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Texas A&M University

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LETTER OF TRANSMITTAL

Technical Report:

Date:	February 15, 2010
Title:	**Technology Assessment: Pilot Testing: Pretreatment Options to Allow Re-Use of Frac Flowback and Produced Brine for Gas Shale Resource Development**
Project Number:	***DE-FE0000847***
From:	**David B. Burnett, Harold Vance Department of Petroleum Engineering, Texas A&M University**
To:	**Mr. John Terneus, Project Manager**

Enclosed is our Project Technology Assessment as required by your office as part of our funded project. The goal of the project is to identify a reliable and cost-effective pre-treatment methodology for use in processes employed to treat and re-use field-produced brine and fracture flowback waters. The project aims to develop a mobile, multifunctional water treatment specifically for "pre-treatment" of field waste brine and conduct field tests of the technology.

TECHNOLOGY STATUS ASSESSMENT

Pilot Testing: Pretreatment Options to Allow Re-Use of Frac Flowback and Produced Brine for Gas Shale Resource Development

DE-FE0000847

The project's objectives are to identify a reliable and cost-effective pre-treatment methodology for use in processes employed to treat and re-use field-produced brine and fracture flowback waters. Our effort aims to develop a mobile, multifunctional water treatment specifically for "pre-treatment" of field waste brine and conduct field tests of the technology.

Current State of Technology

Summary of Existing Industry/Sector Technologies/Tools The Marcellus shale deposit, when fractured yields significant gas production, in some instances reserves of more than 1 bcf per well. However the advanced technology drilling and completion methods (horizontal wells and multi-stage fracturing) used to achieve these high performance levels cause significant environmental problems that must be overcome. Obtaining the needed water to makeup frac water, with subsequent disposal of the flowback water, presents a significant problem for gas production firms. In many areas, the amount of suitable water needed for formulation of frac water is just not available.

Benefits and Inadequacies of Current Technology

Technical Limitations. The best solution to this combined wastewater disposal and water supply problem is to simply treat and recycle the flowback water, over and over again, as frac water. The major problem with use of flowback water for makeup of frac water is the very high content of scale forming constituents present. The high levels of barium, calcium, iron, magnesium, manganese, and strontium common in flowback water will readily form precipitates, scale, which would rapidly block the fractures in gas bearing formations required for economic gas production. Removal of these constituents to much lower levels is thus required for recycle of flowback water, or use of production water, as frac water. Superior Well Services, a major supplier of fracture water chemicals, recommended that fracture makeup water should have a maximum level of 2,500 mg/l as $CaCO_3$ of scale hardness - Blauch, 2009.

Environmental and Economic Limitations. Several companies have commercial technologies that are marketed as processes to remove undesirable contaminants from flowback water. Not all of these technologies work well with full strength, high-salinity flowback water. Various pretreatment steps can be useful in lowering concentrations of critical constituents so that the commercials technologies can more effectively treat the flowback water. Many so-called "commercial processes have been adapted from municipal water treatment technology and are economically and environmentally unsuitable to use in the hyper saline Marcellus Shale,

Development Strategies

New technology and research is required. Current programs on Environmentally Friendly Drilling (EFD) pinpoint the need for waste management at the well site (Haut, et al, 2008). If information were available on techniques that successfully remove interfering solids and/or ions from flowback brines, then companies engaged in desalination, or conversion to other forms "product water" would be able to offer more cost effective technology to the well operators and

provide an attractive environmental alternate to use of fresh water resources and to disposal of waste brines.

Through extensive, laboratory, pilot plant, and field testing, the Texas A&M Desalination program has shown that produced water and frac Flowback brine can be treated and reused to replace otherwise additional fresh water resources (Olatubi 2009). Now the program is planning to demonstrate that low cost, mobile units can be deployed in field operations to replace the more costly and environmentally questionable practices currently being employed in field operations.

The approach proposed is (1) to develop a portable pretreatment system to demonstrate effective water purification measure and (2) to create a mechanism for engagement of elected public officials, community leaders, and members of the general public to make them aware of produced water treatment technology and the potential benefit. Concomitantly with this "human dimension" portion of the A&M program, a systematic effort will be begun to identify potential market mechanisms and incentives that would encourage oil and gas producers to implement water treatment technology.

Future

There are barriers our research is expected to overcome. Shale gas development is expanding rapidly into geographical areas that have not historically supported oil and gas development. As a result, local residents and regulatory agencies do not necessarily have long-term familiarity with industry operations. Shale gas development relies heavily on hydraulic fracturing of each new well in order to make the wells economically viable. Many of the new wells are horizontal wells that may require up to 5 million gallons of fresh water for each frac job. Not all regions of the country have sufficient unallocated fresh water to use "new water" for each frac job. Next, the frac flow back brine must be disposed of in an environmentally acceptable fashion. Many times, this brine must be trucked to disposal sites, a practice that burdens local road infrastructure.

In addition, there are numerous regulatory agency questions and community concerns about development of these new areas, particularly with respect to the safety of the hydraulic fracturing process itself and its potential to harm the environment. It is clear that the human dimension of the problem of developing Marcellus gas resources can not be neglected.

Impact on the U.S. Domestic Gas Supply Industry

In 1990, unconventional gas—from shales, coal-bed methane and so-called "tight" formations—was about 10% of total U.S. production. Today it is around 40%, and growing fast, with shale gas by far the biggest part. The potential of this "shale gale" only really became clear around 2007. In Washington, D.C., the discovery has come later—only in the last few months. Yet it is already changing the national energy dialogue and overall energy outlook in the U.S.—and could change the global natural gas balance (Yergin, 2009).

Natural gas has many favorable attributes—as a clean, relatively low-carbon fuel—abundance is now one of those attributes. One major obstacle remains – not the location of this resource but rather the environmental costs of exploiting it.

According to the National Petroleum Council's (NPC's) recommendations, access to indigenous resources is essential for reaching North America's full supply potential. New discoveries in mature North American basins represent the largest component of the future supply outlook.

However, the trend towards increasing leasing and regulatory land restrictions in the Rocky Mountain region and the Outer Continental Shelf (OCS) is occurring in precisely the areas that hold significant potential for natural gas production. Argonne National Laboratory (Elcock, 2008) evaluated the effect of removing the OCS moratoria and of reducing the impact of conditions of approval on the Rocky Mountain areas – a potential addition of 3 BCF/D by 2020.

Gas shale reserves have been unlocked by horizontal drilling and massive mulit-stage fracturing. As many as 8 million galls and 20 stages are being use (Woodford shale article) How to manage this water is a prime problem.

The ability to cost-effectively treat and reuse flowback water for future frac jobs greatly mitigates the issue of new water requirements for shale gas wells. Pretreatment of Frac flowback brine is absolutely essential in Marcellus because of the lack of deep well disposal facilities to handle discharged brine. Reuse is a key to the development of the resource. More than 50 TCF of potential natural gas resources in the Marcellus Shale hinge on finding a solution to the frac flowback and produced water management in an environmentally acceptable manner.

The specific benefits of this project are characterization and demonstration of different pretreatment technologies that can be moved to shale gas fields to convert highly saline flowback water to moderately saline water that can be more readily and predictably treated by the primary treatment processes.

This program will benefit the industry by improving the public's perception of Energy operations and Energy Research and Development in the Marcellus Shale. The empirical data provides a foundation for the meaningful dialogue about the strengths and potential weaknesses of produced water technology, as well as its future implementation/applications.

Through interactions with the technology companies, the regulatory agencies, and local residents, the project team will promote outreach and understanding of the technologies and the advantages they offer in protecting local water resources. One of the conclusions from the previously funded program (DOE Project DE-FC26-05NT42658) is that public acceptance for oil and gas operations increased by 20% when EFD technologies were used. Significant new gas reserves from unconventional resources could be realized if the increase in public acceptance offsets some of the objections to development.

In addition to its specific application to saline flowback water from shale gas activities, the results of this work can be transferable to other oil and gas unconventional resource development. This project's *Technology Transfer* creates a nation-wide coordination and transfer of environmentally friendly practices to reduce the opposition to development, reduce the footprint of drilling operations, create a basis of comparison of technology and provide regulators and service providers with the means to assure new systems will perform as intended and reduce the risk by operators, service providers and regulators.

A description of the EFD Alliance can be found at
http://www.efdsystems.org/EFDResearch/UniversityNationalLabAlliance/tabid/1296/Default.aspx

Deliverables (Tools, Methods, Instrumentation, Products)

The *project* will identify technologies and approaches for treating the frac water that returns to the surface following a frac job (frac flowback water) so that treated flowback water can be reused in subsequent frac jobs, thereby saving other local freshwater supplies.

The deliverables of this project are reports in accordance with the Federal Assistance Reporting Checklist and the instructions accompanying the Checklist. In addition to the reports identified on the Reporting Checklist, the Recipient shall provide the following:

- Task 1 - Project Management Plan
- Task 3.0 - The design for the pre-treatment work train and the cost engineering models.
- Task 6.0 - Performance and monitoring data of the field operations.
- Technologies will be practical (e.g., work in remote field settings, offer dependable performance over extended time periods, can be easily moved from one site to another),

Reports will be prepared in draft form to regulatory agencies so that administrative issues do not create unacceptable environmental problems in other media and are not prohibited by other regulations.

4. References

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Elcock, D. "*Constraints to Natural Gas Production*", Environmental Assessment Division Argonne National Laboratory, 955 L'Enfant Plaza, S.W., Washington, D.C., 20024