USING THE EQUILIBRIUM CURVE CONCEPT TO DETERMINE THE MOST EFFICIENT GAS LIFT INJECTION PRESSURE AND RATE

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ABSTRACT

The capability of a gas lift system is heavily dependent upon the available gas lift injection pressure. Gas lifting a well from the deepest point of the formation results in higher drawdown pressure, more production with less lift gas, and less gas lift equipment yielding a more efficient system. However, this cannot always be achieved because of limited injection pressure, limited gas injection rate and/or limitations of the gas lift equipment.

In a gas lift project, what size compressor is needed to deliver the desired production? If a compressor is already in place, how deep can gas be injected, and will it achieve the desired production? To answer these questions, an Equilibrium Curve can be developed.

NODAL analysis and production information are necessary to build an Equilibrium Curve for a well. The outcome of this process is a plot of liquid production rate at various gas injection depths. This will provide the necessary information to size the compression needed to achieve the target liquid production rate and to determine the gas lift mandrel and valve design.

Coupling the equilibrium curve with additional analysis will result in liquid production rates at various gas lift injection rates. Injection rate and pressure can then be used to determine compression horsepower required. The most efficient operation will be the gas injection pressure that yields the lowest compressor horsepower per barrel of liquid produced.

INTRODUCTION

Gas lift is a form of artificial lift that uses gas to decrease the hydrostatic pressure of the fluid column in the wellbore. The lower the hydrostatic pressure, the greater the drawdown. A pressure vs. depth diagram depicts this well (Figure 1). At the depth of gas injection there are two distinct sections in this curve: the first, from the bottom of the well to the depth of gas injection the well is flowing with natural reservoir GLR, and second, from the point of gas injection to the surface the GLR includes the lift gas.

Therefore, the most efficient gas lift injection depth is at the bottom of the production string so that the density of the entire column of fluid is affected by the lift gas. This practice will yield the lowest producing bottomhole pressure. However, there may be reasons gas cannot be injected at the bottom of the production string, including limitations of the compressor pressure and rate and the configuration of the wellbore.

The available gas injection pressure is the most significant factor in determining how deep gas can be injected into a gas lifted well. If the available compressor discharge pressure is too high, investment dollars are wasted, and if it is too low, production performance is lower than expected. There is no need to limit the economic viability of the well because of a design that overlooks this part of the system.

The primary objectives of a gas lift system design are to determine the gas injection depth, rate and pressure to achieve the expected liquid production. These are the key parameters for the design, and once they are determined, all that remain are the mandrel spacing and valve specifications to unload the well.

EQUILIBRIUM CURVE DEVELOPMENT

Shell Oil Co. developed the equilibrium curve concept to determine these design objectives. This was done by using the intercept of the formation fluid gradient with the producing gas lift gradients for different gas lift injection pressures (Figure 2).

The pressure gradient curve is determined using a multiphase flow correlation for a given production rate, GLR, water cut, fluid properties and conduit size. This curve shows the pressure in the production conduit at depth.

Also required is the Inflow Performance Ratio (IPR) curve. This curve is determined from well tests and associated bottomhole flowing pressures. This curve shows the expected liquid production rate for a given producing bottomhole pressure (or a given drawdown pressure).

The intersection of these two curves, for the same production rate, is known as the equilibrium pressure – the pressure is the same at the bottom of the gas lift production string as it is at the top of the point of natural flow. The plot of the equilibrium pressures for a series of production rates is known as the equilibrium curve. This curve defines the basic parameters needed for a gas lift design – the gas injection depth, pressure, and rate to achieve the desired production rate (Figure 3).
The basic process steps to develop an equilibrium curve are:

1. Develop pressure gradient curves for various production rates using a constant GLR.
2. Develop the actual IPR curve for the well.
3. Determine the reservoir drawdown pressure for each production rate used in the pressure gradient curves.
4. Determine the slope of the formation gradient using the formation GLR.
5. Plot the formation gradient line from the drawdown pressure associated with each production rate selected on the pressure vs. depth plot.
6. Mark the intersection of the formation gradient and the production pressure gradient for each production rate selected.
7. Connect these points of intersection.

LIFT GAS REQUIRED

The amount of lift gas required is typically determined by NODAL analysis. The IPR curve for the well represents the well production as a function of the drawdown. The outflow is determined by calculating the pressure traverse using multiphase flow correlations and varying the GLR (Figure 4). Drawing a curve of the intersection (node) versus the GLR results in the curve (Figure 5). As can be seen, there is an optimum GLR to achieve the well performance desired. There is a point of the optimum gas injection rate to achieve the desired well performance. Injecting more gas will result in a decrease in production. This curve can be developed for each production rate shown in the equilibrium curve to generate an optimum gas injection rate for each potential production rate.

HIGH RATE AT LOW PRESSURE OR LOW RATE AT HIGH PRESSURE: COMPRESSOR HORSEPOWER

It is possible, in some instances, to inject a higher volume of low-pressure gas at a shallow depth and get the same production as with injecting a lower volume of high-pressure gas at a deeper depth. This may be an option to consider if the compressor is smaller than what the ideal design calls for, and it could reduce the investment by purchasing a smaller compressor. However, the cost to achieve this should be investigated.

Figure 6 shows the calculated compressor horsepower required to deliver gas to achieve different gas lift production rates for a selected well design (Ref 2 and 3). For example, for this well to produce 3000 BLPD, 158 hp is required if the injection pressure is 800 psi and 1.7 MMCFPD is injected. To produce the same production, only 50 hp is required to inject 0.3 MMCPD at 2000 psi. This further supports that the proposition that injecting lift gas deeper will result in a more efficient gas lift operation.

CONCLUSION

The use of an equilibrium curve can aid in determining the optimum gas lift injection depth, pressure, and rate to achieve the production goals. Gas should usually be injected at the deepest point in the production string. It is at this point that there is an optimum amount of gas to be injected to result in the most efficient gas lift system possible (Ref 3). In addition, it is also at this point that the compressor horsepower will be the lowest and thus the most efficient.

REFERENCES

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3. Bertuzzi, A.F.: Discussion of Determining the Most Profitable Gas Injection Pressure for a Gas Lift Installation, SPE 13539 (Nov 1984).

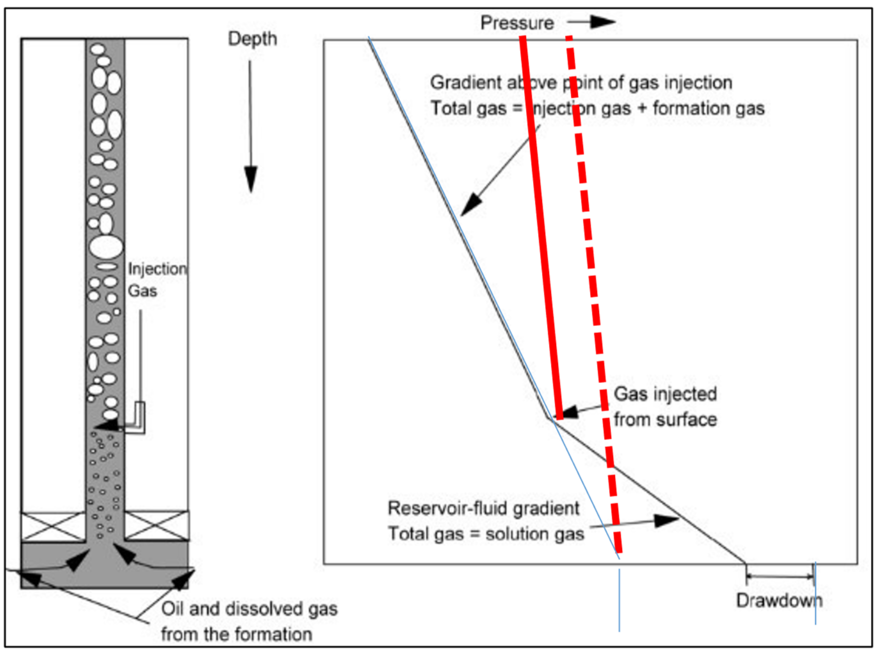

Figure 1: Pressure vs. Depth for Gas Lifted Well

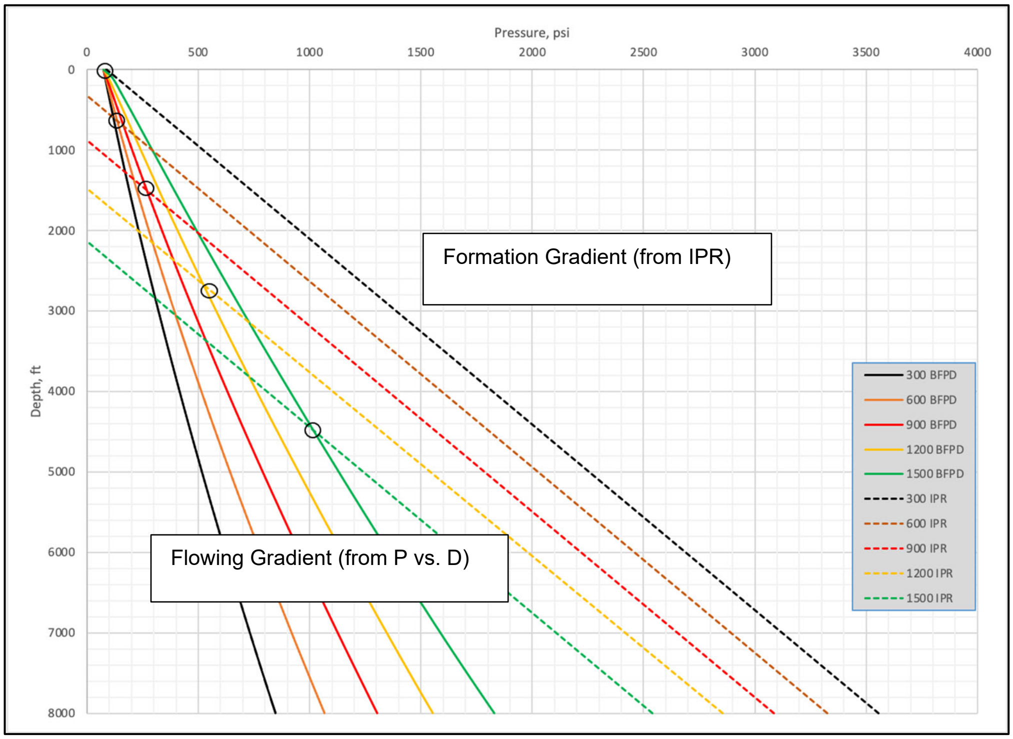

Figure 2: Development of Equilibrium Curve

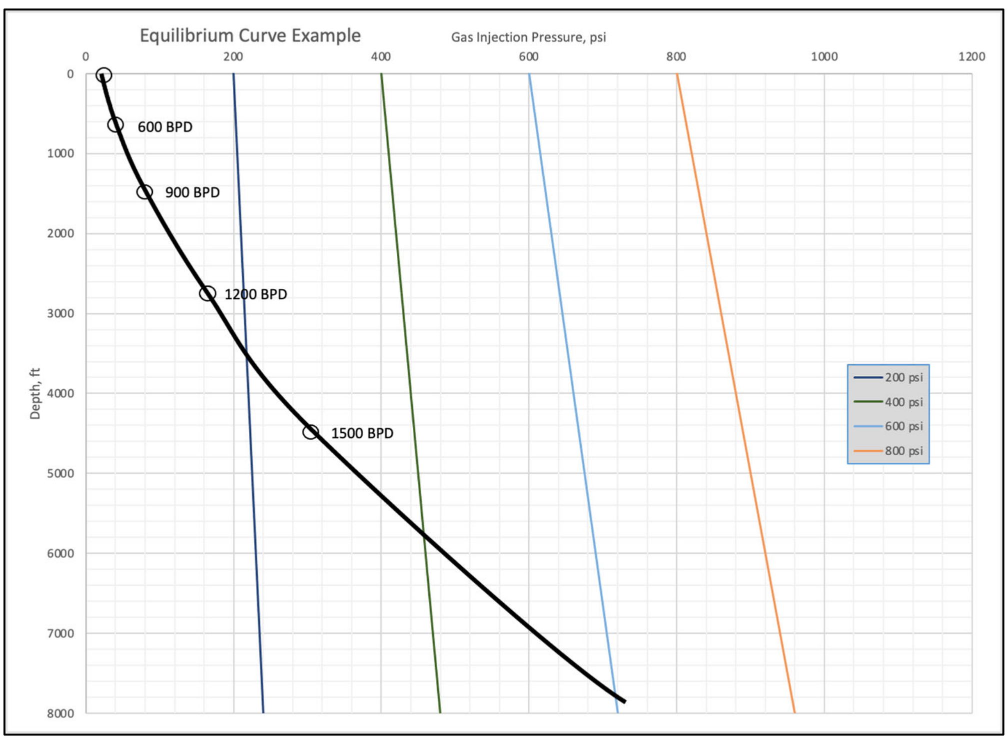

Figure 3: Completed Equilibrium Curve

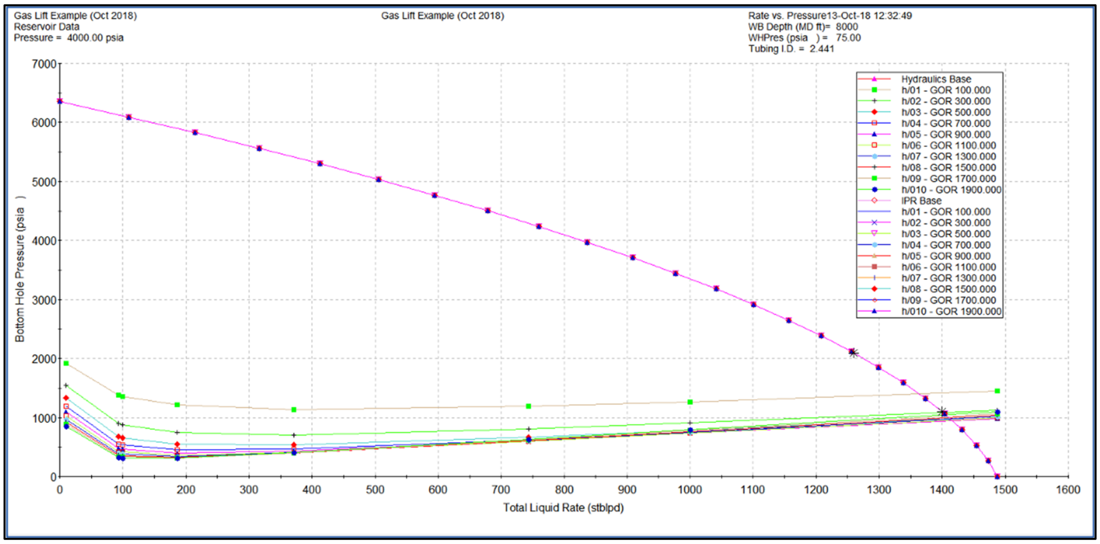

Figure 4: NODAL Analysis to determine optimum GLR

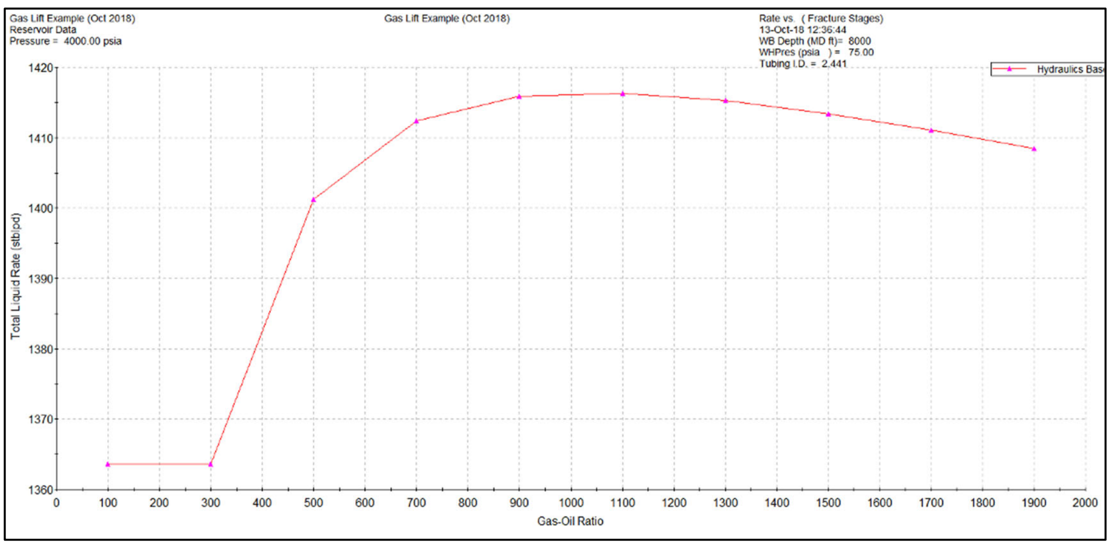

Figure 5: GOR vs. Total Liquid Production to determine optimum gas injection rate

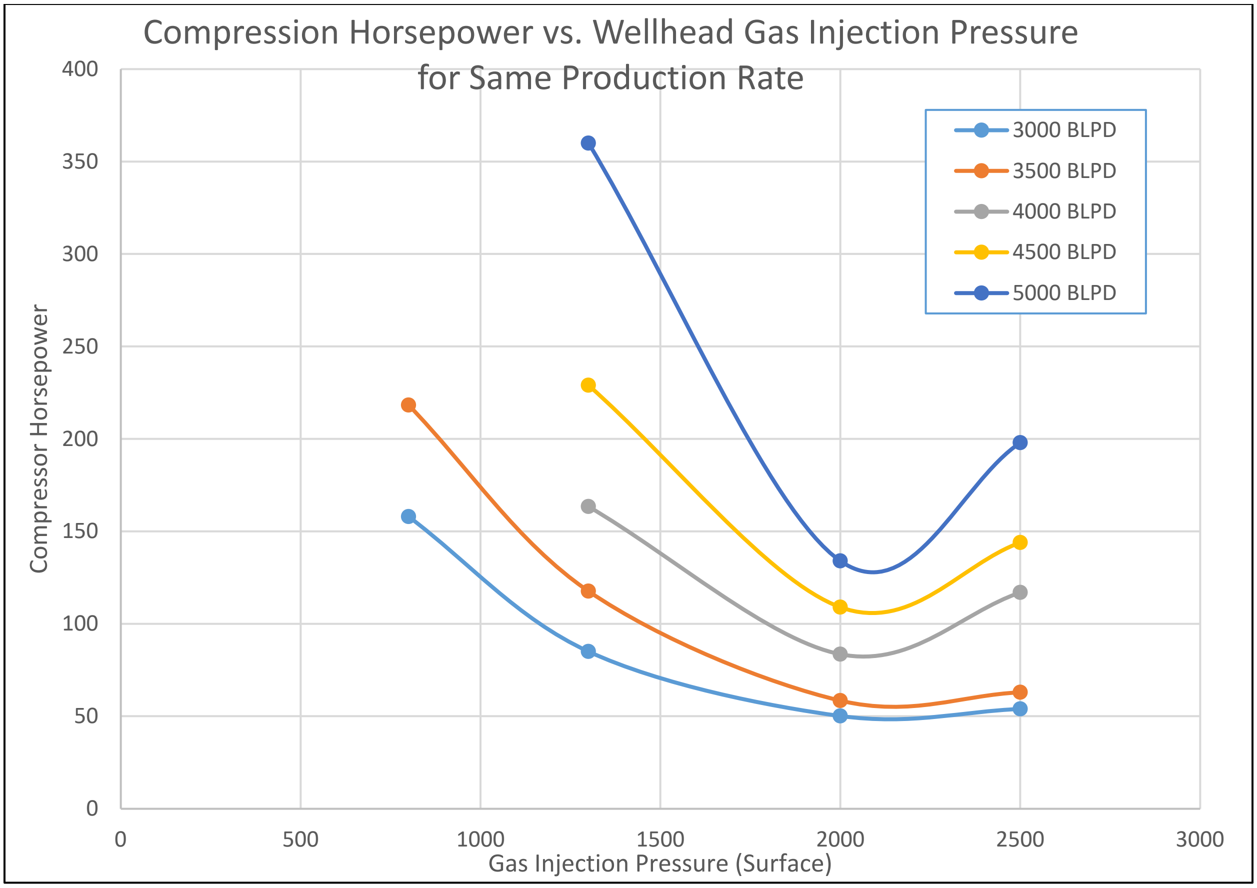

Figure 6: Effect of injection pressure on compressor horsepower requirements (Ref 3)