Task 2.0 Technology Status Assessment

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Creating Fractures Past Damage More Effectively With Less Environmental Damage

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I. Current State of Technology

The well stimulation technique known as hydraulic fracturing has become an extremely important tool for improving oil and gas extraction from the earth. It dramatically improves production rates in previously difficult to produce low permeability reservoirs as well as in high permeability reservoirs. Despite the production advantages, current fracturing technology has operational, environmental, and logistical disadvantages. Our research project aims to mitigate some of these disadvantages with a new novel fracture technology (NFT). This report covers the current status of fracturing technology and the advantages and disadvantages of each technology as well as discusses the innovative NFT.

A. Fracturing Background

Well stimulation techniques have been used for decades to improve hydrocarbon recovery. Hydraulic fracturing has proven to be an extremely effective production enhancement tool. This process involves pumping a specific neat fluid into a well at the necessary rate and pressure to crack the formation and force the fluid into the rock. The neat fluid is followed by a volume of proppant-laden fluid that is pumped into the cracks in the formation. Once the treatment is ended and the pressure is released, the fractures in the rock begin to close. Then the fracturing fluid flows back out of the well leaving the proppant in the rock to prop the fractures open, providing a high permeability conduit for the oil and gas to flow to the wellbore. The equipment, proppants, and fracturing fluids used in modern fracturing treatments have evolved and advanced since the first treatment in 1947.

Optimized fracturing fluid properties are extremely important in achieving an effective fracture. Fracturing fluids must be compatible with the formation, provide sufficient suspending properties for proppant transport, have sufficient viscosity to create and maintain fracture width, possess low fluid loss properties, provide easy clean-up from the formation, have low friction pressures, be easy to mix, and also be cost effective. Also of increasing importance is environmental friendliness. The characteristics and requirements of the fracturing fluid influence the fracturing equipment needs and requirements.

B. Current Technologies & Practices

i. Guar-Based Fracturing Fluids

a. Description

Although polymers such as hydroxyethylcellulose (HEC), carbomethyl hydropropyl guar (CMHPG), and xanthan gum are used for viscosifying fracturing fluids, the most popular polymer is hydroxymethyl guar (HPG). HPG uses a polymer

derived from the bean of the guar plant mixed with propylene oxide to produce a suitable polymer for creating fracturing fluids. The HPG polymer hydrates and forms a linear gel when it comes into contact with water. The linear gel has increased viscosity and proppant transport properties as well as decreased leak-off rates. A cross-linker additive can be added to an HPG linear gel to create a cross-linked fluid with even lower fluid leak-off and higher viscosity and proppant transport properties. Additives known as breakers are also added to cross-linked gels to "break" the gel back to linear gel for easier clean-up. The breaker can be designed to allow sufficient time to pump the treatment and place the proppant before breaking the gel.

b. Advantages and Disadvantages

Guar-based fracturing fluids provide a couple advantages. They provide an acceptable combination of ideal fracturing fluid properties such as low, predictable fluid leak-off, high viscosity, excellent proppant transport, temperature stability and others properties covered in the Fracturing Background section of this paper. The ability to cross-link the polymer allows the viscosity to be further increased without adding more polymer to the system. This reduces the amount of polymer to recover from the formation. These fluid systems also have many disadvantages. Optimizing the break time of cross-linked gels for each specific treatment requires extensive testing and even then it is impossible to break all of the cross-linked gel. This leaves residue in the formation that causes formation damage and a reduction in permeability. Even uncross-linked linear gel leaves formation damaging residue. The enormous equipment and chemical requirements for mixing proppant laden gel adds cost, time, and safety and environmental hazards.

ii. Fracturing Equipment

iii. Description

Proppant is shipped to location and stored in bulk containers. During the job, the gel is hydrated in a hydration unit before it goes to the blender. The blender is a large tub with a spinning paddle inside that mixes the proppant with the gel fracturing fluid. The gel enters the blender tub while a metered amount of proppant is dropped into the opening in the top of the tub. This operation is done on-the-fly while pumping the fracturing treatment.

iv. Advantages and Disadvantages

This equipment has the advantage of allowing changes to be made in the field and even during the job. This adds flexibility to the fracture design. However, there

are many disadvantages. Mixing on the fly requires constant quality control analysis throughout the job to ensure the gel and proppant loadings are correct. Maintaining these loadings can sometimes be difficult. Any problems with the blender can have devastating effects to the fracturing operation, sometimes even requiring another treatment or expensive clean-out work.

II. Development Strategies

A. Research & Technology Development Justification

The new NFT has many reasons for its development. A need for a low cost, environmentally friendly and non-damaging fracturing fluid has arisen in recent years. The increased activity in gas plays has brought with it increased fracturing stimulations to recover the gas. Most of this activity has been by large producers who can afford to properly invest in these areas to economically recover the hydrocarbons. The NFT provides a cost effective stimulation tool for small producers to utilize. The lower cost improves economic recovery from small or mediocre reservoirs. This makes more gas accessible for recovery. Another reason for this technology is due to increasing environmental pressure on the fracturing industry. The NFT has a drastically reduced chemical and equipment footprint compared to current fracturing methods. The biopolymer used in the NFT is degradable and environmentally benign. These reasons establish the need for this new technology.

B. Problems Addressed

As stated in the previous section, the NFT addresses many problems with current fracturing technology. One problem the NFT addresses is formation damage caused by fracturing fluids. The polymer used in the NFT is naturally degradable, leaving behind no residue in the formation. It is covered by U.S. patents 6,949,491, 7,069,994, 7,476,644 and 7,569,523. Despite its excellent clean-up properties, the polymer also provides ideal viscosity and proppant transport properties for effective fracture creation and proppant placement.

Another problem addressed is cost. Large fracturing operations required to economically stimulate gas production can be too expensive for small operators and leave small reservoirs untapped due to high costs. The cheaper, simpler nature of the NFT allows more producers to access more reserves economically.

III. Future

A. Shortcomings of Current Technology

The current technology has many shortcomings. Fracturing operations with current gel systems require extensive planning and mobilization of massive amounts of equipment and labor. Equipment such as water tanks, bulk proppant carriers, proppant conveyors, high pressure pumps, chemical additive units, blenders, and gel hydration units are required to mix and pump current proppant laden gel systems. All of this equipment increases cost, rig-up time, maintenance, traffic, waste, and emissions as well as occupational, safety, and environmental hazards.

B. Impact on U.S. Domestic Gas Supply

The NFT will provide small producers with a simple, effective, low cost, and environmentally friendly tool for enhanced hydrocarbon recovery. It will allow previously uneconomically producible production zones to be tapped by small producers that have limited resources and budgets. This increases the ultimate gas recovery and production from the available reserves in the U.S. It increases the reserves that can be recovered economically.

This technology can be especially beneficial when used on marginal wells known as stripper wells. These are wells that produce 10 barrels or 60 thousand cubic feet of natural gas per day or less. As of 2007, there were nearly 400,000 stripper wells producing almost 300 million barrels of oil per day. If this technology could increase stripper well production by just 0.2%, that would add another 600,000 bpd to the domestic supply.

C. Environmental Impact

The biopolymers used in the proposed NFT are degradable and environmentally friendly. The degradable nature eliminates the need for breakers and other chemical additives, therefore reducing the risks and hazards associated with these chemicals. The NFT uses an additive that is transported in a solid form which eliminates the potential for liquid spills. The reduced fluid volume and required equipment drastically reduces the equipment footprint. The need for frac tanks, blenders, hydration units and chemical additive units is eliminated. This in turn reduces the fuel consumption and air emissions of the fracturing operations. The less equipment also reduces the heavy truck traffic on small county and lease roads leading to the well site. This also reduces noise emissions.

D. Path to Application

During the middle stages of this project, select operators will be asked to identify candidate wells for future applications and demonstration of this technology. This will help

direct the best geologic plays and reservoir applications for commercialization. Dialogue will be established through cooperation with other organizations to provide information to the Bureau of Land Management, the Interstate Oil and Gas Compact Commission (which includes all state regulators), the Texas Railroad Commission and stakeholder groups. Some of the focus areas for this technology will be mature producing basins for in-fill drilling and recompletion activities which will include many of the mature fields in the Mid-Continent, Permian and Illinois Basins.

A number of technology transfer activities are planned. Information will be published about this project through publications. These include articles in the American Oil and Gas Reporter, Hart's E&P and others. Also at least one abstract and paper will be submitted to one of the industry societies including the Society of Petroleum Engineers.

One of most effective technology transfer organizations is the Petroleum Technology Transfer Council (PTTC). This is particularly the case for this technology which lends itself to independent producers which the PTTC reaches throughout the U.S. The PTTC has been contacted in order to provide materials and speakers at appropriate workshops and publications. It is planned to transfer the NFT through participation in industry organizations on a regional and national level.

IV. Deliverables

- A report detailing polymer pilot-scale synthesis, characterization and methodology for loading proppant into polymer
- A comprehensive report containing all of the test results initially conducted from taking the process from idea to field concept. This work includes polymer degradation verses temperature, fluid rheology, proppant suspension, and additional testing for more than 50 biodegradable polymers.
- Technology assessment and current state of the art report including summary on existing literature and patent landscape surrounding the concept.
- A report of the results of the large-scale simulations of the fracturing process including detailed test procedures, results, and interpretation.
- A well selection decision tool. This tool will be developed to aid the selection of candidate wells that can optimally use this technology. This will be a Microsoft Excel™-based program to allow selection based upon a number of well conditions.
- A comprehensive report covering the hydraulic fracture simulation runs at candidate well conditions to determine frac dimensions, predicted pressures, required pump rates, etc.
- Monthly status reports will be provided.

- The subcontractor will provide a final report on the study. This report will include results of the technology development, technology transfer and test effort.

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