equipment items for the 5 TPD SEP facility for testing full-size ITM modules for producing 1 to 5 TPD of O_2 at near 95 percent purity.
- Tested full-size ITM Oxygen modules in the SEP facility and produced O_2 near 95 percent purity and generated process information for further scale up to the ISTU.
- Completed reassessment of the status of ITM Oxygen economic evaluations and updated process economics.
- Completed subscale wafer flux evaluation studies with feed air impurities and determined the effect of potential impurities on the cost and engineering performance of ITM systems.
- Confirmed machinery integration pathways.
- The 5 TPD SEP was operated for over 18,000 hours; commercial flux targets were achieved or surpassed, and product purity exceeded 99 percent.
- Implemented patented advanced process control techniques during heating and cooling at SEP to improve module reliability.
- Two 0.5 TPD ITM modules were successfully tested in the SEP utilizing a prototype flow duct design. The flow duct design will be scaled up to support 1-TPD ITM module operation and fabrication techniques are transferable to the ISTU.
- Successfully tested 1-TPD modules in the SEP.
- Determined the 100 TPD ISTU vessel design and scalability criteria and completed the conceptual 100 TPD ITM Oxygen pressure vessel design.
- Completed the 100 TPD facility conceptual design by including major elements of a commercial ITM Oxygen facility.
- Completed economic assessment of carbon capture power plant cases with ITM Oxygen that feature carbon capture and sequestration technology options.
- Developed and selected a supported getter material that will remove gas phase chromium species upstream of the ITM modules.

COST

DOE/ARRA Funded

Total Project Value
$288,009,889

DOE/Non-DOE Share
$195,956,463 / $92,053,426

Government funding for this project is provided in whole or in part through the American Recovery and Reinvestment Act.

Benefits

The project will accelerate commercial manufacture of ion transport membrane 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 in terms of cost, efficiency, and productivity improvements, such as those involved in the making of aluminum, glass, and steel. Successful development of ITM will also lower the cost of oxy-combustion configurations, enabling lower-cost CO_2 capture.