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NOVEL SELECTIVE SURFACE FLOW (SSF™) MEMBRANES FOR THE RECOVERY OF HYDROGEN FROM WASTE GAS STREAMS

Phase II: Technology Development

Final Report

By
Madhu Anand
Keith A. Ludwig

April 1996

Work Performed Under Contract No. DE-FC04-93AL94461

For
U.S. Department of Energy
Office of Industrial Technologies
Washington, DC

By
Air Products and Chemicals, Inc.
Allentown, Pennsylvania

DISCLAIMER

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Prepared for the
U.S. Department of Energy
Under DOE Albuquerque Operations Office
Sponsored by the Office of the Assistant Secretary
for Energy Efficiency and Renewable Energy
Office of Industrial Technologies
Washington, D.C.

Prepared by
Air Products and Chemicals, Inc., Allentown, PA 18195

PREFACE

This report documents Phase II, Technology Development, which was performed over the period November 1994 through October 1995. It is the second phase of a three phase project for the development of Selective Surface Flow (SSF^{TM}) membranes for the recovery of hydrogen from off-gas streams from various chemical/refinery operations.

In Phase I of the work, the basic laboratory scale technology was developed. In addition, the membrane architecture and the separations device were defined. The system consists of a shell-and-tube separator in which the gas to be separated is fed to the tube side, the product is collected as the high pressure effluent and the permeate constitutes the waste/fuel stream. Each tube, which has the membrane coated on the interior surface, does the separation in the system.

The second phase focused on (i) engineering data development, (ii) field testing of the membrane, (iii) technology transfer to manufacturing stage and demonstration of manufacturability and (iv) design and economic analysis with increased detail and rigor.

Engineering data were developed for two applications : (a) H_2 recovery from waste gas mixtures of H_2 and light hydrocarbons (C1-C4's) and (b) increased H_2 production in plants producing H_2 by steam methane reforming (SMR) followed by purification in a H_2 pressure swing adsorption (PSA) system. . The membrane performance data was generated over a wide range of gas compositions and feed pressures. A membrane test unit with 1 ft^2 membrane area was installed at the APCI hydrogen plant in Martinez, CA for field testing. The following were concluded from the field test : (a) the membrane separation properties measured in the field matched well with those measured in the lab, (b) the membrane was stable over the 2-month test, (c) a relatively constant composition product can be obtained with a varying feed composition by controlling the ratio of the high pressure effluent and the feed flow rates. SSF membrane preparation was scaled up at Golden Technologies Company (GTC), Golden, Co. With improved preparation methods, an SSF membrane with improved separation properties was demonstrated at GTC. Detailed economic analysis showed that the technology is attractive for hydrogen recovery from refinery waste streams. An energy reduction of 13% is estimated for H_2 recovery via this process which results in significant reducitons in NO_x and CO_2 emissions.

In Phase III, the technology will be demonstrated by scaling up to a semi-commercial unit.

This is a cost shared project between Air Products and Chemicals, Inc. and the U.S. Department of Energy, Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Industrial Technologies, under DOE Albuquerque Field Office Cooperative Agreement DE-FC04-93AL94461. Bruce Cranford and Charles Russomanno have been the Program Managers for the DOE Office of Industrial Technologies. Porter Grace and Ken Lucien have been the Project Managers for the DOE Albuquerque Operations Office. Frank Childs, the Project Technical Monitor for DOE, is on the staff of Scientech, Inc., Idaho Falls, ID.

For Air Products and Chemicals, Inc., Madhu Anand and Keith Ludwig were the Program Managers for Phase II of the program. The principal investigators were M. Anand, K. Ludwig, T. Naheiri and J. Yang. Barry Halper is the Contracting Manager. Additional technical contributors to the program were Beth Campion-Louie, Sheila Wirth, Randy Weber and Keith Fabregas. Shivaji Sircar and Madhukar Rao have been active consultants in this work.

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