

Increasing Oil Well Production by Maximizing Under-balance during Perforation

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Perforation is the process that creates a direct link between the wellbore and a producing formation by puncturing holes through the casing and the cement sheath that surrounds it. Perforation involves specialized equipment that creates tiny holes through the casing, the surrounding cement, and any other barrier between the formation and the open well.

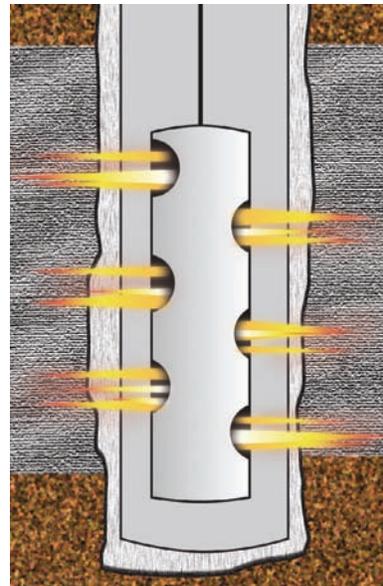
A number of types of completion techniques have been developed, and the method selected for a given application depends on the characteristics and location of the formation. The perforation application discussed in this article centers on tubing conveyed perforated completion.

The primary cause of wellbore damage and reduced production in any perforated completion is the invasion of pulverized rock formation grains that create a restrictive “low-permeability crushed zone.” When accomplished effectively, perforation allows for efficient flow of hydrocarbons into the well hole by minimizing the invasion of this pulverized debris.

Adjusting Perforation Balance

The pressure differential between a well bore and the reservoir prior to perforation can be described as under-balanced, balanced or over-balanced. A desirable under-balance condition exists when hydrostatic pressure inside the well casing is less than pressure in the formation.

This article reports on the formulation and field testing of super-light completion fluids composed of synthetic oil, density reducing hollow glass microspheres, and a rheology control agent to suspend the glass bubbles in homogenous slurry. Laboratory tests show that completion fluid density values as low as 5.0 ppg can be achieved with this formulation.



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Recent studies demonstrate that use of ultra low weight completion fluids in conjunction with perforation can increase dynamic under-balance in a well by an order of magnitude to assist in post perforation cleanup, and resulting in reduced skin damage and increased well productivity.

The lowest achievable density of conventional well fluids is on the order of 6.6 ppg, giving them limited application in perforating depleted reservoirs where this level of density could still lead to an over-balance in pressure.

A common alternative to achieve the necessary under-balance is to swab the well, which imposes additional costs, which may not be desirable or operationally practical. In such cases, a stable reduced density fluid with non-damaging chemical properties can offer an effective alternative.

Unfavorable Over-balance

It is commonly accepted that perforations conducted in over-balanced conditions can result in damage to the rock matrix. SPE Paper 63108I (“Optimum Under-balance for the Removal of Perforation Damage,” I.C. Walton, 2000) reported that such a damage zone typically extends about 1 centimeter into the rock, and results in 20 percent or more of permeability reduction.

Lower permeability rocks tend to exhibit a greater percentage of permeability reduction under conditions

of over-balance. Perforating shock waves and high-impact pressure shatter rock grains, break down inter-granular mineral cementation and de-bond clay particles, resulting in a low-permeability crushed zone in the formation around perforation tunnels. Damage to the rock matrix is caused by crushing of sand grains as the jet enters the rock, as illustrated in Figure 1.

In contrast, under-balance facilitates flow from the formation into the tunnel (Figure 2). This flow aids in the removal of perforating debris while minimizing or eliminating crushed-zone damage in and around the perforation tunnel.

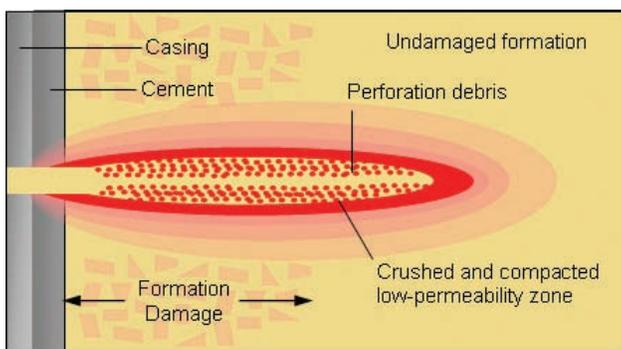


Figure 1 - Perforation shock waves and high impact pressure shatter rock grains that break down inter-granular mineral cementation and de-bond clay particles. This creates a low permeability zone in the formation around perforation tunnels to reduce flow potential.

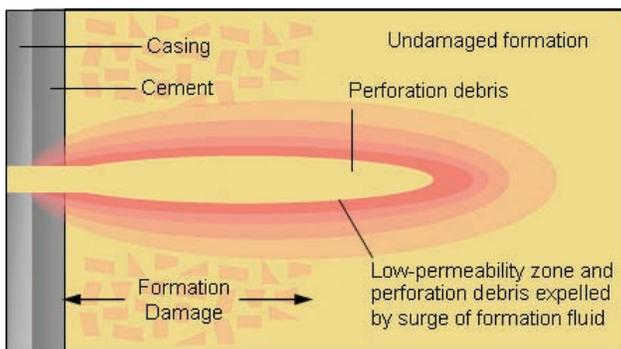


Figure 2 - Under-balanced perforation improves flow channels by effectively removing the crushed zone through an instantaneous surge of fluids from the reservoir into the wellbore when the jet penetrates the rock.

Under-Balance Fluid Formulation

The concept of using a low-density under-balance completion fluid under field conditions was conducted in the Bunga Raya field, located in a joint development area between Malaysia and Vietnam, at the heart of block PM3 CAA. The well is operated by Talisman, and perforation work was conducted by Halliburton.

Super lightweight completion fluids were formulated in the laboratory, consisting of Shell Sarapar™ 147 synthetic oil, with 3M™ Glass Bubbles (see Sidebar) as a density reducing agent. It was determined that the final fluid formulations should be at their lowest possible density, they should demonstrate good stability, and should have an acceptable viscosity.

Experimental work began with screening tests to determine whether the addition of rheology control agents into the slurry to suspend the glass bubbles in homogenous slurry would improve mixture stability and homogeneity. Fluids with various combinations of glass bubbles, synthetic oil and rheology control agents were mixed and their corresponding densities and viscosity values were measured.

Field Test

About 72 barrels of lightweight completion fluids were pumped into the BKC-18 well of Bunga Raya field. Talisman's BKC-18 well was the site of the field case study because reservoir pressure was relatively low, with a perforation zone that stretched 30 meters in a relatively high angled well. A neighboring well, BKC-17, which is producing from the same formation, was perforated using conventional fluids.

Production history of BKC-18 shows a marked increase in production rate compared to neighboring wells that produce from the same reservoir but were perforated traditionally. Production rates of BKC-18 were maintained at above 2000 bpd after 4 months, while production at adjacent BKC 17 dropped to below 1000 bpd during the same period of time.

The total measured depth of the test well is 3,005 meters, with a total vertical depth of 2,058.3 meters, classifying it as moderate to high-angle. BKC-18 is a single zone oil producer with a reservoir pressure of approximately 2200 psi. Well orientation did not allow for wire line perforation where swabbing could be an option, and tubing conveyed perforation was the most practical approach. If a standard base Sarapar 147 had been used, it would have produced a fluid with a density of 7.5 ppg, which corresponds to approximately 246 psi of over-balance under these well conditions.

With the use of the low weight completion fluid an under-balanced condition of approximately 177 psi was achieved. The completion fluid pump rate was set between 0.5 and 1.0 barrels per minute. The completion was run without any issues and successfully

perforated with the lightweight completion fluid in place.

It is difficult to make direct comparisons of well test data because of the many variables in reservoir heterogeneity and well completion characteristics. However, all the major indicators would suggest that Well BKC-17 should be less damaged and a better producer than Well BKC-18. This was not the case, however, and a subsequent pressure build-up showed BKC-18 to have a skin of only 1, indicating the well to be undamaged.

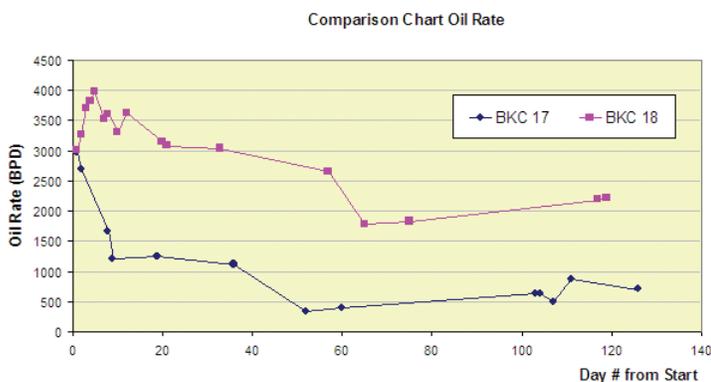


Figure 3 – Production history for Wells BKC-17 and BKC-18.

Further trials are required to verify the outcome and identify any other factors that might be at play, however, the trial is considered a success in that the lightweight fluid was placed in the completion without incident and achieved the objectives for the trial. A production history of BKC-17 and BKC-18 is shown in Figure 3.

Conclusion

This field test confirms that the addition of glass bubbles can result in lower density, lighter weight fluids with a relatively short stability period. The addition of a stabilizing agent increases slurry stability and produces relatively viscous fluids.

Further, the best lightweight formulation was found to be in the proportion of 35 parts glass microspheres and 65% synthetic oil.

This lightweight completion fluid technology is not necessarily limited to depleted reservoirs. For example, in normally pressured zones where permeability is extremely low, the fluid offers potential to increase under-balance by an order of magnitude to assist cleanup. Oil fields in later stages of depletion, in field drilling, reservoirs with low formation pressure, etc. are

all candidates for ultra lightweight completion fluid made with 3M™ Glass Bubbles.

3M™ Glass Bubbles

The 3M™ Glass Bubbles used in successful completion fluid testing are unicellular spheres made from soda-lime borosilicate glass. They are chemically inert, other than in the presence of HF, and have high pressure and temperature resistance.

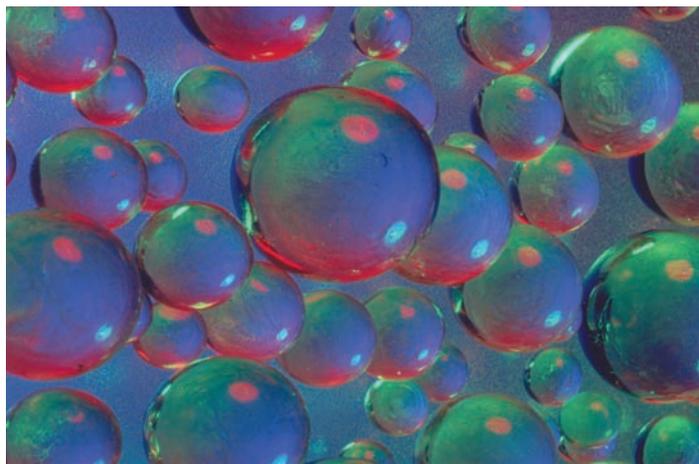
The chemically-stable soda-lime-borosilicate glass composition of 3M™ Glass Bubbles makes them virtually insoluble in water or oil. Their low alkalinity gives them compatibility with most resins, stable viscosity and long shelf life. They are also non-compressible.

By virtue of their light weight and spherical shape, these glass bubbles have a much lower surface area and substantially greater strength-to-weight ratio than other filler alternatives. This allows for much higher “solids” loading in a base fluid system.

3M™ Glass Bubbles are provided in a density range of 2.7 – 5.0 ppg (0.32 - 0.60 g/cc), and are widely used in many industries, most notably aerospace and automotive materials.

3M™ Glass Bubbles HGS series are specially formulated for a high strength-to-weight ratio. This allows greater survivability under demanding downhole conditions. They are available in varying densities and crush strengths to help meet specific downhole conditions.

3M™ Glass Bubbles have been used in the petroleum industry for a number of years in buoyancy modules for sub-sea risers, as a key component in syntactic foam insulation for deep sea flow lines, and in the formulation of reduced-density down-hole cement.



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