Reliability of Thru-Tubing Frac-Pack Completions

Thru-Tubing Frac Pack (TTFP) completions are a reliable and economically viable alternative to Major Rig Workover (MRWO) completions. Our data show that reserves have been successfully depleted using TTFP completions.

When compared to MRWO options, TTFP methods enable tremendous time and cost savings without sacrificing reliability. Through years of experience, the team has conducted several methods of Thru-Tubing Gravel Pack (TTGP) completions; yet, the TTFP has proven to be the most reliable thru-tubing method of sand control. A database was created compiling information on all TTGP completions in the western Gulf of Mexico dating back to 1997. It contains information on 96 TTGP completions across 15 fields and encompasses numerous parameters of each completion, allowing the team to examine the reliability of this work. A few of the analyzed parameters were the deviation at perforations, casing size, tubing size, screen type, screen placement, and perforation interval. The results of the study show that:

- TTFP completions are less expensive, quicker, and are as reliable as MRWO completions at depleting reserves.
- TTFP completions are the optimum choice for reservoir deliverability over other TTGP options.
- Wells have three to four times better recovery when wellbore deviation at the perforation interval is less than 30°.
- Higher reserve recovery was shown in larger casing (7⅝ in. or greater).
- The use of a packer gives an advantage in lifespan and reserves recovery of the well when compared to vent screen completions.
- TTFP completions have an overall 86% mechanical success rate.

Gravel pack assemblies are deployed by coiled tubing or electric line. With the many unconsolidated sand reservoirs in the region, a reliable, non-rig method of sand control was sought for well completions. The rising cost of rig operations led teams to begin conducting these jobs through tubing. The result was increasingly more reliable completions at a fraction of the rig workover cost. **Figure 1** shows the trend of using TTFP completions as the thru-tubing sand control method of choice for the region.

Thru-Tubing Frac-Pack Procedure

A TTFP is performed through the existing tree, tubing, and downhole hardware. The following is a simplified installation procedure:

- A conventional Thru-Tubing Plug Back is performed to isolate lower depleted zones—a Thru-Tubing Bridge Plug (TTBP) is set, cement is dumped on top, and the new zone is perforated.
- The screen assembly is deployed using either electric line or coiled tubing. A cap on the top of the vent screen prevents sand from entering the inside of the screen assembly as the gravel pack slurry is pumped from the surface. Bow spring centralizers ensure even packing of the sand and blank pipe allows for proper spacing. See **Figure 2**.
- After pumping, excessive sand is washed from the wellbore with coiled tubing to expose the vent screen at the top of the assembly.
- In cases where space is an issue, a cement cap is needed to ensure that the gravel pack sand is not washed away by production flow.

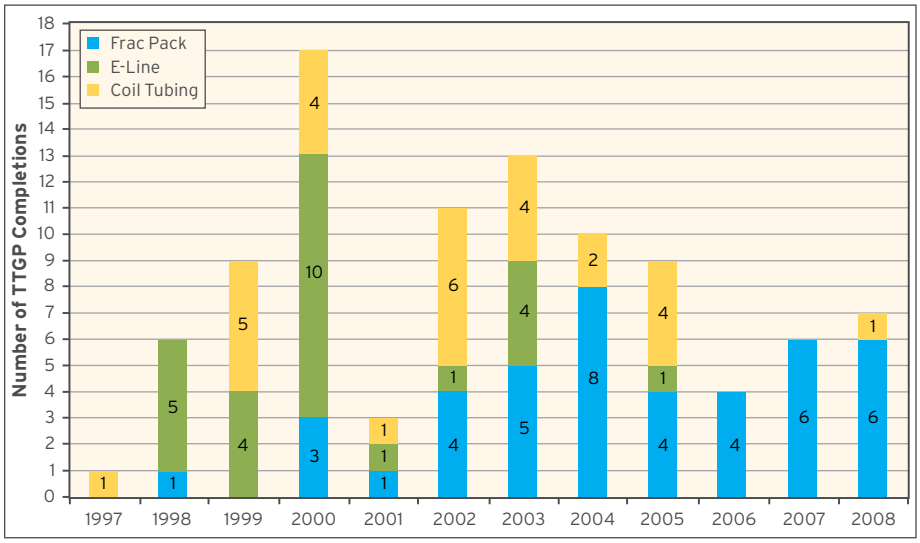

Figure 1 – Various Thru-Tubing Gravel Pack completions per year in the western Gulf of Mexico

- The production then flows through the gravel and screen, through the blank pipe, out of the vent screen, and into the tubing. This screen placement method is referred to as a "Vent Screen" or "Non-packer" type of TTFP. See **Figure 3**, left illustration.

If the sand screen assembly is near the base of the production tubing, the top vent cap is removed and a packer is set inside of the tubing to provide isolation from fluid flow through unwanted areas. This method is referred to as a "packer" type of TTFP. See Figure 3 center illustration. If the productive sand is above the production packer, a cement packer is required for annular isolation. Once this is accomplished, a packer type TTFP can be executed inside the tubing as mentioned above. This method is referred to as a "cement packer" type of TTFP. See Figure 3 right illustration.

By forcing the fracture fluid and proppant into the reservoir, TTFP completions reduce wellbore skin and allow further permeable pathways for fluid flow. In general, TTFP completions at a cost of US $1.1 million dollars are a viable alternative to offshore MRWO completions at a cost of between US $3 million to US $5 million. The larger flow areas of MRWO completions allow for higher production rates, but data has shown that TTFP completions can still produce all available reserves for a much lower upfront cost. Specific case analysis is needed to see if production rate restrictions of a TTFP completion are an economic issue or not.

TTFP completions require good tubing integrity in order to withstand the high pumping pressures of the process. Wellbore geometry also plays a role—longer blank lengths are needed in wells with a higher deviation at the perforation interval. Platform space is a possible limitation for TTFP completions and must be evaluated when selecting a candidate well. Pending water depth, lift boat support for equipment is an option.

Deliverability/Efficiency Tool

A rule of thumb for the Gulf of Mexico is that higher resistivity values generally translate into greater permeability values. A metric was assigned to each completion using the resistivity value (ohm) multiplied by the net thickness of the sand (feet) and was coined "reservoir deliverability" to denote the potential amount of fluid flow that the reservoir would be capable of. In theory, the higher the reservoir deliverability value, the higher the maximum flow rate was expected to be. See **Figure 4**. In practice, operational decisions may also affect maximum flow rates. Digging further into the data and the engineers' notes concerning these outlying completions, it was found that the underperforming outliers circled below the trend line were either due to tight sands or operational problems during the TTFP job. The outliers circled above the trend line had excellent rock properties and showed high water rates toward the end of their lifespan, indicating that the gravel packs were reliable and allowed the production of reserves until the well watered out. The four wells highlighted by arrows are mechanical failures during the TTFP job process and did not produce fluids.

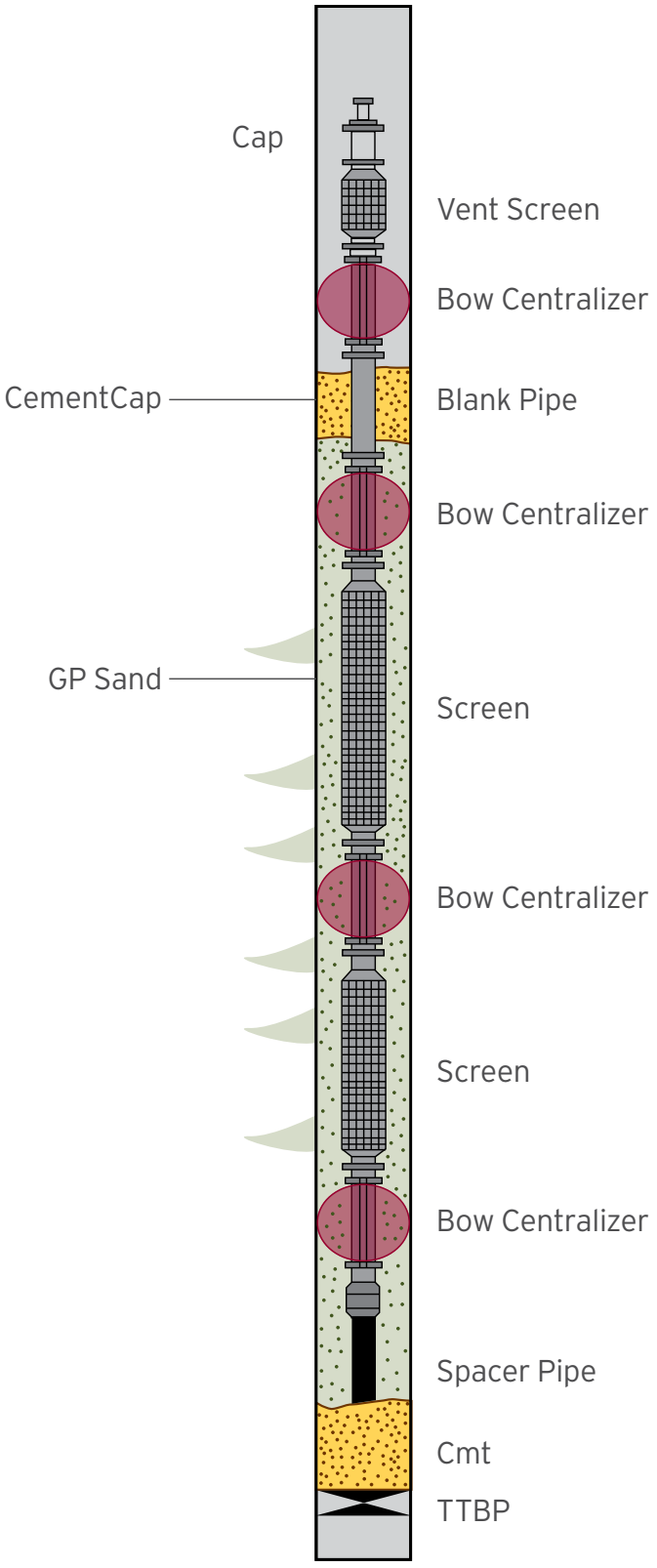

Figure 2 – Typical Thru-Tubing Gravel Pack assembly

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Findings from the Study

The study primarily analyzed the effects of wellbore deviation at the perforations, casing size, screen placement (packer or no packer), tubing size, perforation interval, and fluid production rates on the reliability of TTFP completions. Here are the findings:

- Average reservoir production is higher in wells with a wellbore deviation of less than 30° at the perforated interval. The data show 14 TTFP completions with a wellbore deviation less than 30° at the perforation interval had an average life of 23.5 months and produced an average of 175 thousand barrels of oil equivalent gas (MBOEG). In 23 frac-packed wells with a wellbore deviation greater than 30° at the perforation interval, the completion life averaged five months and produced an average of less than 52 MBOEG. It was also noted that four of the top six producing wells had a wellbore deviation less than 30° at the perforation interval. In addition, shorter perforation intervals are desired in higher angle wells.
- Average reservoir production is higher in wells with a larger casing size. The data show that 12 TTFP completions with a casing size of 7⅝ in. or larger had an average lifespan of 20 months and produced an average of 140 MBOEG. In seven TTFP completions with 3½- to 5-in. casing, the average lifespan was seven months and the average production was 90 MBOEG. In addition, 18 TTFP completions with 5½- to 7-in. casing had an average lifespan of five months and produced an average of 47 MBOEG.
- The addition of a packer to the completion assembly shows greater TTFP reliability. Nine TTFP jobs included packers and showed an average lifespan of 40 months producing an average of 324 MBOEG. The other 28 TTFP completions did not include a packer in the design and produced for an average of eight months and 64 MBOEG. The team is confident in the reliability of the recent TTFP jobs, which include packers. The team feels that the use of a packer gives a definite advantage in the life and reserve recovery of the well when compared to vent screen completions.
- TTFP completions with a cement packer are showing to be successful. Four cement packer type TTFP completions were performed and the data show that to this date, these completions are holding strong and production rates are as expected. All of these have a thru-tubing packer set on top of the screen assembly.
- A number of the TTFP completions were proven to withstand high water and oil flow rates. It was noted that while the majority of the

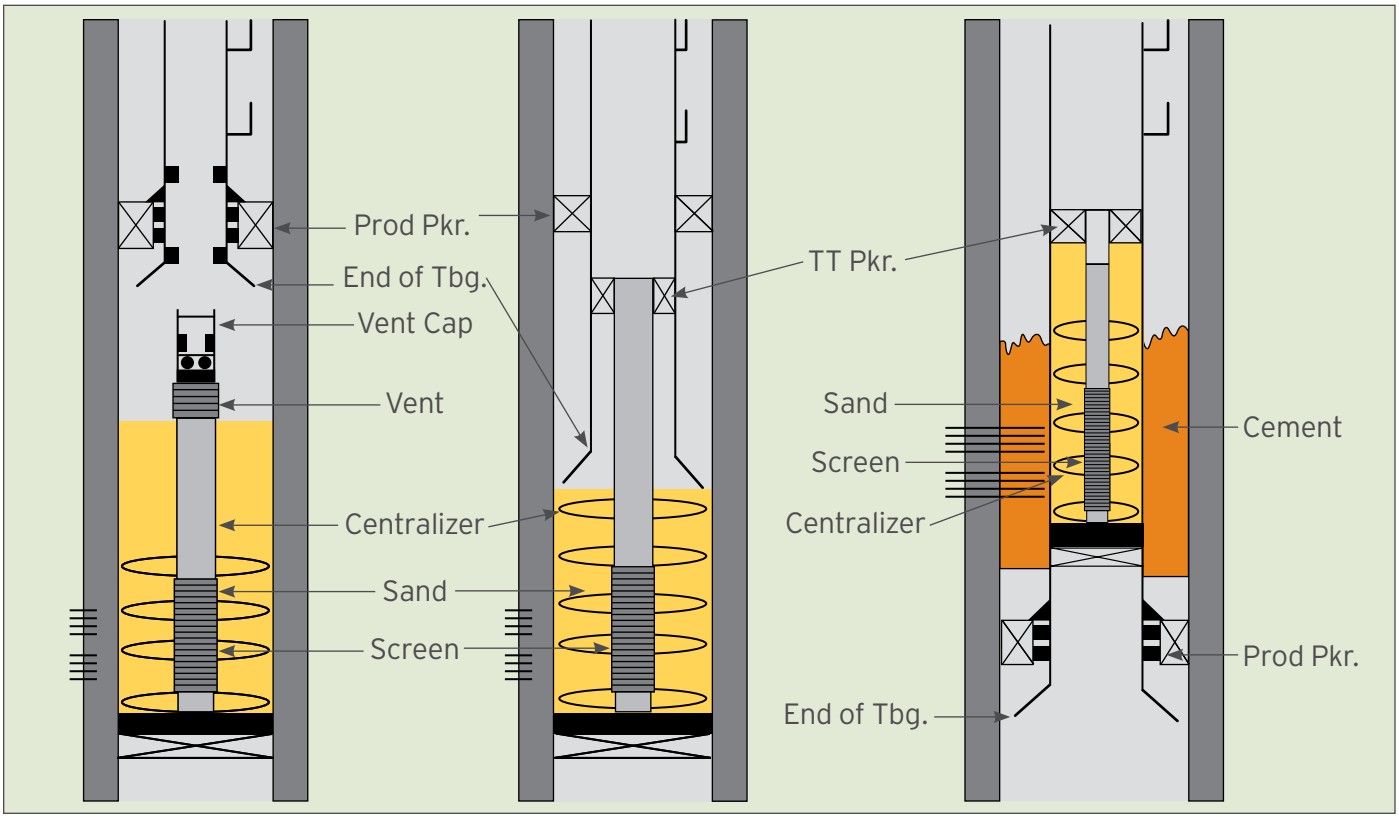

Figure 3 – (Left) "Vent Screen," or "Non-packer" TTFP assembly, (center) "Packer" TTFP assembly, (right) "Cement Packer" TTFP assembly

TTFP completions were designed and expected to deliver up to 400 B/D maximum flow rates, three completions produced at significantly higher rates. On these three wells, the maximum flow rates were a result of water production near the end of the well's life.

- TTFP have an overall 86% mechanical success ratio. TTFP completions have been successfully installed 86% of the time. There were four mechanical failures upon installation of the TTFP caused by various operational occurrences.

A correlation between TTFP reliability and tubing size, screen type, or length of the perforated interval could not be drawn from the data.

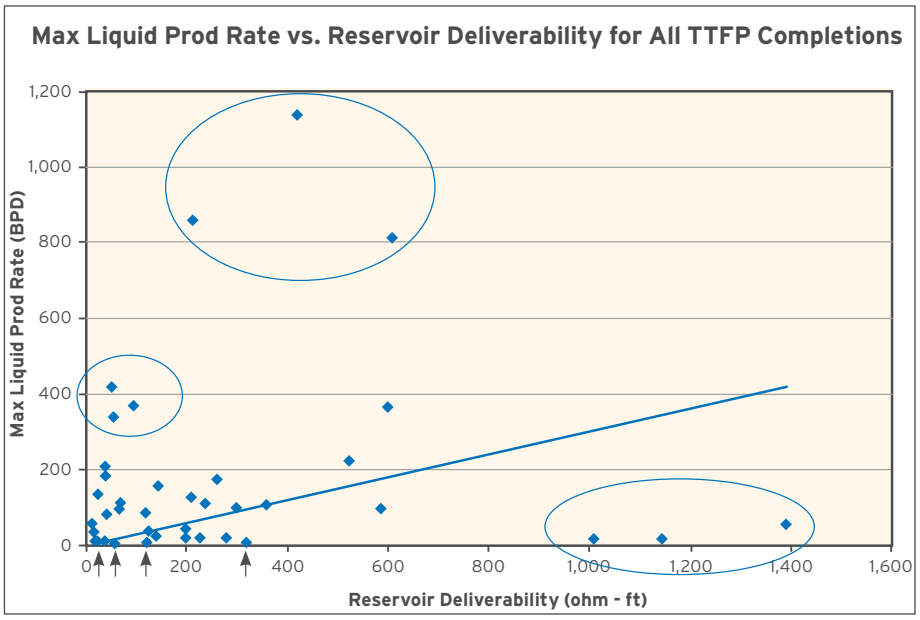

Figure 4 – Maximum liquid production rate (oil + water) vs. reservoir deliverability for all TTFP completions in western GOM

Future Use of the Database

The western GOM Thru-Tubing Gravel Pack Database is intended for future additions and is compiled in a user-friendly Excel® workbook. **Figure 5** is an example of the "Well Card" created for quick and easy information about each completion at a glance. This enables the database to be used as a tool to identify and mitigate risk, and to fine-tune initial production rates and cumulative recovery from TTGP completions.

Summary

At less than US $5/BOEG, TTFP completions are an attractive alternative to expensive Major Rig Work-Over (MRWO) completions. In summary, the information compiled in the Western GOM Thru-Tubing Gravel Pack Database shows that TTFP completions are:

- More productive in low-angle wells (less than 30° at perforations).
- More productive in larger casing.
- More reliable with packers installed.
- Reliable even at liquid flow rates well above 400 B/D.
- Reliable with good installation techniques.

Our data has shown that TTFP completions have proven to be a viable alternative to MRWO completions in both low product-price environments and high rig-rate environments, further enabling us to achieve the goals of cost reduction and operational excellence.

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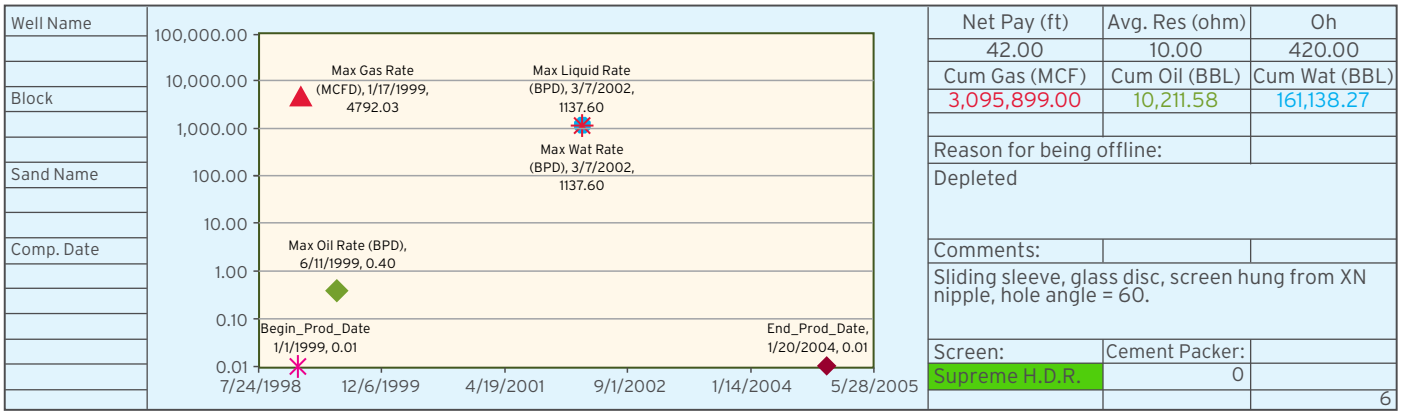

Figure 5 – "Well Card" shows basic production history data for each completion in the database