TENDEKA

Injecting new life into deepwater wells

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To improve the performance of deepwater Gulf of Mexico assets, simultaneously managing injection rates and preventing the formation of material entering the completion during a shutdown, is a common, yet complex challenge. Though tubing deployed injection valves and regulators have been available in the industry for many years, it cannot address the problem of annular flow.

For example, within only a few years of completion, several miocene and lower tertiary water injection wells in the basin had suffered a severe loss of injectivity. This was further compounded by the accumulation of formation solids inside the lower completion. The most damaging factor in solids production is likely cross-flow, wherein varying pressured injection zones can flow between layers inside the tubing/casing annulus.

The challenge to increase the life expectancy of these wells involves sustaining high injection rates, with no loss of injection pressure or the requirement for additional horsepower, while stopping solids being mobilized during shut-ins. A range of options was considered by the operator. This included the costly and complex process of either sidetracking or re-drilling a new deepwater injector well.

Since 2014, Tendeka, the independent global completions service company, has been working with a major operator in the US to develop an innovative technological solution to overcome this problem.

An internal study and analysis of historical data found that the severe loss of injectivity was caused principally by fine matrix sand that had been pulled in from the reservoir. These solids are normally stationary during steady injection, but can be activited due to powerful transient flow effects such as back-flow, cross-flow and even water-hammer. This results in an accumulation of enough solid fill inside the lower completion to diminish the injection rates.

A new sand control technology

To address the challenge of sandface injection flow control, the company developed a new sand control technology, Cascade[3]. This new well screen, flow control completion system utilizes intrinsic check-valves to prevent any back-flow or cross-flow during shut-ins. Depending on well conditions, it also limits the damaging effects of water-hammer: rapid, high-amplitude pressure cycles that can occur during a sudden stoppage of flow.

During the R&D phase of the project, the company used extensive laboratory testing, flow loop testing, and computational fluid dynamics (CFD) modelling to develop a series of non-return valve (NRV) prototypes. Each valve design was tested in-house and further qualified at third party laboratories. The technology was designed to handle a variety of well conditions including erosion, plugging, temperature, and repeated checking cycles[1]. Components were manufactured with high-alloy stainless steel and tungsten carbide components to resist tortuous downhole conditions for up to 15 years. After a series of prototypes and design iterations over an 18-month period, a final design was qualified to reliably withstand thousands of pressure-checking cycles at 1,500psi, and up to 10,000psi static differential pressure.

The three-year R&D project culminated with a field trial in March 2018. Its purpose was to test the valves under the most challenging well conditions possible, so the testassembly was built without a sand screen to filter out any of the solids. This exposed the system to the worst-case injection scenario for any potential erosion or plugging problems to be observed.

Field trials

A Permian salt water disposal well (SWD) was selected to test the system under the most adverse conditions: injection of untreated produced water. SWDs are common across West Texas and Oklahoma, disposing of up to 30,000 barrels of water per day (BWPD) per well.

Figure 1: Representation of Cascade^3 screen with NRV technology

The system was built on 4-1/2" base pipe with an array of 630 NRVs (figure 2). The quantity of valves is a function of the expected injection rate. To minimize flow velocity, and hence erosional concerns, the flow is limited to 40 BWPD per valve. The size and positioning of the valves is critical to be able to mount them flush with the pipe so that a direct wire wrap screen can be manufactured over them without interference.

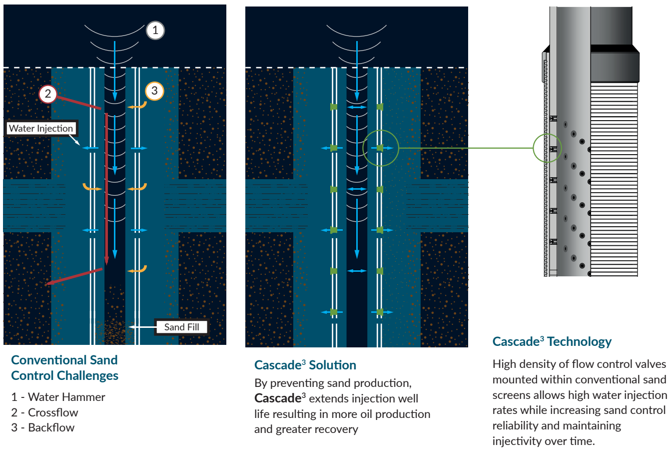

Figure 2: Cascade^3 screen with intrinsic non-return valve (NRV) technology

The test well was completed with the Cascade3 system installed permanently on 4-1/2" production tubing, below a production packer. For the purposes of the test, a single injection zone was adequate to observe the effects of the non-return valves to achieve the following downhole test objectives:

– Observe and record water-hammer, with/without check valves
– Prove that check-valves can hold back pressure
– Observe for any evidence of plugging or erosion over an extended time.

The field trial was set up to test several aspects of functionality using multiple downhole memory gauges to record pressures at reservoir depth:

- Baseline step-rate injection test
- Step-rate injection test through valves
- Check test (bleed off tubing pressure, observe annulus pressure)
- Multiple hard shut-in tests to record water-hammer
- Longevity test, continued injection (3-6 months).

The test assembly was positioned at the top of the injection zone, which was completed openhole with approximately 2,000ft of sandstone pay. With the tubing plugged below the test assembly, and pressure gauges set to record both the tubing and annulus pressures, the test was conducted by pumping down the tubing. A pump truck was brought to location to simulate injection, and portable tanks were tied into the flow line to take any returns.

Evidence of functionality

Baseline injection rates were brought up to 10 BPM with no increase in pressure, verifying that the NRV valves could accommodate a high flow rate without additional pressure drop, as shown in Figure 3.

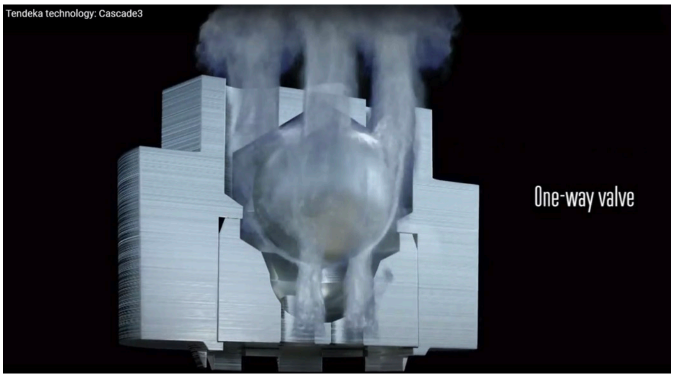

Figure 3: Cascade^3 valve under injection

Multiple hard shut-in tests were done by quickly stopping the surface pumps to record any fluid bounce and/or water-hammer on the downhole pressure gauges. The well was then opened to the surface tanks and tubing pressure was bled off to zero. No flow was observed into the tanks, which indicated that the check valves were effectively isolating the tubing from any back-flow (Figure 4).

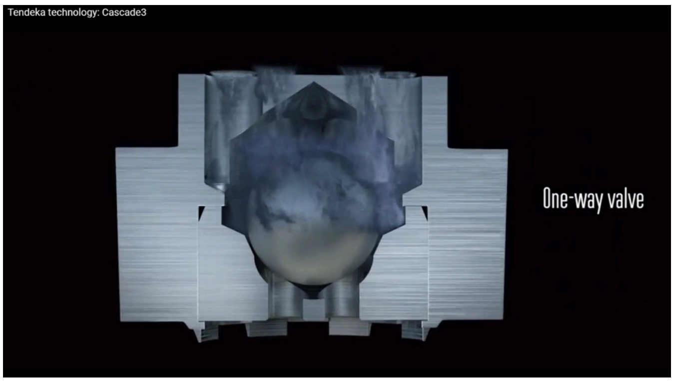

Figure 4: Cascade^3 valve checking against back-flow

Evidence of the technology's check-valve functionality was clearly visible during the check tests and flow rates and pressures were as expected when pumping through the test assembly. Finally, when the tubing pressure was bled off to zero, the NRVs prevented any back-flow and held annulus pressure constant. This observation verified that the system performed as designed for downhole conditions, checking against flow from the annulus to the tubing.

Continued observation

As of October 2018, the SWD well has been put on full-time water disposal duty for several months. Future plans include running a set of downhole pressure gauges to observe the injection rates and pressures after a sustained period of injection.

Offshore plans are currently in progress for the implementation of Cascade[3] in an injector well for a deepwater Gulf of Mexico asset. Several offshore Gulf of Mexico fields are at risk of losing reservoir pressure support without sustained water injection, and the expectation is that this technology will improve injection rates over a longer time. The potential CAPEX savings related to fewer injection wells drilled or re-drilled over the life of these offshore oil and gas assets is considerable.

While the system was originally developed for deepwater, offshore environments in the Gulf of Mexico, it has also found useful applications in land-based injector wells with sand problems.

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References

J Charles & T Webb, Shell, and S Fipke, Tendeka, (2017). New Sand Screen Increases the Reliability of Sand Control in Water Injection Wells by Mitigating Common Failure Mechanisms. Society of Petroleum Engineers. 187103-MS