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Polymer Gels Illustrate Varied Problem Solving Applications

By Randall D. Prater

Editor's note: The following article is adapted from a presentation at TORP's Eleventh Oil Recovery Conference, held March 14-15, 1995, in Wichita, Ks.

HAYS, KS.-Polymer gels have been successfully applied for water control on producing wells in Kansas for many years. Other successful applications include injection profile modification and control of channeling in waterfloods, and as an alternative to cement, or in addition to cement in the repair of casing leaks.

The success rate for all applications of polymer gels has improved markedly as the field processes have improved, blending and pumping techniques and equipment have improved, and experience has been gained in a wide variety of applications. Many polymer gel applications are now routinely applied as a practical alternative for operators interested in cost-effective methods to reduce workover costs and extend the economic life of a producing well.

Water Control

Excessive water production severely limits the economic life of many wells in Kansas, and often results in premature abandonment of reserves. Statistics obtained from the Independent Petroleum Association of America indicate that 16,271 producing oil wells were abandoned in Kansas between 1983 and 1992. Most of these wells were plugged because they were no longer profitable to operate, often because of high lifting costs associated with excessive water production.

Polymer gel treatments have been routinely applied to high water-oil ratio wells resulting in long-term reductions in water production of 60-90 percent, without reducing oil production. Many times, a significant amount of incremental or "flush" oil production results from the treatment.

This additional production often pays back the cost of the treatment in as little as 60-90 days, resulting in a long-term reduction in lifting costs and increased profitability from the well, with no net cost to the operator for the workover. The key to success in a producing well treatment is selection of a viable candidate, well cleanup and preparation, proper treatment design and implementation, and careful planning to avoid over-pumping the well after the treatment.

Design criteria to qualify a well for treatment include wells that exhibit:

- A high producing fluid level, limited by equipment, and is not pumped off, even at high total fluid rates;
- A high water-oil ratio;
- An indication of good remaining oil column or mobile oil saturation (A well which has oil buildup behind the tubing which can be flushed out by circulating the well is an excellent candidate.);
- An inclination toward being relatively high on structure; and
- A high initial production rate, and a good cumulative production history, demonstrating a significant amount of original oil in place
- Ideal formation characteristics are:
- Carbonates (dolomites and limestones);
- Highly fractured (naturally);
- High permeability within produced intervals; and
- Bottom water drive.

Information necessary for treatment design consists of:

- Production data;
- Completion data;
- Lithology (Carbonate or sandstone? Naturally fractured? Degree of permeability variation.);
- Logs and core analysis, if available;
- Produced water analysis; and
- Reservoir temperature.

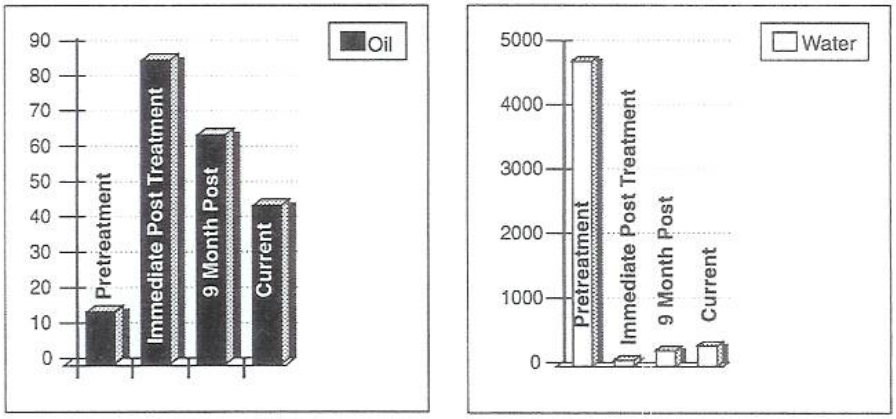
Case History

In March, 1994, an Arbuckle well in the Bemis-Shutts field was treated. Prior to treatment, this well, which was drilled in 1948, had been producing 15 barrels of oil a day and 3,700 barrels of water a day on a submersible pump from one foot of open hole. Even at this rate, the well carried 2,000 feet of fluid over the pump. A 2,500-barrel polymer treatment was designed, and was pumped continuously over three days.

The well was returned to production on a beam pump for 86 barrels of oil a

FIGURE 1

Case History/Bemis-Shutts Field



Over 12,000 Bbl Incremental Oil to Date
(x average price of $15/bbl=$180,000)

day and 188 barrels of water a day, pumped off. The well has averaged more than 60 barrels of oil a day for the past nine months, with 300 barrels a day of total fluid. Total incremental oil recovery since treatment is more than 12,150 barrels. The operator estimates the total cost for the workover was $35,000. Total value of the incremental oil produced to date is in excess of $145,800, using an average oil price of $12 a barrel, yielding a new profit to the operator of $110,800 (Figure 1).

The results from this treatment were unusual because the initial oil rate after treatment was higher than normal, and was sustained for a longer period with very little decline in oil percentage.

This can be attributed to the fact that a larger-than-normal volume of polymer was pumped, which extended the depth of the area around the well bore which was affected by the treatment. This well had an unusually large amount of moveable oil in place, which had simply been overrun by water coning and could not compete with the amount of water coming to the well bore. The polymer treatment was able to selectively block the flow of water deep in the formation and allow the oil to drain more efficiently.

Figure 2 shows the results of nine Arbuckle wells treated in the Riffe Field in Rooks County, Ks., in 1989 and 1990.

Squeezing Casing Leaks

In some circumstances, polymer gels can be successfully used as an alternative to cement, or in combination with cement, to squeeze casing leaks. A number of processes have been developed for this application. The type of polymer and the process used depends on the location and severity of the leak, and whether the squeeze will be required to hold solid pressure, or simply block the encroachment of foreign water in a producing well.

The advantage of using polymer in these applications is two-fold. First, polymer can be washed out of the well bore after a leak is squeezed, preventing the costly rig time involved in drilling out cement. Second, because polymer solution exerts a much lower hydrostatic weight than a cement slurry, there is less possibility of breaking down the formation and losing the squeeze.

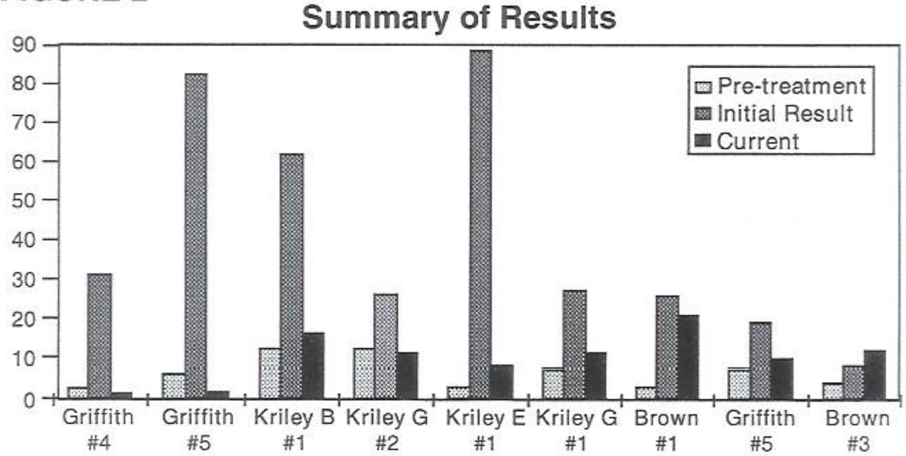
On difficult leaks, such as the salt section, where multiple cement jobs are often attempted before the leak is successfully squeezed off, a small slug of polymer can be run ahead of the cement as a buffer to prevent the cement from "running away" or washing out the section to be squeezed. Because the polymer continues to absorb or bond to the formation, and the bulk gel fills the larger voids, it is often enough to slow the coasting of the cement, and give it something to squeeze against.

Four basic polymer gel systems are in use today in casing leak squeeze operations:

- Acrylic monomer grout. This non-toxic system is most effective on tight casing leaks and pressure leak-off situations such as leaks that bleed off pressure but cannot be pumped into. This system pumps as a water-thin fluid, then sets up into a tough, ringing gel. Gel times can be controlled from 10 minutes to 2 hours, depending on temperature. Treatment sizes typically range from 10 to 25 barrels. This is an excellent application for disposal and injection wells that fail mechanical integrity tests because of a slight pressure leak-off.
- HCLM (high concentration low molecular weight polymer). This system is useful for a variety of leaks ranging from tight pressure leak-off situations, to moderate leaks that can be pumped into under pressure. This system can be crosslinked using standard metallic crosslinkers, or a low-toxicity organic crosslinking system can be used in environmentally sensitive areas, or leak intervals.
- HMW (high molecular weight polymers.) This system is most effective in larger leaks in producing wells, to correct channeling behind pipe, and for some list circulation applications. The primary benefit of using this system is the ability to economically block the flow of foreign water into the well bore, or block the out flow of produced fluids to thief zones. This system is usually not

FIGURE 2

Summary of Results



Riffe Field, Rocks County, Kansas

effective in situations that require the sealant to hold a continuous pressure with no bleed-off, because of the elasticity of the final gel. This system is most effective to block foreign water encroachment in producing wells.

- CPC (cement-polymer combination squeeze). Severe casing leaks that require mechanical integrity and are unlikely to be successfully sealed using either cement or polymer alone are candidates for this process. In most cases, a small (25-50 barrel) slug of high molecular weight crosslinked polymer is injected ahead of 50-100sx cement. In this application, the polymer acts as a filler/buffer, filling larger voids and coating formation surfaces, preventing water loss and cement contamination by formation fluids. The polymer also acts as a pad, holding the cement in the near well bore area, where it is most effective. This process blocks the foreign water away from the well bore, and allows pressure integrity to be obtained more cost-effectively than would be possible with cement or polymer alone.

HMW Case History

In October 1989, an Arbuckle producing well in Rooks county exhibited a sharp increase in water production, with complete loss of oil production. A produced water analysis indicated foreign water encroachment from the salt section had flooded the well. Two casing leaks were pinpointed in the salt section between 2,158 and 2,189 feet, and 2,790 and 2,853 feet. Injection rates were taken on each interval to determine the polymer formulation and volume requirement for each leak.

The bottom interval (2,790-2,853 feet) was given 100 barrels of HMW polymer with a one-hour setting time. Tools were then moved uphole to isolate the top interval. This interval was given 50 barrels of HMW polymer. Pressure increased from 0 to 800 pounds per square inch during injection.

After letting the well sit for two hours, tools were lowered below both leak intervals, excess polymer was circulated from the well bore, and the hole was swabbed down. Swab tests determined that no fluid was entering the well bore from the previous leak intervals. This well was placed back on production, and has produced normally since that time.

The operator reported significant cost savings because multiple cement squeeze and drill-out operations were not required, as had been the case on other wells in the area.

Lost Circulation

An operator had been unsuccessful in previous attempts to fish an anchor and 300 feet of tubing from a well in Garvin County, Ok., because of several deep casing leaks that had been acting as thief zones, preventing him from circulating fill out of the hole. A review of a casing inspection log led to the decision to spot two 25-barrel slugs of a fast-setting crosslinked polymer over the two worst holes-one at 5,500 feet and one at 4,200 feet.

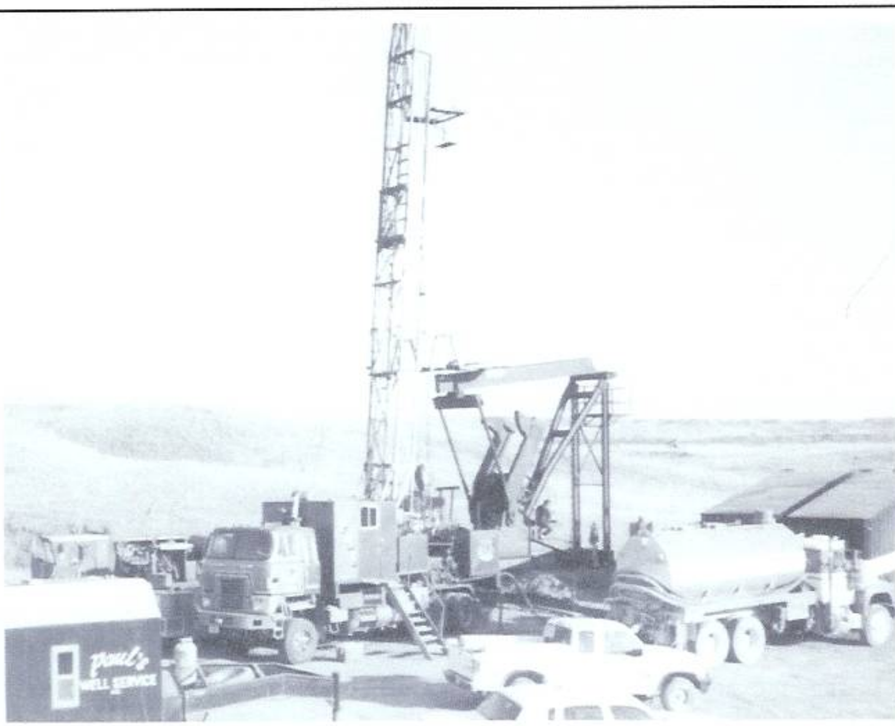
The polymer gels were spotted and allowed to set two hours. Although the operator previously had no returns to the surface, after the polymer was spotted, the well was reverse circulated with nearly full returns at the surface. The operator went on to fish the tubing and anchor out of the hole with no further problems. The well was re-completed and has been returned to production.

The primary waterflood applications of polymer gels are injection profile modification and control of directional channeling, and the resulting early water breakthrough in offset producing wells. Polymer gels are often used to effectively block high permeability streaks deep in the reservoir, and divert the injected fluid to areas in the reservoir that had been previously bypassed. The result is improved sweep efficiency and lower water-oil ratio throughout the field. Gel treatments are run on either the injection well or the affected producing well, and sometimes both, depending on the specific problem. Spinner surveys or other injection profile logs and inter-well tracer surveys should be run to pinpoint the problem and develop a plan of action.

Early Water Breakthrough

A Barton County, Ks., waterflood producing well had experienced a rapid increase in water-oil ratio, and production on the lease had been steadily dropping. A review of information with the operator confirmed suspicion of early water breakthrough in the producing well, directly offsetting the injection well in a line-drive pattern.

Because this was the only producing well affected, a near-well bore waterblocking polymer treatment was performed on it. Production from the well, prior to treatment, was 8 barrels of oil a day and 173 barrels of water a day. A 320 barrel polymer gel treatment was designed and pumped on this well. Ten days after the well was placed back on produc-



A polymer job is shown in progress on an Arbuckle well in the Bemis-Shutts field. A 2,500 barrel polymer treatment was designed for this well and pumped continuously over three days.

tion, water coming to it had been reduced by 60 percent with no loss in oil production. Production for the lease had increased 3-4 barrels of oil a day, and injection pressure had begun to increase, indicating the fluid was being diverted to lower permeability areas in the reservoir.

A Chester Sandstone injection well in Seward County, Ks., was taking 1,800 barrels of water a day on a vacuum over a 100-foot perforated interval. Injection profile logs determined that 20 feet of this interval was taking 52 percent of the injected fluid, bypassing much of the oil-saturated part of the zone. Water production from offsetting production wells was increasing rapidly, with a similar decline in oil production. Inter-well tracer surveys indicated very rapid water breakthrough to the producers, with tracer showing up in the first well after less than 300 barrels of water had been injected following the tracer.

Accordingly, a small 325-barrel polymer treatment was designed for the injection well. Fifteen days after treatment, produced water on the lease had declined by more than 200 bbl/d, and total oil had increased by 18 barrels. Post-treatment tracer studies indicated travel time for the dye to reach the first production well had more than tripled, indicating the injected fluid was being diverted to other areas of the reservoir, which should result in a continued, steady increase in oil-water ratio for this waterflood.

Polymer gels have been shown to be a cost-effective alternative to conventional methods for solving a variety of oil field production problems. Although polymer gel treatment is not a cure-all, it is a viable way to extend the productive life of many wells and reduce the need to abandon reserves for economic reasons. Proper candidate selection and treatment design are the most important factors affecting the success of polymer application. ❐

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