

JOSHUA LEASURE AND JEFF HEBERT,
CARBO, USA, EXPLAIN HOW CONDUCTIVE
PROPPANT-DELIVERED SCALE INHIBITION
HAS BEEN ENGINEERED FOR TODAY'S
CHALLENGES.

PROTECTION IN

EVERY WAY

The recent development of dual-functional proppant-delivered inhibition technology signals a breakthrough in managing the near-wellbore generation of inorganic scale, which ranks as one of the industry's most detrimental flow assurance issues, and one that severely impacts the ultimate value of a producing oil and gas asset.

Fundamentally, the unique merger of interconnected and uniformly dispersed porosity with high conductivity allows the encapsulated SCALEGUARD proppant-delivered scale-inhibiting technology to function as a fully controllable inhibitor delivery vehicle, while simultaneously executing its intended purpose as

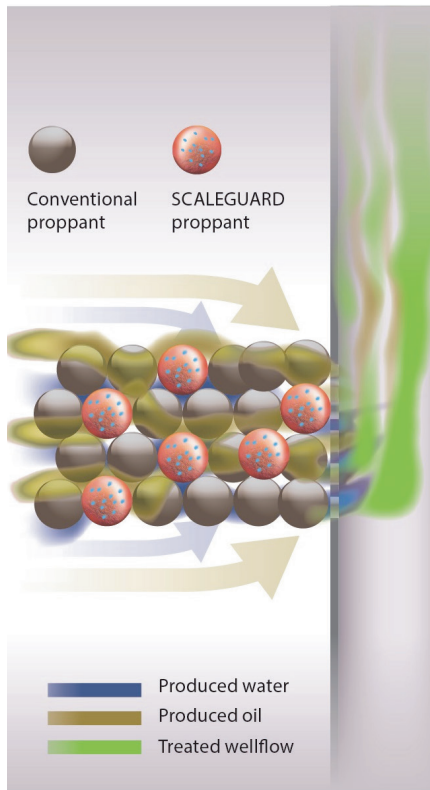


Figure 1. SCALEGUARD near wellbore.

a conductive ceramic proppant in a typical fracturing operation. Placed during the fracturing process, this porous ceramic proppant technology eliminates production decline and intervention costs caused by scale in a single treatment. The deposition of scale in tubulars or within otherwise permeable reservoirs can severely restrict both flow and production, especially in wells spanning high produced water volumes.

Compounding the profit-draining ramifications of lost or delayed production, the recurring formation of barium sulfate (BaSO_4), calcium carbonate (CaCO_3) and other scales requires repeated and tremendously costly remediation, ranging from chemical squeezes to continual topside injection of inhibiting chemicals. The economic fallout from scale was partially borne out in a 2013 survey showing a global spend that year of US\$500 million for scale inhibitors alone – a fraction of the absolute costs. Squeeze treatments require a well to be brought off production which could result in multiple days of lost revenue in addition to costly remediation treatments.

The common denominator of squeezes and other methodologies is remediating, rather than preventing, the formation of scale at its point of origination, which in the case of hydraulically fractured wells, is within the proppant pack. Here, the formation of scale will block or choke back the direct connection from the reservoir to the wellbore, thereby restricting the flow of hydrocarbons.

The recently engineered ceramic proppant-delivery technology addresses that gaping deficiency by preventing the formation of scale at its primary point of conception. During the manufacturing process, scale inhibitors are infused within a porous substrate, specially engineered to retain conductivity. The uniformly dispersed porosity, combined with durable, semi-permeable membrane encapsulation, enables the predictable and controlled release of the inhibitor upon contact with produced water. Importantly, since the infused ceramic proppant is incorporated as part of a typical fracturing operation, the inhibitors can be placed in every fracture and zone within the proppant pack.

Field data to date illustrates the dual-functional effectiveness of the technology, in that many wells currently being monitored have sustained production for nearly a year with no recurrence

of scale issues. The technology has proven to protect for a much longer timeframe than any other treatments in the market, thereby maintaining flow rates and increasing estimated ultimate recoveries (EUR) at appreciably lower operating costs.

Design concepts

Delivery mechanisms aimed at placing inhibitors directly at the point in the wellbore where scale normally forms have yielded widely mixed results. Commingling inhibitors with the frac fluids, for instance, provides excellent placement, but the treatment longevity is extremely low. For another, the comparatively extended treatment lifeline of solid scale inhibitors is offset by the low intrinsic conductivity of the diatomaceous earth (DE) substrate.

Non-encapsulated, porous ceramic proppant likewise have long been recognised as potentially viable chemical carriers, which was verified in early offshore trials. However, while the prototypes indeed performed admirably, maintaining conductivity and delivering chemical, the chemical release longevity was not ideal.

Following those early trials, and owing to the spiralling costs of coping with scale and the dearth of effective prevention methodologies, a research project was initiated with the specific aim of developing porous, yet highly conductive ceramic proppant that could be infused with scale inhibiting chemicals and provide long-term treatment life. Thus, in a single treatment, such a technology conceivably could prevent near-wellbore scale formation, while having no adverse impact on fracture or proppant pack conductivity.

Recognising that the highly porous ceramic proppant required to deliver inhibitors would, at the same time, weaken conductivity, researchers focused on striking a healthy balance between the two. Theoretically, selecting and controlling the pore space relative to the grain volume, or the % porosity, would deliver the desired porosity levels. That concept ran counter to conventional ceramic proppant, which are designed and manufactured to essentially eliminate the internal pellet porosity that effectively reduces conductivity.

Lab tests confirmed that tailoring the type of substrate and engineering uniform dispersion of the porosity throughout each grain of proppant, a porous ceramic proppant could be effectively blended with a standard proppant, thereby having no adverse effect on conductivity. The porous component of the proppant pack would then be infused with the scale inhibitor to produce a proppant that provides both the designed conductivity and efficient chemical delivery.

Early in the development initiative, much of the laboratory investigation centred on extending the elution profile of the chemically infused proppant, which can be simply defined as its capacity to control the activated release of the inhibitor from the host substrate upon contact with water. Doing so would remove another glaring limitation of traditional scale treatment techniques such as chemical squeezes, which have a limited elution profile.

Modifying the elution behaviour of a given scale inhibitor would allow for a slower release, which, in turn, ostensibly would permit a larger volume of water to be effectively treated using the same concentration of infused proppant. Engineering a predictable and controlled release of the inhibitors would make the proppant-delivered technology especially beneficial in applications such as water floods, where the inhibitor would be present instantly after water breakthrough.

At the end of the day, it was estimated that combining an extended elution profile with enhanced placement would produce a clean proppant pack, allowing the well to continue to produce near initial rates of production for a longer period of time.

Engineering principals

These and other predominate design concepts were captured in the final product, which was manufactured and deployed around four core and exclusive engineering tenets: Application-specific chemistry and concentration; unique delivery methodology; encapsulation; and placement.

As for the chemistry, a phosphate-based inhibitor was chosen as the base inhibitor for its general effectiveness and the fact it is well understood within the industry. More recently, a proprietary polymer was added to the inhibitor suite for applications requiring higher salinity, temperature and iron tolerance that extend beyond the capabilities of the base inhibitor.

Each application is designed to specific well and reservoir conditions, beginning with the analysis of a produced water sample provided by the operator. The analysis determines whether in-situ reservoir characteristics, such as salinity and iron content, mandate use of the polymer inhibitor or phosphate-based inhibitor. The pre-deployment well analysis also determines the minimum inhibitor concentration (MIC) required to inhibit a specific volume of produced water over a certain timeframe.

Since the scale inhibitor is infused directly into the porous proppant substrate during manufacture, more inhibition chemicals can be incorporated than what would be possible with a simple coating process. Accordingly, the marriage of uniform dispersion of porosity with higher chemical concentration allows for the delivery of a conductive proppant with enduring scale inhibition capabilities.

As the controlled encapsulation process reduces the amount of inhibitor released only upon contact with water, more chemicals remain within the porous substrate, extending the treatment time. The inhibitors have no interaction with typical fracturing fluid chemistry and are insoluble in oil. Consequently, oil is unable to penetrate the coating and wash out the chemicals; in the case of water breakthrough, the water can infiltrate the coating and activate the inhibitors, which are slowly released into the fluid stream.

The overriding benefit of the dual-function technology is the pinpointed placement throughout the fracture and near the wellbore – the birthplace of inorganic scale, as evidenced by deposits observed on pulled tubulars – and inaccessible by most remediation techniques. Specifically, since all reservoir fluids, including produced water, pass over the proppant pack, placing the inhibitor within the proppant pack provides instant reaction with the source of scale, preventing its formation.

Field recaps

The capacity of the technology to prevent scale and continuously sustain production is best reflected in a producing well in an ongoing E&P operation in Manitoba, Canada where the operator targeted the Triassic Spearfish formation within the localised Bakken play. The 22-stage horizontal production well, comprising an aggregate 130 000 lb of natural sand proppant, experienced a steep decline after being online for nearly a year. A subsequent root cause investigation attributed the severe drop-off in

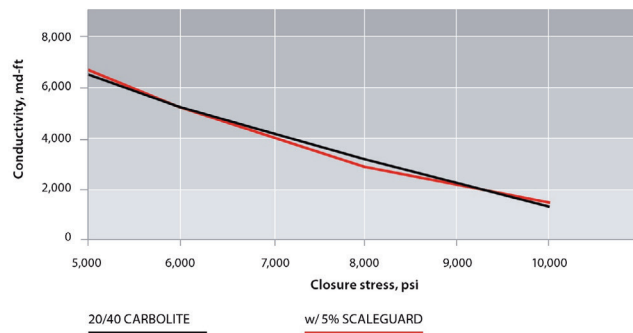


Figure 2. 20/40 CARBOLITE with SCALEGUARD.

production to significant scale deposition, forcing the operator to pull the pumps and drill out the well to remove the scale deposits, dramatically increasing costs and reducing the overall value of the producing asset.

To avoid a recurrence, following a subsequent evaluation of the specific well characteristics and produced water chemistry, the operator modified its stimulation strategy by replacing the sand with a blend of encapsulated, inhibitor-infused, porous ceramic proppant and low-density ceramic proppant to both reduce the near-wellbore pressure drop and treating the produced water before it reached the wellbore, preventing scale from forming.

Results to date show use of proppant-delivered scale inhibition delivering the potential to essentially double the peak production life of the well. No remediation is expected to be required after 12 months of production, and is projected to extend multiple years of sustained production without scale remediation. By preventing the near-wellbore buildup of scale and keeping downhole equipment free of deposits, SCALEGUARD will allow the well to maintain maximum productivity.

Elsewhere, the technology was applied to five wells in eastern Utah's Uinta Basin where an infused porous ceramic proppant was added at a design fraction to natural frac sand treatments to prevent both barium sulfate and calcium carbonate scale deposition.

The controlled release has worked as designed with the wells on production for nearly one year with no scaling problems, while alternative inhibiting products used previously had lasted only a couple of weeks before scale remerged. The technology has maintained scale control above measured MIC and the operator is projecting several years of scale-inhibited production.

In the gas window of the Eagle Ford play in South Texas, the operator had been forced to shut-in a producing well after severe scale deposition. A subsequent re-frac included the proppant-delivered scale inhibition, with the well returning to service at 4 million ft³/d and after nearly four months was holding steady at around 1 million ft³/d, which is above the normal decline rates for the field. Importantly, no indications of scale have been observed, whereas typical recompletions in the area see scale forming within two weeks after going online.

Going forward, the core technologies incorporated for porous proppant-delivered scale inhibition are being used in steadily advancing development programmes aimed at developing products that will address common production assurance issues. ■