

PROPPANT TECHNOLOGY

Improved well economics through formation water reduction technology

New case study data from the Permian basin show how an operator reduced water disposal costs and improved oil production.

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FORMATION WATER CONCERNS

Onshore oilfield water management costs for 2019 are an estimated \$37.5 billion. This is a 12% increase over 2018 costs. Formation water re-injection and disposal account for 25% of the total cost, and the Permian basin continues to generate the largest amount of this formation water. Estimates indicate a growth trend for the next several years, despite the oil and gas industry producing five times more water than is needed for hydraulic fracturing.¹ A majority of formation water is transported by truck or pipeline and disposed of in saltwater disposal wells, which add to operational costs and affect overall well economics.

This is of particular concern for operators developing new areas that do not have the infrastructure in place to handle the massive amounts of produced water. In some cases, oil and gas production is throttled to slow the water production. Operators not only absorb water hauling and disposal costs, they are experiencing diminished returns on investment from the affected wells.

HEXION'S SOLUTION

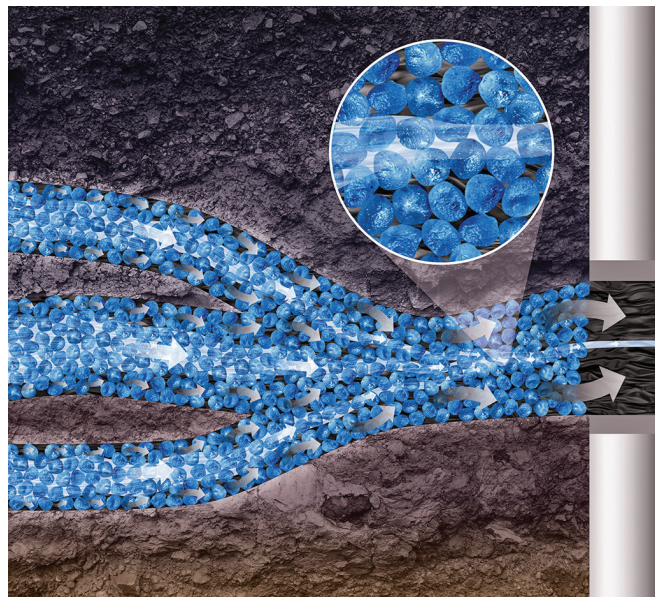
A different approach to dealing with produced water was proposed by researchers at Hexion. The concept was to leave the water downhole and produce the oil and gas. By changing the water cut, less water and more oil is produced to the surface.

To achieve this, Hexion developed the patented AquaBond formation water reduction technology. This advanced technology is a resin system that is coated on proppant that preferentially admits hydrocarbons into the proppant pack over water. This is achieved by tailoring the surface chemistry and affecting the relative permeability of the proppant. Since this unique chemistry is part of the resin itself, it does not wash off the proppant grains during production.

The coated proppant is pumped downhole, just like a traditional proppant, and does not require special equipment or additional chemicals. It is compatible with commonly used hydraulic fracturing fluid components, however, pre-job fluid compatibility testing is recommended. Frac water returns to the surface per typical flowback procedures, but after oil and formation water come into contact with the proppant pack, the technology preferentially flows the oil.

This technology is used in vertical and horizontal wells in the

Fig. 1. The technology works through modification of the surface chemistry of the proppant to preferentially admit hydrocarbons into the proppant pack over water.



Permian basin, Bakken shale, and Granite Wash formation, as well as in East Texas and Louisiana. It is typically used as a tail-in behind natural sand with larger tail-in percentages generating the best results. Users also were successful in re-fracturing older wells with this technology, resulting in more favorable production from wells that were previously not economical to operate. In addition, gravel packing operations can benefit from this technology.

Although the main feature of AquaBond technology is water reduction, it does consolidate at temperatures as low as 120°F (49°C) to provide proppant flowback control. It is important to note that consolidation is not required to achieve formation water reduction characteristics.

HOW HYDROCARBONS FLOW PREFERENTIALLY

AquaBond technology works through modification of proppant surface chemistry. By appropriately adjusting the contact angle and surface energy (**Fig. 1**), the modified coating has been fine-tuned to preferentially admit oil into the proppant pack over water. However, the process is not as simple as creating a hydrophobic/oleophilic coating. A purely oleophilic coating would trap oil at the surface of the proppant and reduce the overall permeability of the pack. This technology has an adjusted surface energy, allowing the free movement of oil that has been admitted into the proppant pack.

An AquaBond proppant pack could be compared to a cell membrane in nature. The coated proppant particles together

act as a semi-permeable membrane, forming a selective barrier that allows some chemical substances to pass through while restricting the passage of others.²

It is important to note that this technology will not create a water block, if water is the only fluid in contact with the proppant pack. Since the proppant pack is a porous medium, water can still flow through it, but there will likely be a difference in pressure compared to a traditional proppant in the same scenario. Once oil contacts the pack, the AquaBond technology will preferentially flow it over water again.

Multiple laboratory experiments were conducted to confirm that a water block will not occur. One such test was the proppant core flow test, developed by Hexion. The test involved a bonded proppant core placed in a reservoir cell containing water and oil. At the onset of the test, only water was in contact with the proppant core. The proppant core was tightly fitted to a rubber cap that was connected to a hose that drained into a graduated cylinder. A vacuum pump pulled fluid through the proppant core and the fluid collected in the graduated cylinder.

The fluid had to pass through the proppant core, in order to be collected in the cylinder. When the test started, water flowed through the core, since it was the only fluid in contact with the core. As soon as the oil, which was floating on top of the water, came into contact with the proppant core, the AquaBond tech-

nology proppant core immediately began to preferentially flow the oil. A traditional resin-coated proppant core was subjected to the same test, and only water flowed through the core, even after oil made contact. Similar results were obtained in tests conducted using various crude and produced water samples.

Additional testing has confirmed that the salinity of the formation water will have negligible effects on the effectiveness of this technology. Similar performance results were obtained when testing AquaBond cores with fully saturated, simulated brines composed of divalent and monovalent salts. Various field samples of produced water also were tested.

PERMIAN BASIN CASE STUDY

In Yoakum County, Texas, a single operator ran a trial comparing two horizontal wells utilizing AquaBond technology on 11 horizontal offset wells in the San Andres formation. The two wells used a 16.5% tail-in of this technology on 20/40 mesh sand. The offset wells used a 16.5% tail-in of 20/40 traditional resin-coated sand. Approximately 3 million pounds of total proppant were used per well. The TVD was 5,280 ft, with 5,300-ft laterals. All other completion details were similar, and all wells were completed with the same service company.

After four months, the average cumulative water production per well (Fig. 2, left) for the AquaBond technology wells was

Fig. 2. Average cumulative water (left) and oil (right) production of AquaBond technology and offset wells in the San Andres formation.

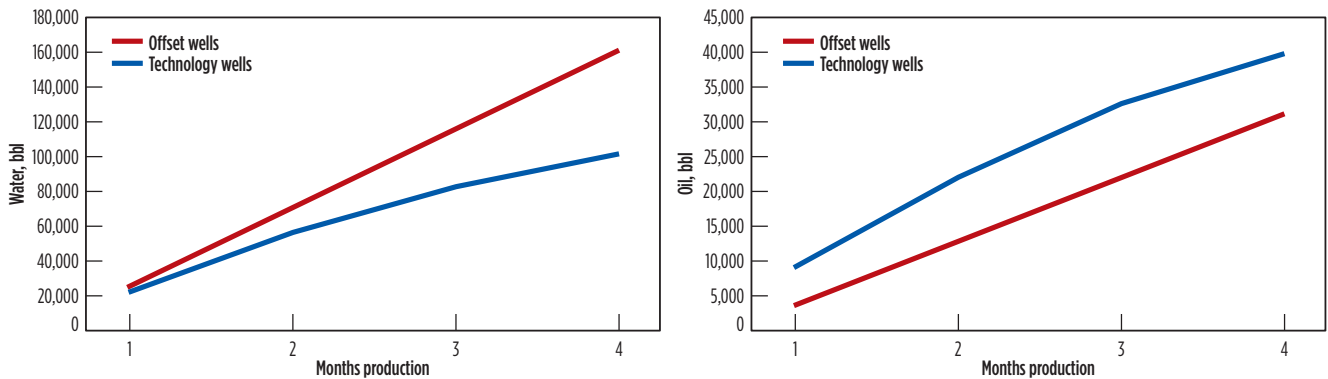
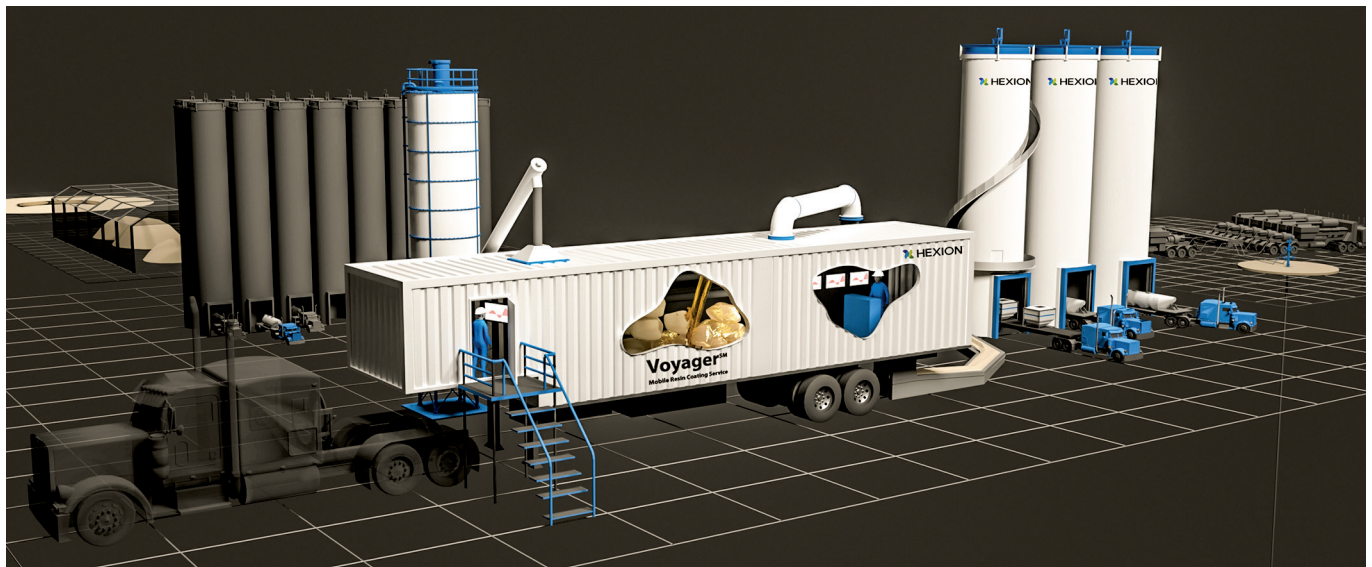


Fig. 3. Hexion's Voyager mobile resin coating unit is currently deployed in the Permian basin.



37% lower than an average of the offset wells. The water cut also shifted from 83% to 68%, resulting in higher oil production for the AquaBond technology wells. The average cumulative oil production (Fig. 2, right) increased by 28%. At \$62 per bbl of oil, the wells that utilized the AquaBond technology generated \$539,527 more revenue than the offsets, and water disposal was reduced by \$75,000 (\$1.25/bbl water disposal cost).

MOBILE RESIN COATING SERVICE

Hexion recently announced the deployment of its Voyager mobile resin-coating service (Fig. 3) to the Permian basin. This is the first mobile unit capable of providing in-basin, resin-coated proppant manufacturing. The unit, itself, is the size of a tractor trailer and is used in combination with add-on equipment, such as sand silos, chemical storage, and a fully equipped quality control laboratory. The total layout is scalable and reconfigurable to adjust for additional capacity requirements.

By bringing coating capability to the in-basin sand mines, expensive freight and transloading costs are eliminated. Additionally, by developing an efficient coating process and utilizing process automation, the Voyager unit provides the most economical resin-coated proppants available. The unit is capable of producing AquaBond Voyager formation water reduction technology, which still offers the same formation water reduction characteristics coated on in-basin sand. By utilizing local, in-basin sand and the most economical coating process available, the cost-benefit of using the AquaBond technology is strengthened even further.

CONCLUSION

Record production of formation water continues to burden oil and gas producers throughout North America. All indications point toward handling and disposal costs increasing in the years to come. AquaBond technology offers a different approach to this challenge by changing the water/oil ratio, making it more favorable for the operator. By adopting this technological breakthrough, it is possible for operators to see increased revenue and lower water disposal costs. It is also possible for operators to take advantage of older assets that were previously deemed uneconomical.

Additionally, AquaBond technology can be produced in the Voyager mobile resin coating unit on in-basin sand. By utilizing the most efficient resin-coating process available and eliminating expensive transportation and storage, the economics of using this technology are even more attractive. **WO**

REFERENCES

1. IHS Water IQ, 2019
2. Green, J., A. Dewendt, J. Terracina, B. Abrams and A. Harper, "First proppant designed to decrease water production," SPE paper 191394-MS, Sept. 24, 2018.



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