TREATING PRODUCED WATER WITH ELECTROCOAGULATION FOR REUSE IN BORATE CROSSLINK FLUID DESIGN

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ABSTRACT

Produced water with high concentrations of total dissolved solids (TDS) and hardness is problematic in traditional crosslinked fracture fluid systems due to negative interactions with buffers and crosslinkers. When combined with high bottomhole temperatures, ordinary formulas result in a fluid system with poor performance characteristics that make it unfit for use. A successful system can be designed, however, with an appropriate treatment protocol and knowledgeable fluid design that will result in a superior product for the job. This paper will discuss the successful design of such a borate crosslink fluid system that used produced water treated with electrocoagulation (EC). The water had high concentrations of calcium and magnesium, total dissolved solids (TDS) greater than 250,000 ppm, and constantly changing oil and iron levels. The hydraulic fracture fluid design was able to accommodate these demanding conditions with little variability in formulation throughout the hydraulic fracturing operation by the expert application of different buffers as well as the use of concentrated borate crosslinkers to maintain stability.

INTRODUCTION

Hydraulic fracturing has breathed new life into the oil field throughout New Mexico and Texas, providing new opportunities for both oil companies and service providers to develop and redevelop many fields. While recent developments in the field of hydraulic fracturing have greatly increased oil and gas production, many of the shale formations in which hydraulic fracturing is utilized are found in regions of the United States that are suffering from droughts and water shortages. Regulations on water use in the oil and gas industry are becoming ever more stringent, causing the price of fresh water to increase. Post-hydraulic fracturing, there are also the additional incurred costs of trucking and disposal of the flowback and production water. Fortunately, water recycle for hydraulic fracture reuse can help to ebb the problems of water shortage, regulations, and disposal. Flowback and production water can be treated using a multitude of treatment methods to remove impurities that are detrimental to fracture fluid stability, and the water can then subsequently be reused again for treatment and reuse. This paper will give an example of water treatment by a patent pending electrocoagulation (EC) system and reuse in a fracture fluid.

A production company operating in Eddy County, New Mexico requested a recommendation for water treatment followed by fracture fluid design from using 100% produced treated water. Tests were conducted to determine the optimal treatment for the operator based on the water quality of a sample obtained from the company's salt water disposal (SWD). Treatment by EC was recommended due to the high total dissolved solids (TDS) and the high iron content observed in the produced water. Initial tests were conducted using a lab-treated sample of produced water, and a stable borate system was developed. The crosslinked fluid was stable for over two hours at 135°F.

Flowback and production water can contain a wide variety of impurities dependent on the location of the fracture treatment and what kind of system was initially pumped downhole. This information was taken into consideration and is critical in designing both the water treatment and the formulation of a fracture fluid using the treated water. Complications that can be encountered in the water treatment and fracture fluid formulation will be discussed in this paper.

LAB TESTING

The first test conducted on any water obtained for reuse is an initial water analysis. This information helps determine the best treatment options and the plausibility of reusing the water in a stable fracture fluid. The water tested from the SWD indicated a high total hardness and TDS concentration. The values obtained for the hardness and TDS were higher than the previously seen values for produced waters in the Permian area. The sample also contained iron and residual boron concentrations that could prove to be problematic in the development of a stable fracture fluid.

The high concentration of dissolved solids can also be problematic in water reuse due to the likelihood of interference with crosslinking and long-term stability. It is due to these issues that treatment by EC was determined to be the most effective method of treating the water. EC has the ability to reduce the concentration of iron in the sample as well as other contaminates by destabilizing the cations in solution and causing a non-chemical coagulation and flocculation process. EC is also a very robust treatment and can easily adapt to changes in water quality, an advantage when sourcing water from a SWD.

The SWD sample was treated by the lab scale EC unit to verify that the iron concentration would be reduced to an adequate level and to provide treated water samples for initial fracture fluid formulation. Multiple tests were conducted to determine the best conditions for field treatment that would optimize the reduction in contaminates while limiting unwanted side reactions. The final treatment recommendation reduced the iron concentration to an acceptable level, but had a negligible effect on the total hardness concentration, which was able to be overcome with specialized frac fluid design.

Fracture fluid analysis was conducted after the optimized treatment was determined. Fracture fluid testing was conducted at both 135°F and 155°F to determine which of two fracturing locations would use the treated water. The concentration of various impurities provided challenges in developing a fracture fluid formulation, challenges not usually observed with fresh water. Some of the impurities in the produced water will react and may precipitate when the pH is raised; this is problematic since most borate systems crosslink and are stable at elevated pH. This problem was overcome by using a proprietary chemical that limits the amount of precipitation while still raising the pH. Further complications with early crosslinking and premature breakage can be mitigated by the calculated use of select crosslinkers. Stability and break profiles were provided to the customer after testing, along with the proposed treatment operations and fracture proposal. Field treatment dates and plans were put together once the operator approved of the treatment and reuse.

FIELD TREATMENT

Prior to setup and treatment, a site survey was done of the location where treatment would take place. This step is vital to determine the placement of equipment for the operation and any limitations on the size and quantity of equipment that can be on the treatment site. A schematic of the equipment layout was generated prior to placement of equipment. Equipment layout and treated water storage were especially important to consider prior to the start of water treatment because the rate of water treatment by EC would not be equal to the rate of consumption for use in the fracture fluid. It is for this reason that extra storage was identified and set in place prior to the commencement of the fracture to ensure that enough water would be available and there would be no delay in the frac.

According to the site survey and treatment flow diagram, the water would flow from the SWD to a set of staging tanks that would be kept full of untreated water to maintain a steady flow of water through the equipment. The water would be pulled from the staging tanks into the EC unit. Next, the water would be allowed to settle and filtered before being pumped into storage tanks. The water would then be pulled from storage tanks to frac tanks on the site of the frac for use in the frac fluid. A total volume of approximately 50,000 barrels was treated for use in the 17-stage frac.

An initial challenge encountered at the start of the treatment was untreated water containing an unusually high concentration of an unexpected contaminate. Modifications to the process were implemented on-the-fly, thus minimizing the impact on the treated water quality. Throughout treatment, the chemical loadings were adjusted to account for these unexpected changes in water quality. Water quality was periodically checked to ensure that the EC treatment was meeting the criteria for use in the fracture fluid.

FRACTURE FLUID TREATMENT

Field treated water was retested in the area lab before the water was used in the fracture fluid on location, and only minor modifications to chemical loadings were required for a stable fracture fluid. A total of 17 stages were fractured over a three-day period with five stages completed on the first day, seven on the second, and five on the last day. The fracture was a continuous pump job utilizing sleeve technology, and all stages were pumped during daylight hours only, per customer request. No fracture fluid stability problems were encountered during the treatment, and the well was successfully fractured per design. The final sand stages contained up to 4 ppg of Garnet 16/30 sand. At this time, there is only two months’ worth of public data for the well, but its production is currently trending with other wells in the same location. There was also an observed increase in production during the second month of production.

CONCLUSION

The high concentrations of TDS and hardness found in produced water makes designing a traditional crosslinked fracture fluid system difficult. The interaction with buffers and crosslinkers, combined with high bottomhole temperature, is a recipe for poor performance. As this paper has shown, though, the design of a successful fracture fluid system is possible when there is a thorough understanding of the water being treated and by using appropriate treatment protocol to address demanding conditions.