Quarterly Research Performance Progress Report

Federal Agency to which the report is submitted	Office of Fossil Energy
FOA Name	Environmentally-Prudent Unconventional Resource Development
FOA Number	DE-FOA-0001076
Nature of the Report	Research Performance Progress Report (RPPR)
Award Number	DE-FE0024314
Award Type	Cooperative Agreement
Name, Title, Email Address, and Phone Number for the Prime Recipient	**Technical Contact (Principal Investigator):** Melissa Poerner, P.E., Senior Research Engineer, melissa.poerner@swri.org, 210-522-6046 **Business Contact:** Jennifer Bigler, Associate Specialist, jennifer.bigler@swri.org, 210-522-3179
Prime Recipient Name and Address	Southwest Research Institute 6220 Culebra Road, San Antonio, TX 78238-5166
Prime Recipient type	Not for profit organization
Project Title	**TA2 Development and Field Testing Novel Natural Gas Surface Process Equipment for Replacement of Water as Primary Hydraulic Fracturing Fluid**
Principal Investigator(s)	Melissa Poerner, P.E., Klaus Brun, Ph.D., and Kevin Hoopes – *SwRI* **Subcontractor and Co-funding Partner**: Sandeep Verma, Ph.D. – *Schlumberger*
Prime Recipient's DUNS number	00-793-6842
Date of the Report	January 30, 2015
Period Covered by the Report	October 1, 2014 – December 31, 2014
Reporting Frequency	Quarterly

TABLE OF CONTENTS

1 Introduction 3
2 Accomplishments 4
2.1 Project Goals 4
2.2 Accomplishments 4
2.3 Opportunities for Training and Professional Development 4
2.4 Dissemination of Results to Communities of Interest 4
2.5 Plan for Next Quarter 4
3 Products 5
3.1 Publications 6
3.2 Websites or Other Internet Sites 6
3.3 Technologies or Techniques 6
3.4 Intellectual Property 6
4 Partcipants & Other Collaborating Organizations 6
4.1 Southwest Research Institute (SwRI) – Prime Contractor 6
4.2 Other Organizations 6
5 Impact 7
6 Changes/Problems 7
7 Budgetary Information 7

1 INTRODUCTION

Southwest Research Institute® (SwRI®) and Schlumberger Technology Corporation (SLB) are working to jointly develop a novel, optimized, and lightweight modular topside liquefaction and pumping process for natural gas to replace water as a low cost fracturing medium with low environmental impact. Hydraulic fracturing is used to increase oil and natural gas production by injecting high pressure fluid, primarily water, into a rock formation which fractures the rock and releases trapped oil and natural gas. This method was developed to increase yield and make feasible production areas that would not otherwise be viable for large-scale oil and natural gas extraction using traditional drilling technologies.

Since the fracturing fluid is composed of approximately 90% water, one of the principal drawbacks to hydraulic fracturing is its excessive water use and associated large environmental footprint. Each application of fracturing consumes between three and seven million gallons of water. During the fracturing process, some of the fracturing fluid is permanently lost and the portion that is recovered is contaminated by both fracturing chemicals and dissolved solids from the formation. The recovered water or flow back, represents a significant environmental challenge, as it must be treated before it can be reintroduced into the natural water system. Although there is some recycling for future fracturing, the majority of the flow back water is hauled from the well site to a treatment facility or to an injection well for permanent underground disposal.

To mitigate these issues, an optimized, lightweight, and modular surface process involving natural gas liquefaction, compression, and pumping will be developed and field tested to replace water as a cost-effective and environmentally-clean fracturing fluid. Using natural gas will result in a near zero consumption process, since the gas that is injected as a fracturing fluid will be mixed with the formation gas and extracted as if it were from the formation itself. This eliminates the collection, waste, and treatment of large amounts of water and reduces the environmental impact of transporting and storing the fracturing fluid.

There are two major steps involved in utilizing natural gas as the primary fracturing medium: (i) increasing the supply pressure of natural gas to wellhead pressures suitable for fracturing and (ii) mixing the required chemicals and proppant that are needed for the fracturing process at these elevated pressures. The second step (natural gas-proppant mixing at elevated pressures) still requires technology advancements, but has previously been demonstrated in the field by SLB. However, the first step (a compact on-site unit for generating high-pressure natural gas at costs feasible for fracturing) has not been developed and is currently not commercially available. The inherent compressibility of natural gas results in significantly more energy being required to compress the gas than is required for pumping water or other incompressible liquids to the very high pressure required for downhole injection.

This project aims to develop a novel hybrid method to overcome this challenge. Several processes will be evaluated to identify the optimal process for producing high pressure natural gas. Initial calculations have shown a substantial reduction in the total topside process energy requirements if a low-yield LNG expansion, instead of a refrigeration production process, is utilized and treatment is limited to removal of only the minimal amount of impurities. Furthermore, by using a turbo expander to capture the energy extracted during the expansion process to help drive the pumping stage, the net energy needed for LNG is on par, or lower, than that required for water. The project will develop, optimize, and test this process both in the lab and in the field.

The project work will be performed in three sequential phases. The first phase will start with a thorough thermodynamic, economic, and environmental analysis of potential concepts, as well as the detailed design of the hybrid LNG creation and pumping process. This will allow the basic thermodynamic pathway to be optimized for the intended application; specifically, the creation of LNG for use as a fracturing medium. The second phase will consist of the assembly and testing of a reduced-scale model in

a SwRI laboratory to measure the overall efficiency and cost savings of the developed process. The third and final phase will be an onsite demonstration conducted in close partnership with SLB. This will allow the real world benefits of the technology to be demonstrated and quantified.

This report covers the work completed in this budget quarter. The project goals and accomplishments related to those goals are discussed. Details related to any products developed in the quarter are outlined. Information on the project participants and collaborative organizations is listed and the impact of the work done during this quarter is reviewed. Any issues related to the project are outlined and lastly, the current budget is reviewed.

2 ACCOMPLISHMENTS

2.1 *Project Goals*

The primary objective of this project is to develop and field test a novel approach to use readily available wellhead (produced) natural gas as the primary fracturing fluid. This includes development, validation, and demonstration of affordable non-water-based and non CO2-based stimulation technologies, which can be used instead of, or in tandem with, water-based hydraulic fracturing fluids to reduce water usage and the volume of flow back fluids. The process will use natural gas at wellhead supply conditions and produce a fluid at conditions needed for injection.

The project work is split into three budget periods. Each budget period consist of one year. The milestones for each budget period are outlined in Table 2-1. This table includes an update on the status of that milestone in relation to the initial project plan. Explanations for deviations from the initial project plan are included.

2.2 *Accomplishments*

In the past quarter, the project team worked to complete all the necessary paperwork to finalize the contract. This task was near completion at the end of the quarter. In addition, the project management plan was completed and submitted for DOE approval. SwRI and SLB have started reviewing concepts for high pressure natural gas production, but very limited work was done. Therefore, no technical accomplishments were made for this quarter.

2.3 *Opportunities for Training and Professional Development*

There were no opportunities for training or professional development during this quarter.

2.4 *Dissemination of Results to Communities of Interest*

No results have been disseminated to communities of interest during this quarter.

2.5 *Plan for Next Quarter*

During the next quarter, the technical work on the project will continue. This work will include 1) identifying the top two to three thermodynamic cycles and 2) begin evaluating the top cycles to find the optimal cycle for production of the high pressure natural gas for fracturing. This work will include a brainstorming session between SwRI and SLB to outline the various concepts to be considered for the design. These concepts will then be evaluated on a high level basis to determine which cycles could provide the most efficient and cost effective option. After this, evaluation of the top cycles will begin which includes a techno-economic evaluation. This will include developing a detailed thermodynamic model for the cycle, estimating the cost of building the cycle design, and evaluating the proposed cycles against a list of metrics (ex. cost, weight, power consumption, etc.).

Table 2-1. Summary of Milestone Status

Budget Period	Milestone Letter	Milestone Title/Description	Planned Completion Date	Actual Completion Date	Verification Method	Comments (Progress towards achieving milestone, explanation of deviations from plan, etc.)
1	A	Top 2 to 3 Thermodynamic Cycles Identified	January 2, 2015 **New: March 2, 2015**	In Progress 5% Complete	At least two combinations of thermodynamic paths and sets of equipment have been identified as being capable of accomplishing natural gas compression from approximately 200-1,000 psi inlet to 10,000 psi outlet	Completion of this milestone has been delayed by execution of full contract. Planned completion date is extended to March 2, 2015.
	B	Top Thermodynamic Cycle Identified	May 1, 2015 **New: July 3, 2015**	Not Started	At least one combination of thermodynamic paths and sets of equipment have been identified as being capable of accomplishing natural gas compression from approximately 200-1,000 psi inlet to 10,000 psi outlet in an economically feasible fashion. (see Milestones NOTE below). This is considered a critical path milestone.	Start of this work has not started due to delay in execution of full contract. Planned completion date is extended to July 3, 2015.
	C	Finalized Detailed Design	September 30, 2015	Not Started	A laboratory-scale compression/pump test train will be designed to accomplish natural gas compression from approximately 200-1000 psi inlet to 10,000 psi outlet in an economically feasible fashion. (see Milestones NOTE below). This is considered a critical path milestone.	With the delay in execution of the full contract, it is anticipated that this milestone will still be completed as scheduled.
2	D	Compressor/Pump Train Set-up Complete	March 17, 2016	Not Started	The laboratory-scale compression/pump test train will be assembled/constructed. This is considered a critical path milestone.	none
	E	Test Data Acquired and Analyzed	September 30, 2016	Not Started	Measured data will confirm that the laboratory-scale compression/pump test train is able to accomplish natural gas compression from approximately 200-1000 psi inlet to 10,000 psi outlet in an economically feasible, compact, and portable fashion (see Milestones NOTE below). This is considered a critical path milestone.	none
3	F	Field Test Set-up Complete	April 17, 2017	Not Started	The equipment for the field testing has been set-up and commissioned at the test site. The test set-up is ready for the start of operation.	none
	G	Field Test Data Acquired and Analyzed	September 29, 2017	Not Started	Measured data will show that the field-tested, laboratory-scale compression/pump train is able to accomplish natural gas compression from approximately 200-1000 psi inlet to 10,000 psi outlet in an economically feasible, compact, and portable fashion (see Milestones NOTE below). This is considered a critical path milestone.	none

3 PRODUCTS

With any technical work, results will be documented and reported to the appropriate entities. Also, the work may produce new technology or intellectual property. This section provides a summary of how the technical results of this project have been disseminated and lists any new technology or intellectual property that has been produced.

3.1 *Publications*

No written works have been published during this last quarter. Also, no abstracts for future papers or conferences have been submitted for this project.

3.2 *Websites or Other Internet Sites*

The results of this project have not been published on any websites or other internet sites during the last quarter.

3.3 *Technologies or Techniques*

No new techniques or technologies have been developed in the last quarter.

3.4 *Intellectual Property*

No intellectual property such as patents or inventions have been submitted or developed in the last quarter.

4 PARTCIPANTS & OTHER COLLABORATING ORGANIZATIONS

The work required to develop the high pressure natural gas processing system for fracturing requires the technical knowledge and effort of many individuals. Also, two companies, SwRI and SLB, are partnering to complete the work. This section provides a summary of the specific individuals and organizations who have contributed in the last quarter.

4.1 *Southwest Research Institute (SwRI) – Prime Contractor*

The following list provides the PI and each person who has worked at least one person month per year (160 hrs of effort) in the last quarter.

- Melissa Poerner, P.E.
    - Project Role: Principle Investigator
    - Nearest person month worked: 1
    - Contribution to Project: Project management, initial cycle review
    - Funding Support: DOE
    - Collaborated with individual in foreign country: No
    - Country(ies) of foreign collaborator: n/a
    - Traveled to foreign country: No
    - If traveled to foreign country(ies), duration of stay: n/a

4.2 *Other Organizations*

In this project, SwRI is collaborating with Schlumberger (SLB). Schlumberger is a subcontractor and cost share supporter for this project. More information about their participation is listed below.

- Schlumberger
    - Location of Organization: United States
    - Partner's Contribution to the Project: Analysis and design support
    - Financial Support: n/a
    - In-kind Support: Labor hours in first budget period
    - Facilities: n/a
    - Collaborative Research: SLB staff supports the analysis and design tasks for the first budget period
    - Personnel Exchanges: n/a

5 IMPACT

Since no significant technical work was completed during this quarter, there is not potential impact.

6 CHANGES/PROBLEMS

During the first quarter, the full contract was not completed. Therefore, this has delayed completion of technical work until the next quarter. The schedule for the project was adjusted to accommodate this delay. The completion date for the first two milestones were shifted as outlined below and in Table 2-1. Even though the first two milestone dates were shifted, the final milestone date for budget period 1 was left at September 30, 2015. It is anticipated that the work in budget period 1 can be completed within the remaining time.

- Milestone A – Top 2 to 3 thermodynamic cycles identified
    - Original Completion Date: January 2, 2015
    - New Completion Date: March 2, 2015
- Milestone B – Top thermodynamic cycle identified
    - Original Completion Date: May 1, 2015
    - New Completion Date: July 3, 3015

7 BUDGETARY INFORMATION

A summary of the budgetary data for the project is provided in Table 7-1. This table shows the initial planned cost, the actual incurred costs, and the variance. The costs are split between the Federal and Non-Federal share.

For the first quarter in budget period 1, only a small portion of the budget was spent ($15,754). This is due to the fact that the full contract was not put in place during this budget period. Therefore, the work on the project was limited to preparation of the required paperwork for the contract and the project management plan.

Table 7-1. Budgetary Information for Period 1

Baseline Reporting Quarter	Budget Period 1	
	Q1	
	10/1/2014 - 12/31/2014	
	Q1	Cumulative Total
Baseline Cost Plan	$112,000	$112,000
Federal Share	$89,600	$89,600
Non-Federal Share	$22,400	$22,400
Total Planned	$112,000	$112,000
Actual Incurred Cost	$15,754	$15,754
Federal Share	$15,754	$15,754
Non-Federal Share	$0	$0
Total Incurred Costs	$15,754	$15,754
Variance	$96,246	$96,246
Federal Share	$96,246	$96,246
Non-Federal Share	$73,846	$73,846
Total Variance	$96,246	$96,246