# ELEVATE™ Additives for Unconventional Foam EOR

## 100% Incremental Oil and 50% Increased Gas Utilization in Fractured/Propped Formations

- Dow and MD America Energy partnered to conduct a Hydrocarbon Foam Huff-n-Puff EOR trial in an unconventional reservoir.
- ELEVATE™ foam additives were used to improve conformance at the well.
- Oil production doubled, showing a clear economic driver in addition to reduced carbon emissions.

### Challenge

**Oil field operators must find a way to limit gas breakthrough, enhance gas conformance without impacting the EOR gas injection rate, and avoid to shut-in the offset wells to contain the EOR gas in Stimulated Rock Volume (SRV), while also sustaining the target pressure.** Cyclic gas injection or more commonly known as "Huff-n-Puff" has been the preferred EOR method by US unconventional shale operators. Additionally, for the tight oil reservoirs, with permeability higher than the shale reservoirs, gas-EOR in drive mode has also been tested. The enhanced gas-oil contact in such formations requires filling the SRV with the EOR gas at a target pressure. However, fracture communications across offset wells causes potentially uneconomical gas cycling and challenges in sustaining target pressure.

### Solution

**Collaboration:** The Dow EOR group collaborated with MD America Energy for an unconventional foam assisted hydrocarbon-gas-drive EOR pilot in the Woodbine field (TX), a tight (μD) hydraulically fractured and propped sandstone reservoir. The objective of this single injector and two producer wells pilot was to correct the gas conformance issues identified as out of zone injection, non-uniform gas sweep, quick gas breakthrough and low bottom-hole pressure (BHP). Dow leveraged our ELEVATE™ conformance enhancement foam additives to support MD America with laboratory de-risking, injection strategy design and pilot monitoring and surveillance within six months.

**Application:** ELEVATE™ foam additive in brine was co-injected with lean hydrocarbon gas into the injection well for two weeks generating an in-situ hydrocarbon-in-water foam in the fracture network that resulted in ***>100% incremental oil, >50% increased gas utilization***, and >20% (600 psi) increase in BHP sustained during the three months pilot period. Overall, as a proof of concept, gas + ELEVATE™ foam additive co-injection confirmed gas mobility control, pressure build-up, gas conformance enhancement, higher oil production and increased gas utilization ratio.

**Technology:** ELEVATE™ foam additives represent the next generation of EOR surfactants designed to generate in-situ foam in propped fractures to provide better distribution of injection gas by limiting the undesirable well-to-well gas breakthrough (Figure 1a, red arrows). These innovative products give rise to commercially viable unconventional gas EOR process by improving the operational efficiency and gas utilization factor. Dow's ELEVATE™ surfactants are structurally tunable to help ensure a phase stable formulation in harsh reservoir conditions, such as high temperatures and/or high brine salinity. Reservoir-to-reservoir variations of shale plays can be complex. ELEVATE™ foam additives can be used to easily pivot formulation characteristics to meet customer performance requirements.

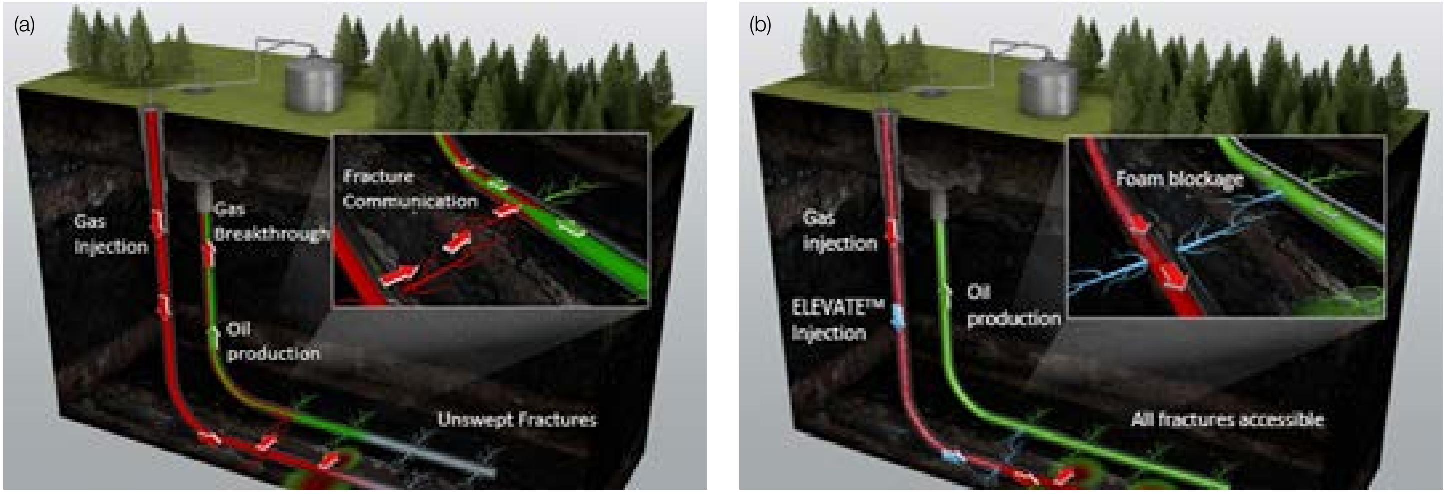


Figure 1. EOR gas (red) injection into a fractured formation (a) gas breakthrough due to unwanted fracture communication to an offset well (see insert) limiting gas-oil contact for EOR as well as oil (green) production from the offset well (b) in-situ gas-in-brine foam (blue) formation in fracture network enhancing gas conformance for uniform gas-oil contact in SRV

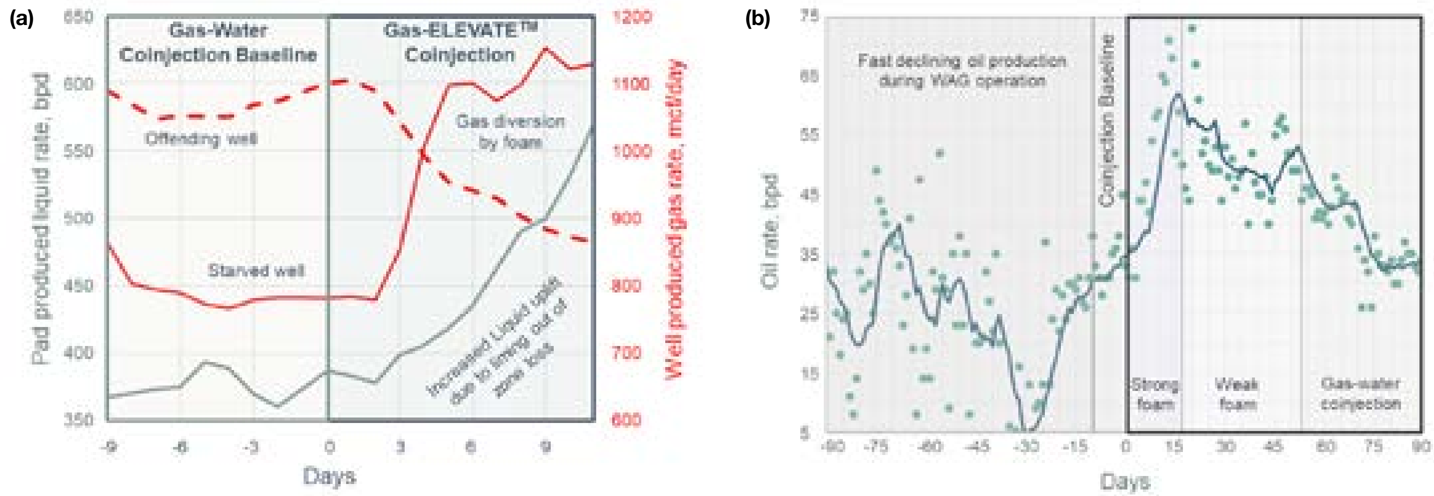


Figure 2. (a) Confirmation of gas diversion from offending well to starved well as well as higher liquid production with potential out of zone injection reduction during strong foam generation period (b) higher oil production from the 2 pilot producers during strong foam generation as well gradual decline during weak foam and gas-water coinjection chase periods while the there was much faster decline in oil rate during WAG operation.

## Result

Before the pilot, three conditions were field tested including gas injection alone, gas injection in WAG, and gas-water co-injection which all showed inefficient oil production (fast decline during WAG, Figure 2b). The gas-water co-injection before pilot served for baseline and conformance characterization (Figure 2a). During the foam pilot, a strong foam forming surfactant composition was injected for the first 10 days followed with tapered dosage of a weak foam for another three weeks after which the injection well was reverted to baseline operation. During the total surfactant injection period of a month, the BHP increased from 3100 psi to 3700 psi confirming viscous in-situ foam formation. Within the first 10 days of strong foam generation, gas diversion from the offending pilot well to starving pilot well was confirmed (Figure 2a). In the same period, the liquid production also increased by 70% potentially from elimination of out of zone injection loss identified before the pilot period as well with uniform sweep from the foam (Figure 2a). Before our foam pilot, oil production from the 2 production wells averaged ~25 bpd during WAG with fast decline and ~32 bpd during co-injection. During strong foam formation, the oil production reached 71 bpd while averaging 51 bpd during weak foam formation and finally declining gradually during the chase period. With a very conservative baseline forecast of ~1900 bbl. of oil produced during the 3-month pilot; the foam pilot resulted in > 4000 bbl. oil production, ***doubling the oil produced***.

### Reducing Carbon Emissions

An additional benefit of the ELEVATE™ foam additive technology is sustainability imparted to the EOR process by >50% reduction in water volume needed for gas conformance and increasing gas utilization without impacting the surrounding environment (i.e., re-using produced water and gas for EOR versus flaring, ability to utilize captured $CO_2$, and higher recovery). The discussed field pilot resulted in 53% reduction of ~81 kg $CO_2$ eq./bbl. of oil produced. This, in turn, represented a benefit-to-burden ratio of 21, implying that for every carbon unit emitted in making the foaming agent saved 21 carbon units in making the gas-EOR process more efficient.

**Application in Bakken Shale Play in Huff-n-Puff Mode:** While the discussed unconventional foam EOR pilot was implemented in drive mode, we are extending it to a foam assisted huff-n-puff hydrocarbon gas EOR in Bakken shale play through a DOE funded project with Hess Corporation and University of Wyoming.

**Contact our Dow expert to discuss how we can help you increase gas utilization today.**



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