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Measurement and Calculation of Key Events During the Plunger Lift Cycle

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Abstract

As a normal gas well's production rate declines below a critical limit, produced liquids begin to collect in the tubing or flow passage, and the gas flow is further reduced or stopped by additional liquid pressure on the formation. Many authors describe the time when liquid begins to collect in the well as the gas flow has decreased below the critical flow rate, although perhaps more reliably, the production rate will begin to drop below the original decline curve. Popular lift methods for dealing with liquid loading caused by gas rates below critical are: compression, velocity strings, beam pumps and other pumps, surfactant injection, and plunger lift. Plunger lift is a popular method for dewatering gas wells due to the low initial installation cost and due to low operation cost by using the well's stored energy to dewater the well. Plunger lift is one of the primary artificial lift methods used to overcome liquid loading problems in gas wells.

A few simple rules-of-thumb are frequently used in the initial configuration of the plunger lift installation. These rules-of-thumb have been translated into mathematical algorithms to allow the operator to estimate the rise velocity of the plunger, the liquid slug size per cycle and time period intervals for the plunger cycle. Algorithms are used in this paper to calculate timings for events during the plunger lift cycle, and the times are compared to key events determined from measurements acquired at the well. For example, the minimum shut-in time calculated from one algorithm is compared to the precise time measured for the plunger to fall from the surface to the bottom of the well. Using the measured tubing and casing pressures and plunger location during the cycle along with other well parameters, the operator can verify the plunger lift system is operating as desired. Both measured plunger lift performance data and calculations from the algorithms guide the operator to effectively analyze, adjust and optimize the plunger lift installation. Acquired data from various plunger lifted wells are used to validate the algorithms presented.

Information presented in this paper will assist the operator of gas wells who is suffering from gas flow rates below critical and is using plunger lift to alleviate the corresponding liquid loading problem.

Introduction

As a gas well's production rate declines below a minimum value, liquid loading begins and produced liquids begin to collect in the tubing or flow passage, and the gas flow is further reduced or stopped by additional pressure on the formation. Liquid loading in gas wells means that the wells are producing at a low velocity (and corresponding low rate), and the liquid droplets in the gas flow are no longer being entrained with the gas or being lifted by the gas drag being exerted on the droplets. The pressures from the accumulated liquids restrict reservoir inflow and may even kill the well to the point of no gas production.

Lowering the surface tubing pressure with compression helps keep liquids in the gas as vapor, increases the velocity and lowers the bottom flowing pressure of the well. Compression may be applied at an individual well or for many gas wells flowing into a large collection system having low pressure maintained by compression.

To remove liquids from the well, the gas must have enough velocity to lift droplets with the drag of the gas flowing against the profile of the droplets. Large diameter tubing results in gas flows no longer carrying liquid droplets to the surface; so reducing the diameter of the tubing is a lift method to increase the gas velocity and kift liquids. If the increased velocity is above the critical rate, then liquids are lifted to the surface. If the tubing is too small in diameter, then friction and not liquid loading will reduce formation inflow.

Beam pumps and other pumping methods, although effective are often a last resort due to initial investment and the continual energy consumption costs. The usual method when pumping is to produce the liquids up the tubing and allow gas flow up the casing. The pumps may experience inefficiency due to gas interference unless the pump intake can be placed below the perforations or some gas separation method is found to be effective.

Surfactants can be used if the liquids in the tubing will foam. The surface tension between the gas/liquids will be reduced and the effective liquid density will be reduced. Surfactants decreases the critical gas flow rate required to lift the liquids and may allow the well to flow at a much lower gas rate. Surfactants are usually introduced to the well by dropping soap sticks down the tubing, dumping chemicals