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Effective gravel packing improves production

Dynamic surging, followed immediately by prepacking, enables more effective gravel packing for sand control and, in an example from Malaysia, improved well performance.

AUTHORS
Rajeswary Suppiah and Norhisham Safiin, Petronas Carigali; and Samyak Jain, Shahryar Saebi, Raymond Tibbles, and Jock Munro, Schlumberger

Sand production is a common occurrence in unconsolidated formations, and in most cases it leads to reduced productivity and/or excessive maintenance of downhole and surface equipment. It also can cause catastrophic failure of the well bore. Sand production can be controlled using operational, chemical, and mechanical methods. Operational methods use restricted flow rate and pressure drop to reduce sand production. Chemical methods use materials such as resins to consolidate the formation in the near-wellbore area. Mechanical methods hold back formation sand with liners, screens, or gravel packs.

Gravel packs are the most common solution for mitigating sand production. In gravel pack operations, a steel screen is placed in the well bore, and the surrounding annulus is packed with gravel of a specific size designed to prevent the passage of formation sand. The primary objective is to stabilize the formation while causing minimal impairment to well productivity. Gravel must be placed across the entire production interval, as any gap or interruption in the coverage will enable sand or fines to enter the production system.

In cased-hole applications, perforations provide communication between the reservoir and the well bore. Effective perforating, followed by packing the perforations with high-permeability gravel, is critical to enabling a well to deliver its potential productivity. High shot density and big-hole charges are usually the optimum gun charge configuration when perforating for sand control completions. Maximizing flow area reduces fluid velocities and the drawdown required to achieve a given production rate, which can decrease the risk of sand production through the gravel pack and sand screens. However, production rates can be reduced severely if the packed perforations are damaged, preventing effective gravel packing.

The link between perforating and gravel-pack success is well established, but this link can be neglected in field operations, particularly when perforating and gravel packing are handled as independent operations. Maximizing the flow area for reservoir fluids requires a systematic approach to perforating, post-perforation cleanup (the removal of perforation damage), and effective gravel packing of the perforation tunnels.

Perforation damage
Damage can result from several sources. In very weak sands, the formation can collapse on itself during the perforating process, leaving no defined tunnel. In all sands, the explosive jet blasting through the formation pulverizes sand grains, creating a track of impermeable debris along its path. In addition, drilling mud and mud filter cake can extend into the formation. The combination of mud damage and perforation damage leaves a flow-restricted area often referred to as skin. This damaged area inhibits the uniform placement of gravel behind casing during the completion phase, resulting in reduced productivity and injectivity and increasing the probability of earlier onset of sand or water production.

Underbalanced perforating
Underbalanced perforation is a widely accepted technique for optimizing perforated completions. Establishing a lower static pressure in the well bore than in the formation allows fluids to flow from the reservoir, sweeping debris from the perforating tunnels. However,
in most conventional underbalanced perforating operations, particularly with big-hole, high shot density charges, over-pressure is created in the wellbore for a short duration after the gun detonates. This overpressure negates much of the effect of the initial static underbalance and is likely to inhibit cleanup in all, or parts, of the perforated zone (Figure 1).

Underbalanced perforating in unconsolidated formations also can result in “sanding in,” which happens when large volumes of sand enter the wellbore and fill the void between the gun and casing inner diameter. Sanding-in traps the guns, incurring cost and delays during subsequent fishing operations. While never planned for, it has been noted that wells that have had guns sanded and later retrieved often perform better than neighboring wells, as the large influx of sand brought into the wellbore effectively removed perforation debris and drilling damage.

Perforation surging
The surging technique encourages post-perforation flow into the wellbore while avoiding the risk of sanding-in. An atmospheric chamber is run into the well with the gun assembly. After perforating in an overbalanced condition, the guns are moved clear of the zone. The atmospheric chamber is then activated, exposing the perforated interval to a short, sharp pressure drop (Figure 2). This drop in pressure draws a controlled volume of fluid into the wellbore, which breaks down a hemispherical region at the entrance of each perforation. The initial drop in pressure is followed by a period of controlled flow into the chamber, pulling loose sand and debris from the collapsed region into the wellbore, resulting in cavities behind the casing and cement that can subsequently be filled with high-permeability gravel.

Perforation prepacking
Complete packing of perforation cavities is of critical importance to maximize flow and avoid the early onset of sand production. Successful packing of cavities requires clean, open perforations; a prepacking operation with adequate pump rate; and a nondamaging carrier fluid with good carrying capacity; while still being able to maintain sufficient leakoff into the formation. Research and field experience indicate that, for cased-hole gravel packs, best results are obtained when cavities are prepacked with gravel as soon as possible after perforation damage is removed. This helps to prevent tunnel collapse, control fluid loss, and prevent the entry of formation sand during production. In addition, prepacking immediately after perforating results in two opportunities to place gravel in the perforations — first during the prepack and then during the main gravel pack.

Implementation in Malaysia
Combinations of perforation surging and prepacking of perforation cavities were applied to four wells (named A, B, C, and D) in the Abu Cluster field, West Malaysia. This reservoir has high permeability (1.5

![Figure 2. The surge technique creates a large low-pressure volume that sweeps the perforation tunnels of any debris.](image2)

![Figure 3. A comparison of pre-surge fluid loss rates with loss rates after employing the surge technique shows dramatic improvement in all cases.](image3)
to 3.0 Darcy), and sand production is a major concern. Expected production rates are up to 5,000 b/d per well. All zones in the four wells were surged after perforating except one zone in well D, which was perforated underbalanced.

Well A was then completed with a conventional high-rate water pack without any dedicated prepack.

Well B was scheduled to have a dedicated prepack immediately after surge; however, after the perforation operations, the well was shut down because of inclement weather, resulting in a 10-day delay between the surging and prepacking.

Well C had two zones that were completed separately. The upper zone (C1) was a gas zone, whereas the lower zone (C2) was an oil zone. Both zones were perforated and surged, followed by a dedicated prepack operation performed before the main gravel pack.

Well D had two zones that were completed together. The upper zone was surged after perforating, while the lower zone was perforated underbalance. After perforating, a dedicated prepack operation was performed before the main gravel pack.

**Increased loss rates**
The effectiveness of the surging operation can be measured by comparing pre-surge completion fluid loss rates with losses after the surging operation (Figure 3). Post-surge completion fluid loss rates increased significantly in all of the wells, indicating that the process had at least partially removed perforating and drilling damage, thereby improving reservoir connectivity.

**Pack factor**
Perforation pack factor is a measure of the quantity of gravel placed behind casing during the gravel-pack operation.

Experience with new oil wells in clean formations indicates that average pack factor is usually in the range of 0.25 cf per foot of perforations. The gravel used in these operations had a bulk density of 96 lb/cf, so to exceed the average, pack factors should be higher than 24 lb/ft.

Well A (no prepack) had a pack factor of 8 lb/ft. Pack factor for Well B was 5 lb/ft, indicating that perforation tunnels may have collapsed during the 10-day gap between perforating and prepacking. By contrast, the two zones of Well C had pack factors of 29 lb/ft and 38 lb/ft, while the two zones of Well D had an average factor of 27 lb/ft (Figure 4).

These results indicate that dynamically surging the perforations was an effective cleanup process and that prepacking, when performed immediately after perforating and surging, greatly improved packing efficiency.

**Productivity improvement**
The oil productivity index (PI) of the four wells was compared with the pack factors to evaluate the impact of perforation prepacking on well performance. Plotted PI was normalized for permeability and perforated interval as the wells are producing from different zones of the reservoir. Productivity data was not available for the C1 gas zone. The analysis showed a strong relationship between pack factor and normalized PI. The limited data indicate that, in this case, every additional lb/ft of gravel placed in the perforations increases the normalized PI by approximately 0.22 b/d/psi (Figure 5).