Multistage Plunger-Lift Systems Can Provide Economical Alternative to Pumping Units

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Plunger lift is a simple and economical artificial-lift (AL) system for wells that primarily produce gas. It is a widespread method of deliquefying wells with high gas-to-liquid ratios (GLRs), for lifting production from wells in which natural depletion has reduced flow rates below critical levels, or for producing from wells with high accumulations of solids, such as sand, salt, coal fines, paraffin, and scale.

However, for some wells, plunger lift by itself may not add enough energy to the wellbore to produce gas in economic volumes. Deep gas and low-GLR wells, with ratios ≤1:1, may have lift requirements exceeding the capabilities of conventional plunger AL systems. Gassy oil wells often fall into the latter category. Frequently, pump jacks are installed on wells where conventional plunger lift is considered inadequate. Foaming methods to reduce the density of flowstream liquids may also be employed, but these are typically most effective in wells producing primarily water. A more effective strategy for increasing production from gassy oil wells and other wells where conventional plunger lift may be insufficient can be to install a multistage plunger-lift system.

In these systems, a downhole tool is used to create multiple plunger-lift systems in one well. This multistage tool allows the liquid load to be lifted in sequences, a process that uses the well's own energy to remove even large accumulations of liquids, or heavy liquids, efficiently.

Multistage Plunger-Lift Tool

The multistage tool **(Fig. 1)** is placed by wireline roughly 40–70% of the way down the tubing above an installed plunger-lift system, typically composed of a bottomhole bumper spring and a plunger above it. Then a second plunger is set on top of the tool.

The system is operated like a conventional plunger-lift system. During the first sales cycle, the lower plunger carries fluids up the tubing and delivers them to the tool. They flow through the tool and are held above it by gas flow. Upon shut-in, the ball check in the tool engages, retaining the fluids until the upper plunger falls from the surface, settles through the liquids and lands at the tool. Simultaneously, the lower plunger falls back to the bottom.

During the next sales cycle, the upper plunger delivers its fluids to the surface, while the lower plunger delivers more fluids to the tool. Both plungers work in tandem in subsequent cycles. In this way, the multistage tool acts like an intermediary standing valve. This process lifts smaller and more frequent liquid loads in stages, allowing the well to more efficiently use its own energy to remove liquids and increase productivity.

The "nodding donkeys" visible at many wellsites demonstrate the popularity of using pump jacks as an AL method. Pump jacks (also known as sucker-rod pumps or beam-pumping units) are typically powered by fossil fuels or an electric motor. They require a significant up-front investment in equipment and installation, and maintenance costs can be considerable.

The cost of installing a plunger-lift system with the multistage tool is usually about 10% of the amount required for a pump-jack installation. A multistage plunger-lift system is entirely mechanical, operating only on the well's energy, and has no power or fuel requirement. Thus, operation and maintenance costs are quite low by comparison. Operational issues in general are few for multistage plunger-lift systems, and conversion of conventional plunger AL to multistage capability is relatively simple. For marginal wells, especially, incorporating multi-

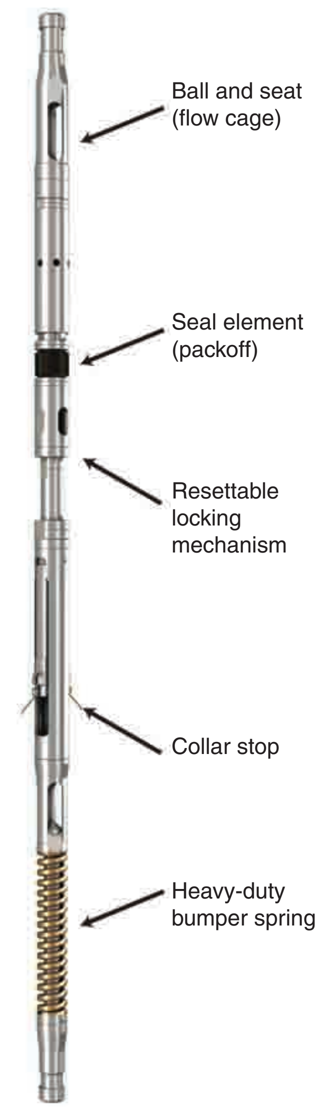

Fig. 1—Multistage tool in its open position, with primary components labeled.

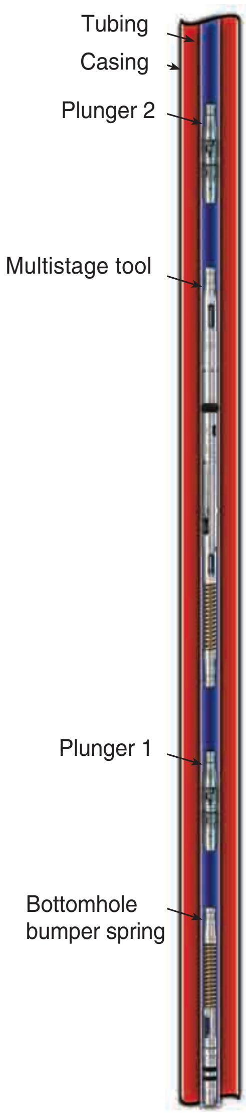

Fig. 2—Diagram of well casing and tubing shows multistage tool positioned between two plungers within a plunger-lift system.

stage plunger lift may prove crucial to maintaining economic production.

Case Studies: Multistage Plunger Lift

Multistage plunger lift is being used successfully in wells in the Denver-Julesburg basin and central Alberta, Canada, as well as other regions of North America. Following are two case studies.

Well A. This well was frequently loading up and no longer able to lift fluids on its own. Initially, a plunger-lift system was installed, with the bottomhole bumper spring set at 8,169 ft. The plunger cycled, but because of the large amount of liquid, long shut-in times were required. By the time the plunger was able to run, the tubing pressure was >800 psi, which overloaded the separator. When it would cycle, the well was able to produce roughly 17 Mcf/D of gas and 12.6 B/D of oil. A pump-jack installation was considered, but the cost was prohibitive because of the marginal production.

The multistage tool was installed to work in conjunction with the existing plunger-lift system at a cost of approximately USD 3,000 for the multistage tool and the addition of a second plunger. The tool was set at 4,872 ft, with a dual-pad flow-through (bypass) plunger below the tool and a padded plunger above it. The tubing pressure was 1,460 psi, and the casing pressure was 1,510 psi. (An example of a multistage tool set between two plungers in a plunger-lift system is shown in **Fig. 2.**)

After a couple of cycles, the pressures decreased enough so that the separator was able to function and constant production was achieved. The cycle times were fine-tuned, and the well was able to produce 106 Mcf/D of gas and 37.7 B/D of oil. After 1 month, production leveled out and remained at 124 Mcf/D of gas and 12.6 B/D of oil **(Table 1).**

TABLE 1—WELL A PRODUCTION DATA BEFORE AND AFTER APPLICATION OF MULTISTAGE PLUNGER-LIFT TOOL

	Gas Production (Mcf/D)	Oil Production (B/D)
Before Stage Tool	17	12.6
After Stage Tool	124	12.6

Well B. This well suffered from similar production issues. Additionally, the well was producing significant frac sand and wax. The bumper spring was set at approximately 8,136 ft. Because of the amounts of fluid, wax, and sand that the well was producing, the plunger would not cycle consistently, and the well was shut in a majority of the time. Pump-jack installation and chemical injections were being explored as potential methods to stabilize and maximize production.

Instead, a multistage tool was installed to work with the existing plunger-lift system. The tool was placed at approximately 5,085 ft, with a solid flow-through (bypass) plunger below it and a solid ring sand plunger above it. Before the multistage tool was set, the well's tubing pressure was at 250 psi, and the casing pressure was at 1,200 psi. During the first few cycles, the sand production was challenging. As the casing pressure came down, the well produced more and more sand, causing the bottom plunger to stop cycling and the top plunger to wax off.

After simply pulling the multistage tool by wireline and cleaning the tubing, the sand production decreased. The plungers were able to cycle regularly, keeping the tubing clean and prohibiting wax buildup. The initial production was extremely high for a typical plunger-lift system at 70 Mcf/D of gas and 37.7 B/D of oil. Well production then slowed to its current rate of 42 Mcf/D of gas and 8.8 B/D of oil **(Table 2).**

Conclusion

Multistage plunger lift, as shown by field case studies, is a reliable AL method to increase production significantly from wells with lift requirements exceeding the capabilities of conventional plunger-lift systems. Low-GLR, gassy oil, and deep gas wells, in particular, are wells that can benefit from incorporating this easy-to-operate AL technology. Low installation and maintenance costs, compared with pump-jack systems, and low operating costs, relative to pump jacks and foaming methods, can result in substantially improved production economics. This can have an especially important impact on marginal wells. **JPT**

TABLE 2—WELL B PRESSURE AND PRODUCTION DATA BEFORE AND AFTER APPLICATION OF MULTISTAGE PLUNGER-LIFT TOOL

	Tubing Pressure (psi)	Casing Pressure (psi)	Gas Production (Mcf/D)	Oil Production (B/D)
Before Stage Tool	250	1,200	0	0
After Stage Tool	800	1,450	42	8.8