FINAL REPORT
COOPERATIVE RESEARCH AND DEVELOPMENT
AGREEMENT (hereinafter "CRADA") No. 09-N087
BETWEEN

NATIONAL ENERGY TECHNOLOGY LABORATORY (NETL)
U.S. DEPARTMENT OF ENERGY

AND

PARSONS INFRASTRUCTURE AND TECHNOLOGY GROUP INC.

RESEARCH AND DEVELOPMENT OF NATURAL GAS HYDRATE PRODUCTION

BACKGROUND

Natural Gas Hydrates (NGH), found naturally in the environment under extreme pressure and temperature conditions, hold significant promise as a means of transporting significant quantities of natural gas where pipelines are not an option and where safety and cost issues make transport of liquefied natural gas (LNG) unsuitable. Recent R&D developments in Japan verified that it is possible to manufacture NGH pellets that concentrate natural gas to 170 times standard volume (approximately 1/3 the energy density of LNG) and that can be transported at much higher temperatures and lower pressures than LNG. These relaxed requirements for transport could result in a significant increase in safety and at the same time a decrease in capitalization and operating costs for natural gas transportation; making it possible, for example, to service stranded natural gas deposits and offshore deposits that are currently not profitable to produce.

What is needed is to capture the existing knowledge base in the form of a proof-of-concept effort aimed at understanding the engineering requirements for NGH pellet production and, in turn, generating prototype engineering design.

PROJECT DESCRIPTION

This project consists of developing sufficient basic data for an NGH pellet production and storage system to design a small proof-of-concept demonstration facility. This project was to determine the technical feasibility of developing a commercial process for pelletizing natural gas hydrate which would facilitate the transport of natural gas where pipelines are not an economical solution. NETL's Pittsburgh R&D campus has facilities that were used to perform initial R&D activities to generate basic data for a prototype design. NETL and RDS personnel, who have a lengthy history of involvement in methane hydrate research on behalf of the DOE fossil energy directorate, will act as subject matter experts, project managers and sources of chemistry, engineering, and operations talent for the performance of the evaluation.

This proposed research and development is the result of recent discussions between Parsons Corporation, Miami University, and Mitsui Engineering and Shipbuilding (MES) during a review of MES facilities in Japan. This project addresses the issues associated with the transport

and use of natural gas in geographic regions that do not have a traditional natural gas infrastructure. The transportation of natural gas is facilitated by the development of a stable form of natural gas hydrate pellet that stores 170 times its volume in gas and can be maintained at 1 atm. and -20°C.

Studies are currently underway in Japan that demonstrates the production of natural gas hydrate pellets in small quantities. These studies have produced a pelletized form of natural gas hydrate from natural gas which can be stored and transported in a stable form at -20°C. A second generation pellet has been produced that has increased the density of the pellet and reduced the % water content such that the pellet stores 170 times its volume in natural gas. The construction of a new demonstration facility is underway in Japan that will increase the production rate and demonstrate the transportation and re-gasifying of the NGH pelts for energy production during 2008.

This project was to design and demonstrate the method for the rapid and continuous production of methane hydrates from a mixture of methane and water.

PROJECT SCOPE

RDS was tasked to design, build and operate an NGH production demonstration facility. The design was based on a novel formation nozzle designed at NETL. NETL, Parsons Corporation, MES, and Miami University will partner to develop a small scale NGH production facility to determine the technical and commercial feasibility of NGH production. Specific areas of interest include the minimization of the water that is incorporated into the pellet during the production step, and the removal and recovery of the water during the final processing steps in the process.

Initial research and development activities utilized NETL facilities with the capability for cold room processing and bench scale processing. These initial efforts will develop a proof of concept NGH production process.

PROJECT OUTCOME

PROJECT DELIVERABLES

Project deliverables that NETL received during the CRADA were:

- Study data from basic NGH production experiments and defined path forward.
- Design for a small scale NGH production facility at NETL.
- Construction of the small scale NGH production facility (The 15L unit) at NETL.
- Design of a rapid hydrate formation nozzle.
- Construction of a rapid hydrate formation nozzle.
- Process confirmation of the rapid NGH production facility.
- Study of process heat removal methods (Miami University of Ohio).
- Economic evaluation of natural gas transport using NGH (Miami University of Ohio).

PUBLICATIONS

(1) "Rapid Gas Hydrate Formation Processes: Will They Work?", Thomas D. Brown, Charles E. Taylor, and Mark P. Bernardo, *Energies*, 2010, **3(6)**, 1154-1175; doi:10.3390/en3061154

PRESENTATIONS

(1) 2010 AIChE Spring Meeting "New Natural Gas Storage and Transportation Capabilities Utilizing Rapid Methane Hydrate Formation Techniques", Thomas D. Brown, Charles E. Taylor, and Mark Bernardo, San Antonio, TX, March 22, 2010.

(2) 241st Spring National Meeting of the American Chemical Society, "Method for Rapid Methane Hydrate Formation", Charles E. Taylor, Anaheim, CA, March 27, 2011.

PATENTS

(1) U.S. Patent Application, DOE Case No. S-119,800 - Docket No. 09N-28; Entitled "Rapid Gas Hydrate Formation Process", Thomas Brown, Charles Taylor, and Alfred Unione, filed on June 11, 2010

FINAL REPORTS

(1) "Rapid Heat Removal During Natural Gas Hydrate Formation," Final Report, Attachment H Engineering Team Effort, RDS Subtask 800.01.04 Department of Mechanical and Manufacturing Engineering, Miami University School of Engineering and Applied Science, Oxford, OH July 28, 2009.

(2) "An Economic Model of the Feasibility of Natural Gas Hydrate Production and Transportation: Results and Implications for Future Production and Economic Analysis," Armstrong Institute for Interactive Media Studies & The Department of Manufacturing and Mechanical Engineering, Miami University, Oxford, OH July 30,2009.