Discussion of SPE 89175

"Advances in Polymer Flooding and Alkaline/Surfactant/Polymer Processes as Developed and Applied in the People's Republic of China"

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In the February 2006 issue of *JPT,* H.L. Chang et al. reported on some of the pilot and commercial-scale field activities of polymer flooding and alkaline/surfactant/polymer (ASP) flooding that were performed in China (Chang et al. 2006). Unquestionably, polymer flooding and ASP flooding are proven processes, and China should be proud of their work in these areas. Unfortunately, the article also advocated a controversial technology [flooding with aqueous colloidal-dispersion gels (CDGs)] as being superior to polymer flooding. I submit that this claim is misleading and generally incorrect. CDGs [i.e., relatively low concentrations of partially hydrolyzed polyacrylamide (HPAM) crosslinked with aluminum citrate] should not be applied without carefully examining the purported science and engineering behind this process.

Chang et al. speculated that low-concentration aluminum citrate/HPAM microgels propagate through porous rock like superpolymer solutions. Specifically, they suggested that these CDG formulations penetrate deep into porous matrix reservoir rock and subsequently provide higher resistance factors (effective viscosities in porous media) and residual resistance factors (permeability-reduction factors) than comparable HPAM polymer solutions without crosslinker. However, independent results from three university research laboratories demonstrated conclusively that this assertion is not correct (see Seright 2006 and Wang et al. 2006 for details). Another assertion made in the February article (Conclusion 3 on page 87) is that "a large amount of CDG would preferentially enter the high-permeability or thief zones and divert polymer or water into medium- and low-permeability zones." This assertion contradicts basic calculations with Darcy's law (Seright 2006). Furthermore, the field evidence given to support CDG gels can readily be attributed to other, more plausible, factors. In many cases, questions arise whether the aluminum citrate had a positive effect on the field results. More details can be found in Seright 2006 and Wang et al. 2006.

References

Chang, H.L., et al. 2006. Advances in Polymer Flooding and Alkaline/Surfactant/Polymer Processes as Developed and Applied in the People's Republic of China. *JPT* **58**(2): 84–89.

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Response to Discussion of SPE 89175

"Advances in Polymer Flooding and Alkaline/Surfactant/Polymer Processes as Developed and Applied in the People's Republic of China"

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The results presented in paper SPE 89175, *JPT* **58**(2): 84–89, are from a commercial-scale field test conducted in the Daqing oil field. It took 4 years, May 1999 to June 2003, to inject the chemical slugs, and the operator spent more than U.S. $5 million on chemicals and data collection. The entire project was conducted in five stages: prechemical waterflood (PCWF), first colloidal-dispersion gel (CDG-1), polymer, CDG-2, and post-chemical waterdrive (PCWD). PCWF was initiated in December 1998 and proceeded for approximately 6 months, and PCWD was continued on from June 2003.

Baseline data—such as the oil rate, water cut, salinity of produced fluid, and injectivity index—were collected and used as a basis to calculate the increased resistance factor and sweep efficiency in the field and the incremental oil recovery. Three chemical slugs—(1) CDG-1, 0.179 pore volume, V_p; (2) polymer, 0.155 V_p; and (3) CDG-2, 0.196 V_p—were injected sequentially in this project. A 600-ppm polymer was used in all three chemical slugs, whereas most of the polymerflood (PF) projects conducted in Daqing used 1,000 ppm or higher.

Comparisons of the total dissolved solids, ionic species (Cl^-, Na^+, Ca^{2+}, and Mg^{2+}), the polymer produced, and changes of injection profiles during the injection of each slug along with the performances of other PF projects conducted in the adjacent area enable analysis and interpretation of the degree of success of the project and enable reaching our conclusions. Detailed field data from December 1998 through the end of the chemical-slug injection in June 2003 were reported in paper SPE 89460.

Water injection has continued since the completion of the final chemical slug, CDG-2. Fig. 4 in the article is an update of the performance from this unique project during the PCWD from June 2003 through February 2005. A comparison was made of the post-chemical water cut in the CDG project with a typical PF project in the adjacent area. To our knowledge, this type of comparison was the first made for CDG and PF. The reasons we selected the results from this PF project for comparisons were as follows.

- It is one of most successful large-scale PF projects and was conducted in the best part of the reservoir (Type I).
- It was discussed in detail in the same paper.
- The post-polymer waterdrive response is typical of the Daqing oil field.

Because it is well known that water cut increased quickly after the termination of polymer slugs in the Daqing oil field, we are trying to show that the injection of a small CDG slug after PF may be a viable option to take advantage of the residual resistance factor generated by CDG in the reservoir to delay the increase of water cuts and to prolong the economic life of the project. We did not have any bias/prejudices in mind in making such comparisons or any intention to downgrade the PF, to advocate the CDG process, or to mislead the readers. Furthermore, we did not speculate any interpretations, but arrived at our conclusions using concrete field data. We have never claimed the CDG fluid to be a superior polymer solution. Instead, we are trying to show that CDG would complement PF and improve the overall recovery efficiency and economics.

In addition to the first CDG project reported in SPE 89460, operators in the Daqing oil field also initiated other commercial-scale multipattern combinations of CDG/polymer projects independently in 2002 on the basis of successful results from the first CDG project. One of these projects showed that even if a lower concentration of polymer (500 ppm) is used in the CDG/polymer project than in the straight-PF (1,000 ppm) projects, the combination of CDG and polymer not only showed much higher oil rates and lower water cuts, but also showed improved economics derived from lower chemical costs, higher oil recovery, and lower produced-fluid treatment costs because of less water and polymer production.

Admittedly, with CDG, like many other enhanced-oil-recovery processes (including PF), certain aspects of the fundamental mechanisms of the CDG process are not completely understood and may require more research to fully understand the transport mechanisms in the tortuous porous space. But we cannot ignore the field data and simply rely on interpretations from simplified mathematical formulations and limited laboratory data not designed for this field project.

Because gels are highly dependent on chemical type and concentration, experimental procedure and conditions, water quality, aging and shearing conditions, and many other factors, we did not intend to compare our field results with laboratory results on gel behaviors and properties. The operator was diligent in collecting, presenting, and interpreting the field data for the CDG project conducted in the Daqing oil field. It would be difficult for us to change any conclusions on the basis of the data that were collected. JPT