Cyclic Gas Injection and Continuous Gas Injection into a Low Permeability Depleted Reservoir

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Summary

This study reviews 20 wells in the Belly River formation that have been stimulated by cyclic gas injection/production over the course of 6 months (Huff and Puff). The wells are horizontal multi-fractured wells. The Belly River formation was at very low reservoir pressures (around 300 psi) due to depletion of solution gas drive mechanism. The resultant increase in oil rate was approximately 43 barrels of oil per day (bopd/well) over the three months following return to production – an 89% increase.

Historically, Enhanced Oil Recovery (EOR) schemes have driven production in much of the world. By maintaining pressure, the ultimate recovery factor of a given pool is dramatically increased in relation to its primary-production-only counterpart. Lower permeability assets are inherently more difficult to apply EOR developments for reasons of injectivity and voidage balance issues. However, in-situ cyclic gas injection and production projects (Huff and Puff) has recently shown strong potential in modern unconventional assets. Nonetheless there are also some failures in huff and puff field projects. Current market environment dictates maximizing recovery of existing assets, leading to a potential resurgence of this technique in modern unconventional low permeability ($k_{effective}$ <1md) assets.

Huff and Puff is a single wellbore cyclic gas injection-production EOR scheme. This EOR technique is best suited for lower permeability reservoirs with limited connectivity between injectors and producers. The benefit of this technique is twofold – localized re-pressurization and a decrease in live oil viscosity.

Huff and Puff (H&P) was implemented in a shallow low permeability light oil reservoir. Continuous water injection schemes in past have been unsuccessful due to injectivity and VRR issues. Continuous gas injection schemes have shown success in flattening existing oil rates. Huff & Puff was applied to 20 producing wells in the Brazeau Belly River group on a 30-90 day cycle of gas injected into a previously producing well, before returning the well to production. Some of such wells were allowed a soaking period of inactivity (10-30 days) to allow gas diffusivity before returning to production. Average gas injection rates were between 500 and 1500 Mscf/d. These were followed by a production period of 3 to 6 months.

Of the 20 wells under Huff & Puff, 14 wells have production times of one month or more following gas injection. Of the 14 wells, 9 have three months or more of production. The study focuses in detail on the 9 wells with substantial production, but comments on response seen in all 20.

Affected wells see increased oil production sustained over multiple months. High early gas retention is indicative of increased size of affected drainage area. The higher initial rates paired with sustained production signifies increased EOR efficiency when compared to that obtained

by pure gas flooding. This is backed up by injection falloff tests, as well as production buildup tests during soak periods. Interaction between the fractures and matrix is key to understanding recovery and especially injected gas retention. This interaction is key to other area of interest, such as geothermal, ground water and Carbon Capture and Underground Storage.

Huff and Puff implementation is a qualified success, but later cyclic and possibly gas drive will better quantify the upside potential.

Early into full field integration, but promising initial results were seen on all 20 well conversions. Increased iteration on cycle periodicity, injection volumes, and soak times are key to maximizing incremental production in low permeability reservoirs.

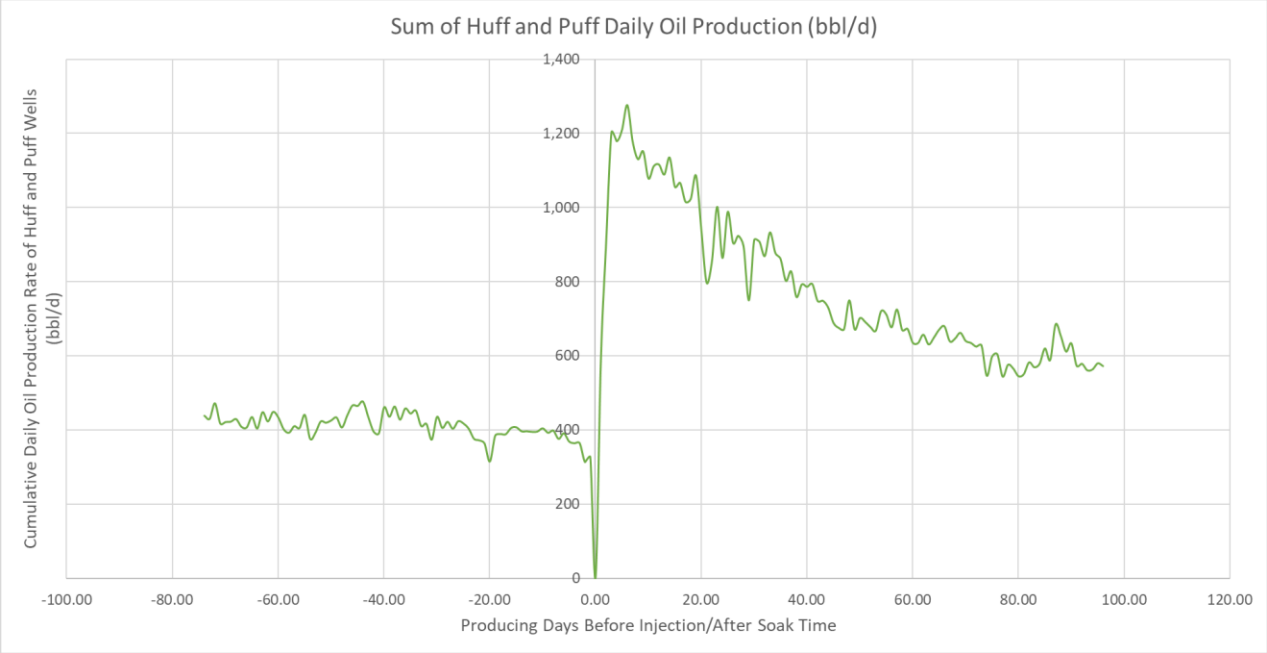

Figure Summed production rate change for the 9 Studied Wells

Novel/Additive Information

Typically, pressure depleted low permeability reservoirs are neglected assets because for secondary recovery waterfloods, the time to repressurize is too long to make it economically worthwhile. Similarly, gas injection flooding can be plagued with early gas breakthrough and difficulty re-pressurization due to high gas production. This Huff and Puff is a single wellbore cyclic gas injection-production EOR scheme, seems to be successful in locally building up pressure and increasing recovery factor.