EVOLUTION OF BALL-DROP COMPLETIONS IN THE PERMIAN BASIN

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ABSTRACT

Traditionally, ball-drop completion systems were limited by application, pressure, rates, and stage count. This paper describes the history of the ball-drop completion systems in the Permian Basin and how the development of new technology has allowed ball-drop systems to be used in more applications than just open hole, as well as how this technology has overcome the aforementioned limitations.

INTRODUCTION

Ball-drop (BD) completion technology has been used as a primary completion method in the oil and gas industry for more than 15 years. Ever since BD completion technology was introduced as a primary option for completing a well, the industry has been developing BD technology (Seale et al, 2006). The continual progress has allowed the technology to advance far beyond what was possible a decade ago, and even a few years ago.

This paper discusses the history of the BD completion systems, the limitations faced in the past including application, pressure, and stage count. There will be discussion into how technology has developed to extend to applications beyond straightforward open hole (OH) completions.

As horizontal drilling began to take precedence in tighter formations, completion technology was limited, using the same strategies as for vertical wells. The BD completion system development first began circa 2000 and was limited in stage count and application (Seale et al, 2006). Despite these limitations, the cost savings in completion time were worth the risks.

HISTORIC LIMITATIONS

The first major limitation in the early stages of the of the BD completion technologies was its application. Because the vast majority of vertical wells are cased and cemented, the completion design required the wells to be OH, limiting the BD systems to horizontally drilled wells.

Another reason the use of BD systems has been limited in vertical applications is because the pay zones being targeted were typically not thick enough to stimulate using the OH style system.

The second major limitation was the maximum pressure the systems could withstand. Maximum pressure is closely related to stage count limitations, because the limiting factor for both of these is the ball. Balls were initially unable to withstand higher pressures. As ball sizes increase in a BD system, a larger cross-sectional area of pressure on the ball equates to a smaller cross-sectional area for the ball to remain in contact with its respective seat. This means the higher the stage count and the larger the ball, the less differential pressure the ball can withstand. For example, in a 4 ½", 11.6 lb/ft liner, the stage count was limited because the balls being used were ¼" larger than the seat. This amounted to a maximum of 8 ball/seat combinations in a 4 ½" liner in 2006 (Seale et al, 2006).

BALL DEVELOPMENTS AND ADVANCEMENTS

As technology has progressed, so have the capabilities of BD completion systems. This is largely due to the enhancements made to the ball itself. Originally, balls were phenolic. Phenolic balls have a low specific gravity which allow them to flow back to surface more easily, but operators encountered limitations with strength and durability of the material. In response to this, composite balls were engineered to withstand higher pressure differentials.

The development of composite balls allowed BD systems to increase in stage count because the balls could withstand greater pressures on ⅛" increments instead of the previous ¼" increments. Further enhancements allowed for the composite balls to be used on 1/16" increments.

This ability to increase the number of stages was accompanied by unexpected consequences. Because some types of composite balls had a higher specific gravity, they were difficult to flow back to surface after stimulation. On the other hand, due to their composition, the composite balls were easier to mill out.

Another liability of composite balls is their strong and weak orientations. These balls are comprised of many thin laminations, meaning the differential pressure integrity that the ball can withstand varies depending on the orientation. A composite ball that lands on a seat in the weakest orientation may be unable to withstand the differential pressure, resulting in delamination or deformation. If a ball gets stuck on the seat, it will inhibit flowback (Baihly et al, 2012).

For high differential pressures, a metallic ball is better suited for a BD completion. Metallic balls across the industry consist of multiple different alloys and are able to withstand high differential pressures (some exceeding 13,000 psi) on a minimal seat overlap (Baihly et al, 2012). These high differentials allow the operator to design a high pressure, high rate treatment. Metallic balls can be designed to be easily milled, or they can be designed to easily flow back. In the latter case, balls designed with low specific gravity allow operators to immediately flow the well back without millout (Packers Plus, SF-11 Case Study).

Degradable balls have been the most recent breakthrough in BD system technology. This type of ball has since allowed operators to bypass the milling operation and decrease costs and risks at the same time. By using a metallic degradable ball, operators are able to get the high differential rating they need to pump at higher pressures and higher rates while having the integrity of a metal ball. A degradable metallic ball is far less likely to experience the same deformation as the composite balls, and with its durability and ability to degrade over time, it does not become lodged in the seat. This type of ball is so far the most versatile and can be used for many applications.

BALL DROP APPLICATIONS

As previously discussed, applications for BD completions has been mostly limited to horizontal OH completions. However, there have been reported successes in other applications such as:

- Vertical wells
- Cemented ball-drop and hybrid systems
- Refrac and recompletion technology

Vertical Wells

As mentioned previously, BD systems are not typically used in vertical applications. One of the reasons for this is that it is difficult to find a formation thick enough to justify a multi-stage completion in a vertical well. In addition, many formations that are currently being drilled and completed are horizontal; as a result, few completions use BD systems. However, given the right application, BD systems have proven to be as or more successful in certain vertical applications.

In the Permian Basin, the Wolfcamp and Bone Spring formations together are 1500 ft thick in certain areas. This combination of the two formations allowed for a study to be done comparing a BD completion system to a plug-and-perf system in 2013 (Keener et al, 2013). This study directly compared the different completion types by location and stimulation schedule, amongst other variables.

Before the stimulation procedure was optimized for the BD system, the production increases were 9% and 1% for 30 days and 90 days, respectively.

After the stimulation was optimized for the BD system, the production increases were significant.

- 30 days after the completion, the BD systems were outperforming nearby plug-and-perf wells by 64%
- 90 days post-completion, the BD systems were out performing nearby plug-and-perf wells by 88%

Furthermore, there was an estimated 20% reduction in costs, mainly from saved time (Keener et al, 2013).

Cemented Ball-Drop and Hybrid Systems

A hybrid system is a combination of BD and plug-and-perf technologies. In most cases, this is to increase the stage density of an extended reach lateral. By combining the two technologies, operators can maximize number of stages while saving time and money during completion and milling operations.

When replacing toe stages with BD style completions, the average completion time can be reduced by 30% or more. For example, in the Eagle Ford, a cemented BD application was applied to increase the lateral length from 4,750 ft to 6,000 ft. This increased the stage count by up to 6 stages per well while reducing the average completion time from 5 days to 3.5 days (Ferguson et al, 2012).

Another example of using a hybrid system was in the Niobrara formation in Colorado. The operator completed lateral wells with an average length of 4,238 ft and an average of 20 stages. By using a hybrid system, the operator completed a 50 stage well in two days (Packers Plus, 50 Stage Case Study).

In the Mississippi formation, an operator was able to pump at a rate of 100 bpm while treating the toe stages of a hybrid system using a BD system. The system allows a single ball to open multiple sleeves. This mimics the completion methodology of plug-and-perf in the sense that the number of entry points is limited and multiple sleeves can be used for each stage.

This well was recently completed, and production data was not available at the time of this paper.

Refrac and Recompletion Technology

With the amount of oil being left behind in reservoirs, the ability to recover residual oil is a challenge. Secondary and tertiary recovery methods help produce this oil from the reservoir, but most of these recovery methods are in older, vertical wells. Horizontal wells create more concerns when considering them for recompletion.

One solution to recompleting producing wells is a BD system. These systems will usually include hydraulically actuated packers to isolate the existing perforations. This type of system can also be employed in a vertical well. Inside 5 ½” liner, a 3 ½” system can be used which is capable of 32 stages, while inside a 4 ½” liner a 2 7/8” system can be used and has the ability to recomplete 16 stages (Packers Plus, 11 Stage Slimhole Case Study).

In 2008, a well was completed in the Cotton Valley Lime that had an initial monthly volume of 7,493 BOE. Less than 3 years after its initial completion, production was down to 66 BOE. The operator used a 5 stage slimhole system to recomplete the well. For the next 5 months following the recompletion, the average production from the well was 2,685 BOE (Figure 1). This amounted to a 150% increase in production compared to the average production period 5 months prior to restimulation (Packers Plus, 5 Stage Slimhole Case Study).

This same technology can be easily applied to vertical applications, as was the case in the San Juan Basin. The well in question was originally completed in the 1990s. A sharp decline in production led to a recompletion in 2013. Prior to recompleting the well, the 5 month average production was 26 BOE. After the recompletion, the 5 month average production was 2,095 BOE (Figure 2). The BD system used to restimulate the well was designed to be retrievable to allow the operator full ID post-frac (Packers Plus, 3 Stage Slimhole Case Study).

CONCLUSION

With the advancements made in the past decade, the capability of the industry to develop new technology and procedures has been unprecedented. Ball-drop systems continue to advance, beginning from an idea to a reliable completion technology in just over a decade.

The needs of the industry have shaped the development of BD systems and will continue to do so in the future. From a phenolic ball with limited applications to the ability to track downhole temperature and pressure, BD technology has improved significantly since the first systems were developed (Smartball, Open Field Technology).

Along with the continuing efforts to perfect cemented ball-drop technology, the development of a fully retrievable, multi-stage recompletion system capable of withstanding high pressures and rates for horizontals is on the horizon. Ball-drop completion systems are currently not the preferred completion methodology used in the Permian Basin. However, there are numerous applications where it has proven to be as or more effective than plug-and-perf technology and results are expected to improve as the technology continues to develop.

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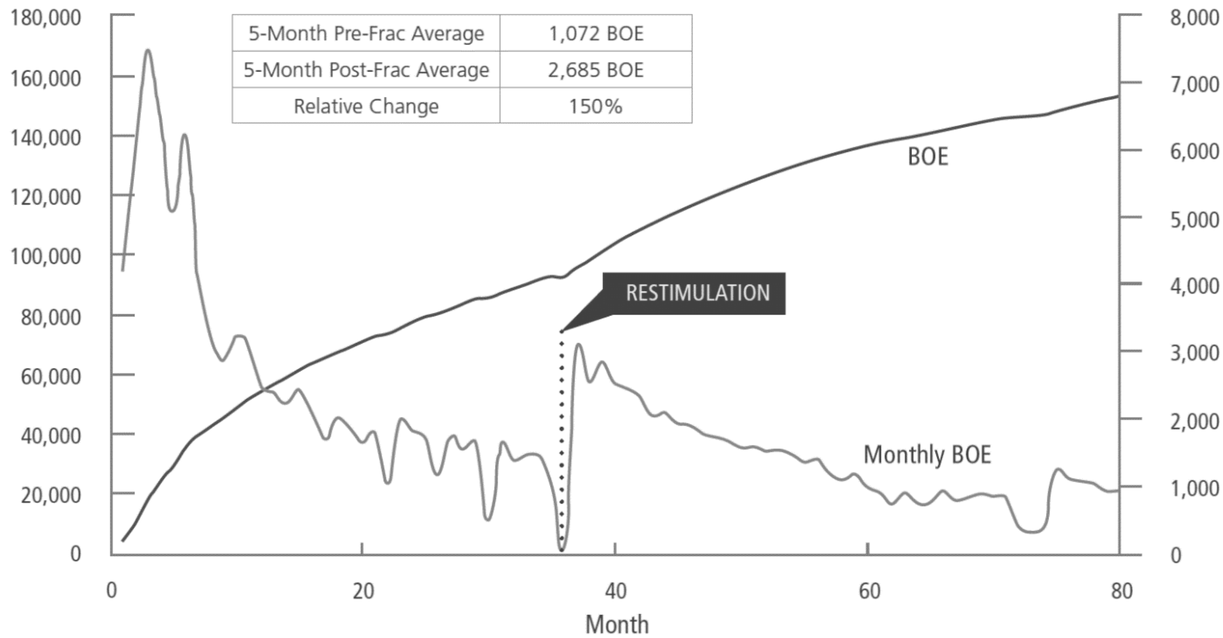

Figure 1: Restimulation Results for Cotton Valley Lime Well

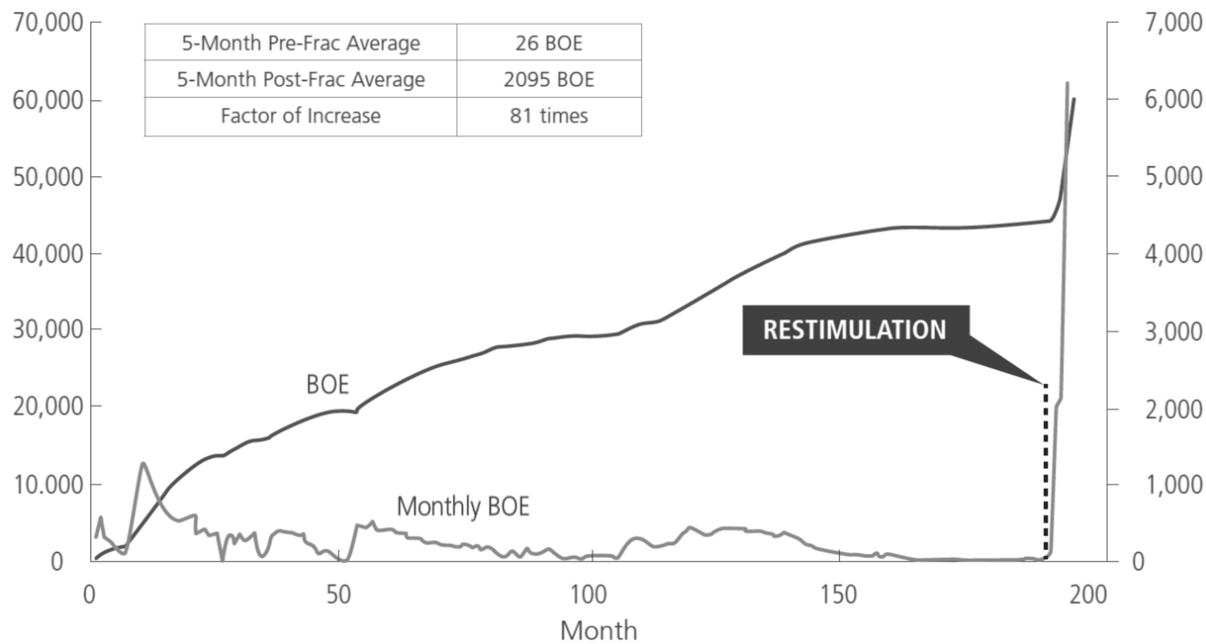

Figure 2: Restimulation Results for San Juan Basin Well