

First 100% Reuse of Produced Water in Guar-based Fracturing Fluids: Enabling Closed-Loop Completions and Production, Eliminating the Need for Freshwater

Schlumberger Technology Corporation – Large Company Category

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Summary & Brief Explanation:

Production of oil and gas from shales requires that very large volumes of water, chemicals, and sand be injected during hydraulic fracturing treatments. The demand for fresh water in hydraulic fracturing is increasing due to increases in lateral lengths, stage count and volumes pumped. At the same time, most existing wells also produce highly saline water along with oil and gas. This produced water is usually injected in disposal wells as a waste rather than being reused to replace fresh water in new completions. This is because the industry has not had a cost-effective and reliable chemical approach to “gelling” this highly saline water source, until now.

Schlumberger has developed and successfully implemented a new fracturing fluid technology that enables the use of 100% produced water without treatment and without resorting to gelling agents other than standard oilfield guar. Pilot projects with two operators, one each in the Permian and Williston Basins, demonstrate equivalent to improved production from horizontal wells. This technology enables operators to use a waste product (produced water), eliminating their need for fresh water. This practice cancels the costs and waste streams associated with water treatment processes and decreases the amount of waste water reinjection required in an active field. Given the optimum logistical approach to water management, the accumulation and reuse of produced water can eliminate up to 600 water truck trips per horizontal well in the Bakken shale play. This method, applied correctly, will allow an operator to attain “closed-loop” completions and production, ending the industry’s dependence on fresh water and greatly reducing reinjection of waste water into other geological strata.

Purpose of the Project:

Fracturing fluids increase oil production from shales by breaking open rock in the reservoir and transporting proppant into the cracks to establish a flow path for the produced hydrocarbon. In general, the service company performing the fracturing work accepts mixwater for fracturing fluids from the operator, chemically engineers this water to attain a proppant transport objective appropriate to the well that is to be treated and then delivers the treatment. Crosslinked gels are the preferred type of fracturing fluid in shale oil and “tight oil” plays. Schlumberger undertook to solve a long-standing challenge in the engineering of hydraulic fracturing fluids: developing a highly viscous crosslinked gel that is competent to transport and suspend proppant at reservoir conditions using highly saline produced water as the mixwater. In this project we were responding to industry requests to find ways to accept highly saline, “off-spec” water that was either accumulating along with oil production or flowing back from previous treatments as new wells were commissioned. The most successful and widely used gelled fluid is a high pH combination of guar gum and borate salts – these fluids generally do not function properly if blended in water with more than 4 to 8% salt content. By contrast, most of the mixwaters we were offered were between 10 and 32% salt. The usual approaches to make use of this water are limited to dilution with fresh water into an acceptable form or treatment to remove problem ions such as calcium, magnesium, iron, and boron, or combinations thereof. These approaches are costly and largely ineffective because they seek to make the water fit the fluid. Our approach is to start from scratch and make a fluid that fits the water.

Our criteria for success required the new system to be the same or better as borate-crosslinked guar in terms of performance, cost and environmental impact to ensure acceptance by operators. We envisioned that laboratory demonstrations of a competent gelled fluid would encourage operators to take the necessary steps to accumulate sufficient volumes of produced water to perform a few fracturing treatments to verify the effectiveness of the fluid and validate its operational use. We were also eager to learn what logistical and regulatory requirements the operator would have to consider to implement this process change efficiently.

Process taken to complete the Project:

Schlumberger's Client Support Laboratory took a new approach to the design of a salt-tolerant crosslinked gel that uses standard oilfield guar gum as the primary gelling agent to ensure cost parity with borate-crosslinked guar. Several members of our team worked for more than 18 months on this project to arrive at a successful solution that hit our cost, performance, and environmental targets. We were conscious of the need to develop a laboratory workflow that delivered the required set of engineering outputs to allow this system to succeed in long horizontal multistage wells. We were fortunate in having two operators who were willing to participate in implementation exercises and field trials. After several laboratory validations and logistical discussions, we began field trials in December of 2013 in the Bakken shale. Six stages of our Produced Water Reuse (PWR) system were pumped in the last stages of a Bakken well with one of our engineers overseeing the jobs. The water was obtained directly from operator's separators and was untreated prior to use, other than simple filtration at the operator's request. We observed significantly lower treating pressures than borate-crosslinked guar gels in the same wellbore. No operational issues, hazards, or inefficiencies were reported. The operator was very satisfied with the results, and they began to arrange permits and infrastructure that allowed them to centrally collect, store, and dispense produced water via dedicated underground lines rather than trucks (facility shown in Figure 1).



Figure 1 Outside of a double-walled above-ground storage tank holding produced water in North Dakota (Williams County)

This significant project was undertaken to enable a full-well test - for this fluid system to gain widespread appeal we needed to verify its ability to give acceptable production. The operator therefore planned its water storage facility to gather produced water from several producing wells, and to service an upcoming two-lateral pad comprising a planned 62 stages. Work was concluded on these wells in early June – 59 stages of the designed 62 were pumped in both the Bakken and Three Forks formations with 100% success. The total volume of produced water was seven million gallons (2.2 million gallons crosslinked). Early production reports indicate that these wells are at least equivalent to offset wells in

the same area. The operator [reported the overall outcomes](#) on its web page and has also presented its findings in a [Bakken industry meeting](#). Based on the strength of this result, Schlumberger has engaged with two other major Williston Basin operators to implement this service in their operations.

In a parallel effort, we worked with a operator in the Bone Spring/Wolfcamp area of Pecos County in the Permian Basin. The well geometries were somewhat different and the salinity of the produced water was lower (8 to 12%). The regulatory environment in Texas allows for the accumulation of produced water in lined pits. We have performed 14 stages in two wells in this area, and we are waiting for the operator to execute a full Permian well with this technology.

Contributions to the Environment:

This project saved the first operator seven million gallons of fresh water, which in North Dakota is typically drawn from agricultural reserves, municipal supplies, or the Missouri river and its tributaries. The reinjection into disposal wells of seven million gallons of produced water was also avoided. Depending on logistical considerations, up to 1,200 trips by water hauling trucks were eliminated, equating to substantial decreases in carbon emissions and wear-and-tear on county roadways. The decreased number of trips also has an effect on local accident rates that is difficult to quantify. The operator's decision to use subterranean lines to handle water has greatly improved the optics of fracturing operations in Williams County.

Results and path forward:

We have demonstrated that this technology can be applied successfully with equivalent or better production results in the Williston Basin where the produced water is highly saline and unfit for any other use. With this technology, the operator and the State regulator worked together and learned how to design acceptable infrastructure to support accumulation, storage, and distribution of appropriate volumes of produced water. It is hoped that the lessons learned in these pilots will be enabling for other operators who wish to approach "closed-loop" operations with respect to their water production and water sourcing.

The measurable benefits include:

- Elimination of the need for fresh water.
- Reduced injection of waste water.
- Reduced trucking requirements, resulting in decreased carbon emissions, degradation of public infrastructure and reduced traffic accidents.
- Fluid and completion performance equal to or better than industry standard practice, demonstrated by equivalent to better production.
- Substantial completion cost reduction to the operator, demonstrated by the mutual cancelling of freshwater sourcing and produced water disposal costs.

This technique can be applied anywhere and we are working to help operators understand their local conditions and logistical plans in order to apply the technique appropriately.