Enhancing Downhole Gas and Solids Separation and Lowering Operational Risk by Taking Advantage of Multiphase Flow Reversals

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Objectives / Scope

Downhole separation of gas and solids for sucker rod pumping continues to be a significant challenge, particularly in horizontal wells. An advancement in downhole separation has been achieved by realizing there was an opportunity to intentionally take advantage of transient multiphase flow conditions where liquids and solids flow reversals exist. Multiple case studies in this presentation, demonstrate that taking advantage of multiphase flow reversals can enhance downhole separation performance and capacity, while at the same time lower operational risk.

Methods, Procedure, Process

Improving downhole separation without undesirably increasing operational risk and cost has been challenging. A separator design that requires a packer or annular seal, such as a cup, is inherently more operationally risky from an installation and retrieval perspective. Further, a separator design that impose pressure drops and/or increase flow turbulence face the risks of scale deposition, erosion, and reduced separation capacity due to turbulence worsening of the amount of entrained gas in the liquid.

It is generally understood that separation capacity has been physically limited by a separator's cross-sectional area for separation. It is less understood that separation capacity has also been limited by the location and orientation of a separator's intake, and that it has been limited by a common mechanical design practice of a concentric or centralized pump intake dip tube or mandrel.

Technical literature, industry research and transient multiphase flow simulations have revealed, under certain conditions, that multiphase flow reversals are not only present, but also occur at high frequencies. In a wellbore, after the onset of a flow reversal and during the liquids accumulation process, parts of the liquid phase in a multiphase fluid stream move upwards concurrently with the gas, and simultaneously, other parts of the liquid phase move counter-currently downward with the gas. In other words, parts of the liquid flow will frequently reverse direction from upward to downward. Counter-current flow reversal experiments observed that as the gas rate continues to decrease this partially-concurrent/partially-counter-current liquids behavior progresses up until the point where the liquid's hydrostatic pressure gradient becomes zero (hanging liquid film field) and then after that point, the multiphase flow transitions to a fully counter-current liquid flow (i.e., net liquids flow rate is negative) leading to a maximum rate of liquid accumulation downhole.

Industry research has also disclosed that gas-liquid separation in an eccentric annulus is more efficient than in a concentric annulus. In addition, such research disclosed separation efficiency is greater an open top tube versus an annulus. Both of these separation efficiency benefits are due to the changes in the slip between various parts of the eccentric cross-section of the multiphase flow field.

It was hypothesized that such transient, ongoing, partial flow reversals could be taken advantage of and in combination with the separation benefits of eccentric flow paths, downhole separation of gas and solids could be significantly enhanced in conjunction with lowered operational risks. A separator was then designed, built, extensively flow loop tested and successfully field implemented.

Results, Observations, Conclusions

This presentation describes the design process and results of the field implementation of an enhanced downhole separator that intentional uses transient multiphase flow reversals and eccentric flow paths. Flow loop testing results and comprehensive analytical transient multiphase flow simulation will be shared. A set of case studies, in multiple basins, reviews the field installations and presents the results of improved downhole separation performance, lowered operational risks, lowered Opex and increased production.