Solvent-free consolidation system controls proppant flowback

An aqueous-based consolidation system aids in maintaining production rates in fracture-stimulated wells.

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Halting or minimizing proppant flowback after fracturing or installation of liners can increase productivity and reduce operating costs to turn marginally commercial fields into profitable assets.

Wells are often shut in or abandoned when they become uneconomical to produce at lowered production rates. In many cases, production of hydrocarbons becomes restricted when producing intervals are covered or partly covered with produced proppant and/or formation solids. Additionally, proppant flowback during hydrocarbon production often causes damage to downhole pumps and surface production equipment; removing the proppant from the well bore and repairing the equipment is expensive and results in lost productivity. Worse, simply cleaning the well bore does not prevent recurrence of proppant flowback, and the cleanup process may have to be repeated several times to keep the well producing at desired rates.

ABC chemistry
Operators can now control proppant flowback using an aqueous-based consolidation (ABC) system applied following fracture-stimulation treatments or perforated liner installations in openhole well sections. Being aqueous-based, ABC systems are essentially noncombustible and contain no solvent-based resins. Halliburton and BP America developed this consolidation system in a joint effort.

A surfactant is used in a brine preflush fluid to pre-treat the surface of proppant grains to enhance the coating of the consolidating material onto the solid surfaces. In addition to coating the surfaces, capillary action helps pull the consolidating material to the contact points between proppant grains, which, after curing, transforms the loosely packed proppant or sand particulates into a cohesive, consolidated, yet highly permeable pack. Since the consolidation treatment is normally water and nitrogen gas, it is not necessary to displace this material out of the pore space to recover permeability in the proppant pack and formation even after it has cured. Use of ABC systems offers many advantages:

- Easy cleanup;
- Minimized potential of fluid contamination during placement, a noted problem when using solvent-based resin systems.

Field application
The consolidating and activator components of the ABC system are preblended and handled separately; they are the only preblended ABC system solutions delivered to the well site. If kept separated, these two solutions can remain stable for many months. During application, the two solutions are metered together “on the fly” through a static mixer or batch-mixed to form a homogeneous mixture just before they are injected downhole into the perforated interval. They coat the proppant in the fractures and the formation sand surrounding the perforations or gravel placed behind eroded screens or slotted liners and the formation sand. Injecting the treatment solution as a single component helps ensure that wherever the proppant pack is treated, consolidation will take place without the uncertainty often encountered with other externally catalyzed consolidation systems. Curing of the ABC system takes place slowly, allowing complete placement of the treatment into the proppant pack.

Both successful placement of the treatment and its effective coating onto the proppant are required to ensure reliable cohesion between the treated particles. The objective of this treatment is to treat the proppant near the well bore rather than to treat the entire proppant pack in the fractures. Based on this principle, a volume of about 5 gal of consolidating fluid is used to ensure treatment of each 1 ft (.3 m) of perforated interval with two fracture wings having ¼-in. fracture width. This provides about 10 ft (3.3 m) of penetration in each wing. The consoli-
Dating treatment fluid provides high cohesion between the proppant grains to keep them in place without causing plugging in the pore spaces of the proppant matrix (Figure 1). Treating long intervals presents special challenges:

- Multiple perforated intervals with multiple fractures;
- Non-uniform placement of treatment fluids into different perforated intervals; and
- Effective diversion to ensure adequate placement of treatment fluids.

Field tests have shown that treatment fluids that have been foamed to a quality of 60 or more can effectively divert the treatment fluids to treat relatively long intervals when treating propped hydraulic fractures.

Prior to placement of the ABC system, it is imperative to clean out all proppant or debris that is left behind to ensure that the well bore is free of obstacles during the consolidation treatment. Such a barrier or proppant bridge could prevent complete placement of consolidation treatment into all perforations and contribute to failure of the consolidation treatment.

The fluid sequence of an ABC consolidation treatment is as follows:

- **Preflush 1.** Inject a volume of mutual solvent solution to remove residual oil coating from the proppant or formation sand particulates;
- **Preflush 2.** Inject a volume of liquid or foamed brine that contains a surfactant to promote the wetting of the resin to the particulate surfaces in subsequently injected fluids. Meter and mix a foaming agent into the liquid brine to be foamed with nitrogen;
- **Consolidation fluid.** Inject a volume of foam generated from a homogeneous mixture of ABC system component and hardening component. This fluid mixture is premixed with a foaming agent similar to that used in the Preflush 2 stage to allow a foam of about 80-quality to be generated with nitrogen; and
- **Postflush.** Inject either nitrogen gas or other displacement fluid to displace consolidation fluid from the well bore, perforations, and part of the proppant pack near the well bore.

During the curing period of the treatment, it is recommended that the well be shut in to prevent or minimize fluid swabbing, backflow, or crossflow (which can disturb the cohesion between proppant grains), and to allow the treatment to cure sufficiently. As recommended in the treatment procedure, the well should remain shut in from 24 to 48 hours, depending on the bottomhole temperature.

**Proof from the field**

ABC material was used to control proppant flowback in a cased-hole completion. To determine the effectiveness of the remedial proppant treatment of the ABC system, a cased well was perforated in two intervals with two shots per foot for a gross height of 150 ft (45.8 m) and a net height of 100 ft (30.5 m). A low-viscosity, nitrogen-assisted, water-fractured treatment fluid was performed; no measures were taken to restrict proppant flowback.

Proppant concentration during the treatment ranged from 0.5 to 2.24 lb/gal, injected at 50 bbl/min injection rate to place a total of 200,000 lb of 16/30-mesh sand. The well had a bottomhole temperature of 120°F (49°C) and a bottomhole pressure of about 1,000 psi after flowing back for four days following the fracturing treatment.

Four days after the stimulation treatment the operator used wireline to tag sand that had flowed back during the initial cleanup. The presence of a large open rat hole below the perforations made it possible to perform the consolidation treatment without cleaning out the well because the top of fill sand was tagged well below the perforated intervals.

The consolidation treatment was monitored in real time through a fiber-optic distributed monitoring system to provide continuous temperature profiles over the entire interval length and to confirm whether a complete interval coverage of treatment fluids was achieved. The method was based on the principle that comparing and analyzing temperature profiles over time provides direct indications of injection distribution at various points in the intervals.

Post-treatment analysis by the fiber-optic monitoring method indicated that complete zone coverage was achieved with the consolidation treatment. The proppant appeared to be distributed in the bottom half of each perforated interval, consistent with a water-fracture treatment. Post-treatment production results indicate that the well is producing equal to or better than the offset wells. No measurable proppant production has occurred since the consolidation treatment. Offset wells are prone to proppant production, especially during early production stages.

### Table 1. Proppant-pack strength.

<table>
<thead>
<tr>
<th>PROPPANT TYPE</th>
<th>CURE TEMP. (°F)</th>
<th>UCS (PSI)</th>
<th>MAX. WATER FLOW RATE (BPD/PERF)</th>
<th>PROPPANT FLOWBACK</th>
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<tbody>
<tr>
<td>20/40-Brady</td>
<td>100</td>
<td>&lt; 5</td>
<td>35*</td>
<td>Yes</td>
</tr>
<tr>
<td>20/40-Brady</td>
<td>125</td>
<td>15</td>
<td>130*</td>
<td>Yes</td>
</tr>
<tr>
<td>20/40-Brady</td>
<td>150</td>
<td>80</td>
<td>&gt; 275**</td>
<td>No</td>
</tr>
<tr>
<td>20/40-Brady</td>
<td>175</td>
<td>200</td>
<td>&gt; 275**</td>
<td>No</td>
</tr>
<tr>
<td>20/40-Brady</td>
<td>200</td>
<td>350</td>
<td>&gt; 275**</td>
<td>No</td>
</tr>
<tr>
<td>20/40-Carboline</td>
<td>200</td>
<td>160***</td>
<td>&gt; 275**</td>
<td>No</td>
</tr>
<tr>
<td>20/40-Bauxite HSP</td>
<td>200</td>
<td>70***</td>
<td>&gt; 275**</td>
<td>No</td>
</tr>
</tbody>
</table>

* Flow rate when proppant begins to produce out.

** Pump rate limited by allowable pressure

*** Only 20-hour cure time.

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