INCREASED WELL PRODUCTIVITY UTILIZING IMPROVED FRACTURING FLUIDS AND HIGH pH ENZYME BREAKERS: A CASE STUDY ON SAN ANDRES FORMATION WELLS IN THE PERMIAN BASIN

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ABSTRACT

A case study was conducted on San Andres Formation wells to evaluate the benefit of focused efforts to optimize hydraulic fracturing treatments for improved well productivity. The application of conventional fluids and techniques had provided lower than expected post-treatment productivity and a rapid decline rate, suggesting that fracture conductivity was less than optimum.

Several recently introduced hydraulic fracturing technologies were combined to develop an integrated treatment design and application package to improve well production. Included among these were realtime fracture treatment analysis, advanced minifrac analysis, the use of state-of-the-art fracturing fluid and breaker chemistries, and the application of resin-coated sands and forced-closure techniques.

Average incremental production was significantly increased through application of the new technologies. The effectiveness of the modifications in design, chemistry, and application is clearly demonstrated by the production improvements.

INTRODUCTION

The study was conducted on San Andres Formation wells northwest of the city of Hobbs in Lea County, New Mexico. In this field, the Permian age San Andres is a shallow shelf carbonate margin at a depth of approximately 4,500 feet with a zone thickness between 200 and 300 feet. The reservoir pressure was reduced from 1,600 psi to about 700 psi by primary production. Water flooding, initiated in 1978, has increased the average pressure to near 1,300 psi. The bottomhole static temperature is typically about 100°F.

Hydraulic fracturing operations have been applied as a means to stimulate the wells for many years with marginal success. The application of conventional fluids and techniques had provided lower than expected post-treatment productivity and a rapid decline rate, suggesting that fracture conductivity was less than optimum. Premature screenouts were common when aggressive schedules were attempted to increase proppant concentration. Proppant flowback problems were frequently experienced, resulting in additional production expense.

The joint efforts of the operator and the service company technical teams were directed toward the improvement of well stimulation through the application of cost-effective, advanced fracturing technologies. Ultimately, several recently introduced hydraulic fracturing technologies were combined to develop an integrated treatment design and application package to improve well production. Included among these were realtime fracture treatment analysis to improve subsequent designs, advanced minifrac analysis to aid treatment design, the use of state-of-the-art fracturing fluid and breaker chemistries to improve proppant transport and maximize fracture conductivity, and the application of resin-coated sands and forced-closure techniques to control proppant flowback.

Realtime Fracture Analysis

The application of realtime hydraulic fracture treatment analysis was introduced to this area in 1991.[1] The primary value of the realtime analysis was the knowledge gained for use on subsequent treatments. Results from the analysis of several wells provided a characterization of the reservoir and a basis for improved treatment design. The need for higher fracture conductivity and an extended frac length was evident. In order to address these needs, it was determined that higher concentrations of a larger proppant, and a fracturing system providing high fluid efficiency in addition to maximum retained permeability would be required.[2,3] Higher viscosities were also desired to provide greater frac width through which to place the proppant. Minifracs were routinely conducted to determine the fluid efficiency as well as to evaluate the reflected reservoir behavior for incorporation in the actual treatment design.[4]

Fracturing Fluid Selection

Crosslinked fluid viscosity, fracturing fluid efficiency and retained fracture conductivity were identified by the treatment design analysis as being critical parameters in the productivity optimization process. Historically, the choice of breaker for low-temperature applications such as these has been between catalyzed persulfates and hemicellulase enzymes. Recent studies have reported that proppant-pack conductivity damage is typically greater than 50% when fluids such as the conventional borate systems with either catalyzed oxidizers or conventional non-specific enzyme breakers are applied.[5] The addition of the highly reactive breakers is also known to rapidly degrade the fluid efficiency and proppant transport capabilities. Such competing phenomena can often limit the size of the treatment, the proppant concentration which may be placed, and ultimately, the well productivity. The limitations of the conventional fluids effectively precluded the execution of the advanced treatment designs to improve well productivity.

Organo-borate crosslinked guar fracturing fluids were selected for these applications due to the superior proppant transport properties provided by the unique colloidal-crosslink structure.[6] The colloidal-crosslink structures exhibit much stronger crosslink junctions and greater elasticity due to a greater number of bonds per junction than experienced with conventional mono-borate crosslinked fluids. High viscosities are an additional advantage provided by organo-borate crosslinked fluids, often allowing fluids with reduced polymer loadings to successfully transport high proppant concentrations, while maintaining sufficient fracture width to minimize proppant bridging.

Polymer Specific Enzyme Technology

The breaker selected for the system was a newly developed polymer specific enzyme complex. As described in earlier studies, the guar molecule is most efficiently degraded by enzyme breakers.[7,8] Enzymes do not change their structure during the reactions they initiate. Enzymes exhibit a unique property called turnover number, which translates to initiating many more reactions at much higher rate than any conceivable inorganic compound. For instance, this guar polymer specific enzyme on the average has a turnover number of 68,000, meaning one enzyme unit (molecule) can initiate or cleave 68,000 linkages in the guar molecule per minute. Many more over the supposedly life-span of this enzyme unit.

Furthermore, enzymes are highly specific. For example, a purified guar enzyme will not degrade a cellulose polymer. It will only degrade the guar polymer. In fact, it will only cleave specific linkages in the polymer. For instance, in the guar molecule we have $\beta(1,4)$-mannosidic linkages and $\alpha(1,6)$-galactosidic linkages. The enzymes to cleave each linkage are not interchangeable, meaning the mannosidic linkage enzyme will not degrade or cleave the galactosidic linkage or vice versa.

In addition, a high pH enzyme complex was developed to have activity at the higher pH ranges normally associated with these borate crosslinked fluids.[9] Activity simply means reaction rate under specified conditions and can be controlled by concentration of the enzyme complex and other factors.

Combining the two state-of-the-art technologies provided the opportunity to improve treatment design by increasing the proppant concentration and reducing the polymeric damage to the proppant pack. Independent laboratory testing of the polymer specific enzyme applied in conjunction with the organo-borate fluid at 100°F confirmed that the combined system provides high viscosity, excellent fluid efficiency, perfect proppant transport, and 97% retained proppant pack permeability[10]. Examples are illustrated in Figures **1** and **2**.

Control of Proppant Flowback

Historically, the fractured San Andres wells in this area have been plagued by sand production. Resin-coated sand was tailed in to stem the proppant flowback problem. Conventional oxidizers tend to interfere with the fluids integrity and bonding strength of the resin-coated proppant. Conversely, polymer specific enzymes do not react or interfere with anything else other than their intended purpose of polymer-link cleavage. Examples are illustrated in Figures **3** and **4**.

Field Case Histories

An extensive study, comprising 50 wells, was conducted to evaluate the effectiveness of the stimulation optimization. Five one square mile sections of the field were selected for the studies. Each section was compared individually to normalize variances in reservoir quality across the field. The production data presented for comparison represent the normalized production six months after each respective well was fractured. The average normalized production from six to 10 conventionally treated offset wells in each section was used to establish a baseline for comparison. The production data comparisons are presented graphically in **Figures 5 through 9.**

The average six-month normalized production from seven conventionally treated wells in Section I was 65 BOPD, as shown in Figure **5**. The five wells treated, utilizing the presented combination of new technologies, yielded six-month normalized production rates ranging from 77 BOPD to 197 BOPD. The average of the five wells was 143 BOPD, a 2.2 fold increase.

In Section II, the average production from the conventionally treated wells was 36 BOPD. As illustrated in Figure **6**, improved treatment design and fluid chemistry provided a 2.9 fold increase in the normalized production to an average 106 BOPD. A 2.4 fold increase was observed in Section III, as shown in Figure **7**, improving from 55 to 132 BOPD. Similar improvements were observed in Section IV and V, as shown in Figures **8** and **9**.

An average 2.5 fold increase in the six-month normalized production was observed from the combined data from all five sections.

CONCLUSIONS

In all cases the effectiveness of the combined efforts, between the operator and service company, regarding modifications in treatment design, fluid chemistry, and stimulation techniques clearly demonstrates how production improvements can be made.

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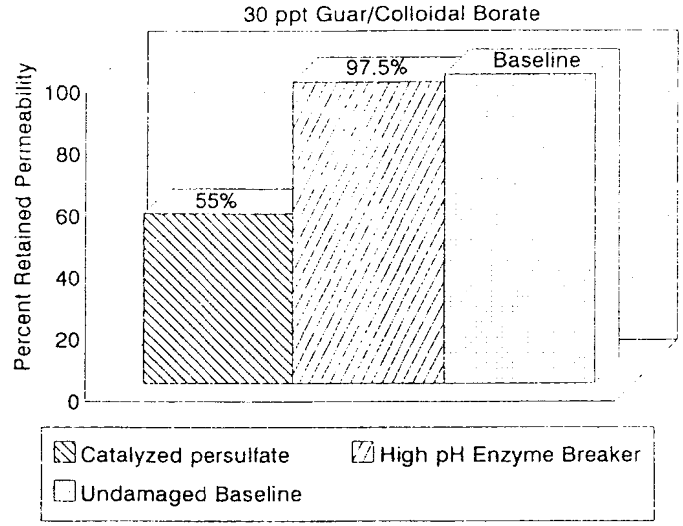


Courtesy Stim-Lab Inc.

Figure 1 - Retained permeability @100°F/2000 PSI

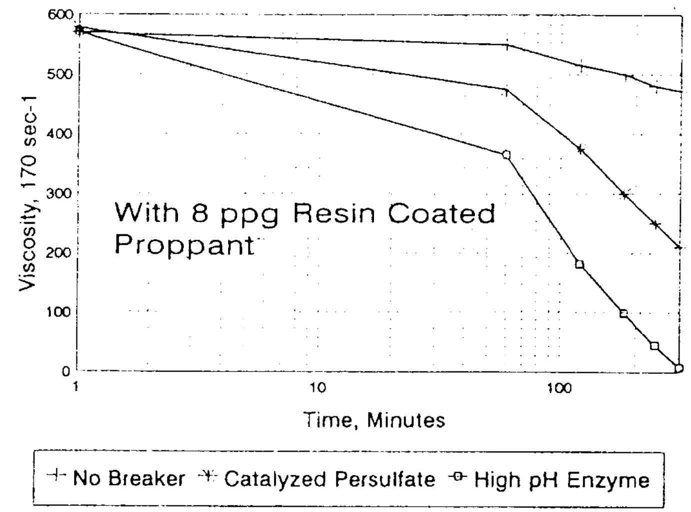


Figure 3 - Fluid rheology: 30 ppt guar/colloidal borate

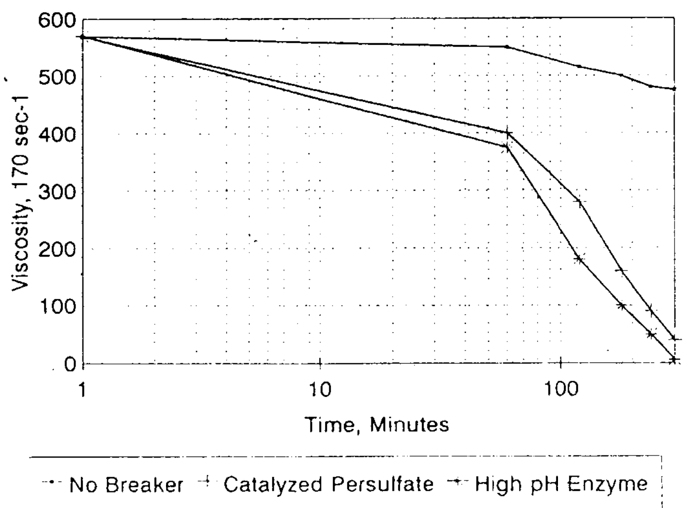
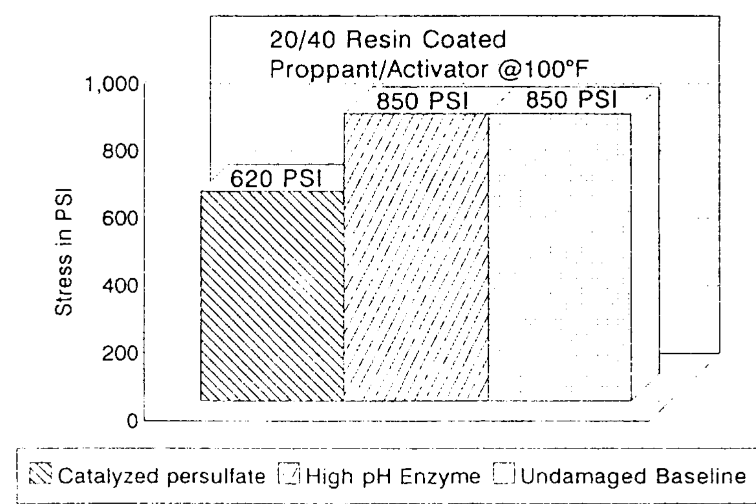


Figure 2 - Fluid rheology: 30 ppt guar/colloidal borate



Courtesy BJ Rock Mechanics Laboratory

Figure 4 - Bonding strength comparison

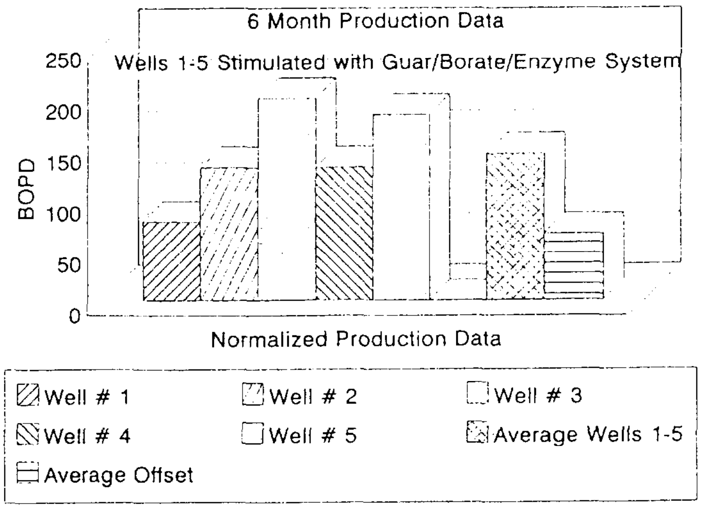


Figure 5 - San Andres formation wells section #1

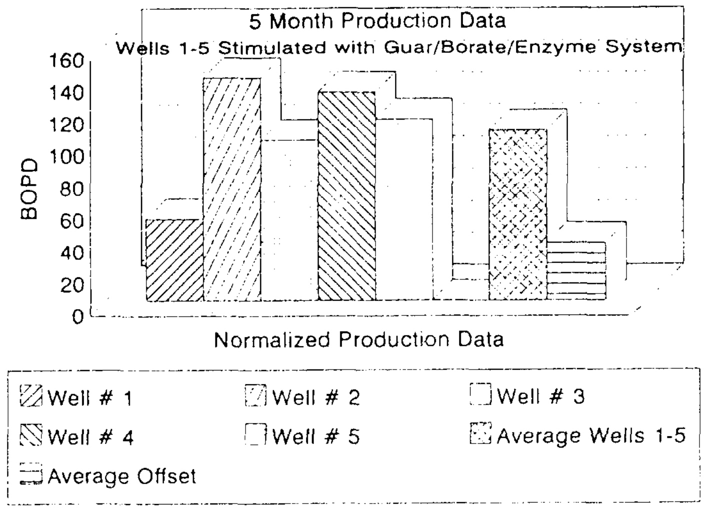


Figure 6 - San Andres formation wells section #1

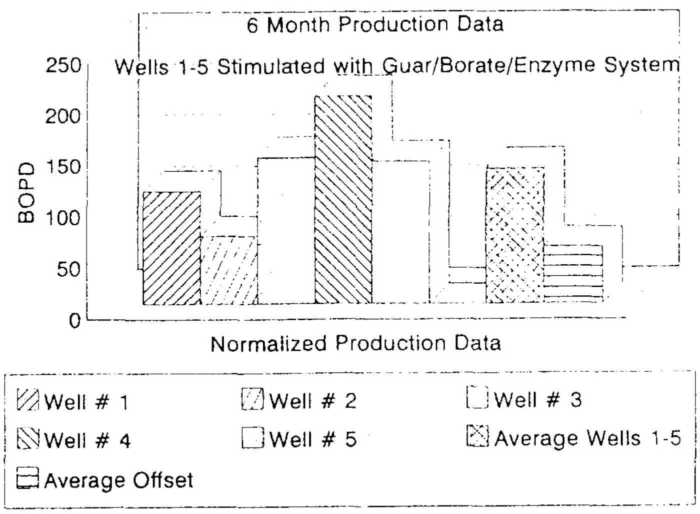


Figure 7 - San Andres formation wells section #III

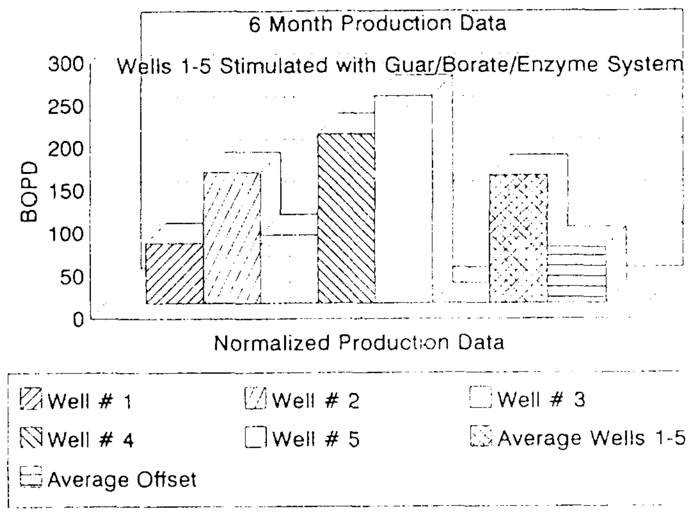


Figure 8 - San Andres formation wells section #IV

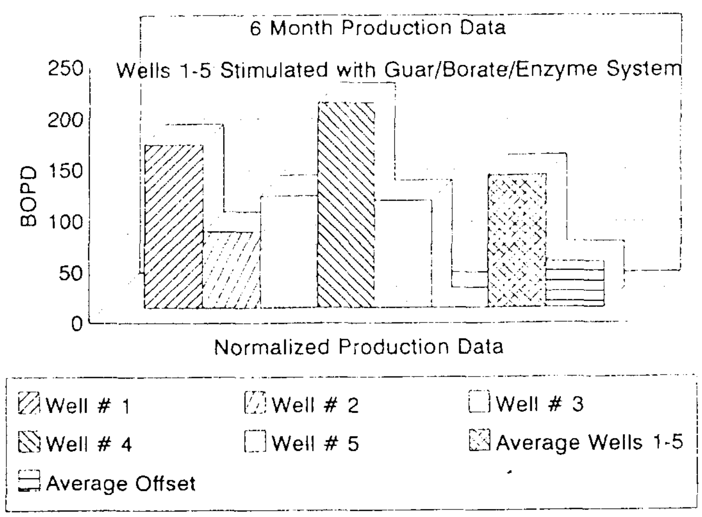


Figure 9 - San Andres formation wells section #V