A Grainy Problem –

Managing Sand Through Flow Control in the Modern Completion

In today's competitive market place, oil and gas industry operators are continually searching to find new and improved means of working in a smarter manner and reducing costs. Such a commitment creates challenges and a requirement to rethink best practices at almost every stage of the process, especially as the industry seeks to exploit ever more difficult reserves. A key question in the drive for enhanced production is how best to control and manage sand, and the recent introduction of a number of new technologies in this field have significantly improved performance with associated cost savings.

BY DUNCAN HARPER AND CHRIS RODGER

Options for Sand Control

Controlling the flow of unconsolidated sand into the well is one of the most critical challenges in any sand face completion. The failure to address sand production correctly will impact heavily on productivity, well life, completion equipment life and safety through eroding surface equipment, as well as the environmental and financial impact of disposing of large quantities of sand.

In unconsolidated formations, high flow rates and drawdown pressures, pressure depletion and water production trigger sand production, carrying these unwanted products into the well. Besides prematurely killing well production, excessive sand production may cause erosion and the blockage of downhole hardware, seriously damaging or disabling downhole and surface equipment.

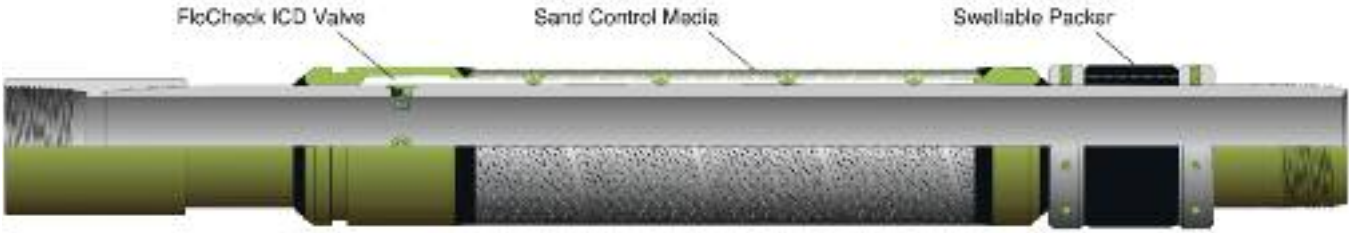
Over the last few decades, drilling technology has advanced to such an extent that horizontal and multi-lateral wells are now the norm, with greater reservoir penetrations and lower draw-down pressures. This increased length and uneven pressure profile along the wellbore has resulted in an increase in sand control issues, such as installation risk due to extreme drag and water influx due to reservoir heterogeneities.

Sand control is basically the control of sand production in unconsolidated formations, and the first step in any sand control application has to be a detailed exploration of the characteristics of that formation. There are various methods used to determine the optimum sand control methods for each specific well and in and in many cases the decision can come down to a trade-off between the various solutions to provide the best overall option for the client.

Establishing the formation sand grain size is essential to sand control selection and laboratory technology is utilised to help establish the most suitable sand control method. Traditional completion methods that allow sand-prone reservoirs to be exploited often dramatically reduce production efficiency and are being replaced by a number of newer technologies that keep formation sand in place without unduly restricting productivity.

Most options for completing sand-prone reservoirs offer physical restraint of the sand migration into the well. These include:

- Resin injection, where a resin is injected into the formation to cement the sand grains in situ.
- Gravel pack, where a slurry of gravel in a carrier fluid is pumped into the annular space between a centralised sand screen and the open hole, creating a granular filter. This is deployed in un-uniform, unconsolidated formations to provide a highly permeable sand layer between an open hole and the sand screen. Although successful in many cases, gravel packing involves meticulous pre-planning and is labour/time intensive. It also involves additional pumping equipment and personnel to execute effectively.
- Standalone screens, which are simple installations suited for uniform formations, typically where the uniformity coefficient is calculated at less than 3. However this has been classed as being far too conservative by many industry experts.
- Inflow control device (ICD) screens. Again a relatively straightforward installation, these can be deployed to reduce or delay an influx of water, but have added sand control benefits in that they can reduce annular flow to near zero, thereby reducing the risk of erosion hot spots. ICD screens have been used as an effective alternative to gravel packing.



Tendeka completion diagram showing various configurations of sandscreens, ICDs and swellable packers – Tendeka FloRight product with FloCheck ICD valve, FloMax Ultra Screen and SwellRight slip-on Packer *(illustrations: Tendeka)*

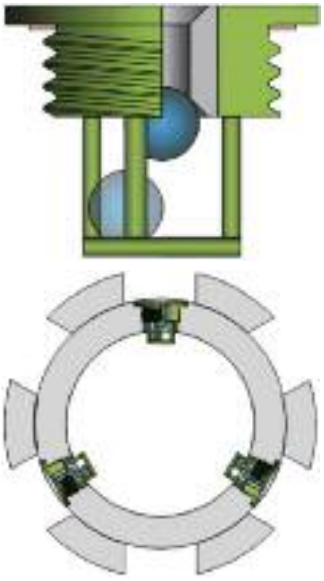
Tendeka, the provider of completion and reservoir monitoring products and services to the upstream oil and gas industry, has developed a complete suite of standalone screens and ICDs within its portfolio. The company recognises that although such technology may be well established, and in some cases deemed a commodity, sand control still requires to be considered properly by experts in the field.

The company's bespoke high-quality standalone screens exceed the standards set in the industry (ISO 17824) and are relatively simple to deploy through being made from proven components. It currently has the large single site screen manufacturing capacity and one of the shortest lead times available in today's market.

Go with the Flow

More recently, great emphasis has been placed on extending production by utilising ICDs in conjunction with sand screen technologies. This type of completion solution has been most prominent and highly successful in the Middle East and the North Sea, but is gaining greater recognition elsewhere in the world Passive ICDs are used to enhance the performance of horizontal wells in unfavourable environments, such as non-uniform permeability and/or pressure along horizontal sections. The advent of passive inflow control technology has dramatically improved well productivity and wellbore cleanup, resulting in increased recovery and the associated benefits.

An ICD is deployed as a part of a well's completion to create an evenly distributed flow profile along a segmented producing zone. Each ICD placed along the producing zone creates a localised restriction to flow that is pre-determined during the completion design. This restricted flow creates



Top, the FloCheck insert (side view) and FloMatik cross-section with FloCheck valves

an additional pressure drop, balancing the wellbore pressure drop. The resultant evenly distributed flow profile can reduce water or gas coning and sand production and solve other drawdown-related production problems.

Stand-alone ICDs can be spaced throughout the completion liner adjacent to the production or injection reservoir. They can be placed on every joint or run in combination with blank joints to provide the desired well compartmentalisation and inflow profile as per client requirements.

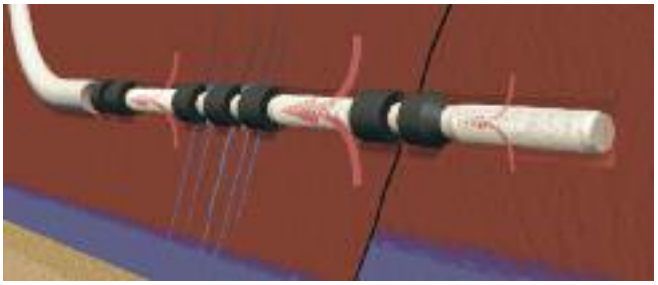
A well-designed ICD completion assisted by wellbore hydraulic modelling can accomplish the following:

- Promote production from the entire horizontal laterals and mitigate the effect of the severe pressure gradients.
- Eliminate cross-flows existing in open hole completions.
- In certain cases, ICD completions can significantly reduce water cut thus significantly improving well performance.

ICD technology comes in a variety of modes: fixed, adjustable, and with shut off capabilities in conjunction with sliding sleeve technology. The current drive within the industry is to develop and gain confidence in a self regulating, autonomous ICD.

Tendeka's ICDs can be installed as a stand-alone ICD sub or in conjunction with a sandscreen in a FloRight ICD. By installing ICDs, a predetermined pressure drop can be created between the reservoir and the completion liner. This choking effect creates a back pressure on higher quality sections of the reservoir allowing tighter sections to contribute evening out the inflow profile from the well. This evening out of the inflow profile will result in better coning control therefore delaying water breakthrough. Tendeka's innovative FlowCheck™ valve allows for the following during an ICD completion:

- Full wash down capability without the need to deploy an inner string.
- Ability to set liner hanger/packers and mechanical packers simultaneously against the valve.
- Fluid loss control.
- Ability to pressure test the full string without setting any additional packers.
- This has enabled ICD completions to be installed during periods of high well losses without having to pump a loss control material (LCM).



ICDs are is deployed as a part of a well's completion to create an evenly distributed flow profile along a segmented producing zone

The FloCheck™ valve is a convergence technology based on several important lessons learned during the last decade of ICD installations:

- Deploying inner strings is sometimes mandated due to poor hole conditions.
- Low bottom hole pressure may cause differential sticking due to inability to circulate.
- Low bottom hole pressure may lead to multiple runs with inner string to set mechanical packers.
- Inner strings take time to run and may increase weight and stiffness.
- Fluid losses during running of upper completion is difficult and costly to control.

The valve allows for circulation to the bottom without an inner string, permits the setting of mechanical packers without an inner string, enables the spotting of breakers and spacers prior to pulling out and provides fluid loss control while running upper completion.

FloCheck is a simple but effective system. When used in conjunction with ICD technology it closes off the nozzle, thus preventing any fluid loss while running in hole. Once production is initiated the ball merely comes off seat and the cage is shortly eroded on flow, allowing for both production and injection.

Tendeka's ICDs achieve an even, consistent flow of fluid along each interval throughout the completion string, improving perform-

ance, efficiency and production. Combined with a sand screen in an unconsolidated reservoir, the reservoir fluid passes from the formation through the screen and into the flow chamber, where flow is regulated by the ICD orifice. Along with other ICDs, the pressure drops in the production zone are balanced, yielding a more efficient completion.

Due to the design simplicity of ICDs they can and have been installed on to various screen types with great success. They can also be used successfully as an inner screen completion within a failed screen gravel pack, stabilising water production to a manageable rate and completely stopping sand production, which in a marginal well can be the difference between being uneconomical or completely viable.

World First in the Gulf of Mexico

Tendeka recently successfully deployed the world's first slimhole ICD completion in a sandstone reservoir in the Gulf of Mexico.

Due to a severely depleted reservoir with difficult drilling conditions, the well was planned as a re-entry out of a 5-inch liner with a 4 1/8-inch openhole, which negated the use of conventional technologies. Offset wells with sand control equipment installed experienced very high completion skin and used a variety of high rate water packs, frac-packs and expandable screens.

The company's solution was to provide inflow control screens and swellable packers, which were installed in a 4 1/8-inch openhole section of the well. Coarse metal mesh sand screens were used to minimise the plugging of sand and mud during well flowback, and the swellable packers were of a slip on sleeve design which were simple to deploy and quick to install. The new FloRight 2 3/8-inch ultra slim hole ICD screen system was used across the 170 metre zone at a depth in excess of 4000 metres.

The ICD technology used for sand control in the Gulf of Mexico was based on a recent successful 3 7/8-inch openhole re-entry completion deployed by the company in the Middle East to manage water in an open hole multi-lateral horizontal oil producing well. That project was another world first in that it allowed the deployment of passive inflow control devices to manage inflow from two lateral wells connected to the motherbore.

The carbonate well had reached 50% water cut. Limited success was achieved with plugging it back to minimise water production, so it was decided to carry out a workover and install the ICDs to passively control inflow from the laterals, uniformly produce from the motherbore and reduce the potential for cross-flow between the laterals.

Fourteen Tendeka FloMatik passive ICDs and six swellable packers were installed into the motherbore to compartmentalise the reservoir, and numerous wellbore hydraulic simulation runs were undertaken to match flow and pressure profiles.

The successful project saw the ICDs create proportionate inflow along the well and passively control influx from the laterals with no cross-flow or packer leaks. A rate of 4.1 MBD oil with 0% water cut was achieved, compared to 1.5 MBD before the workover.

Cost-Effective Completion Designs

There is no doubt that sand management and control is a major concern facing the oil industry today, as it looks to maximise yield from ever more challenging resources. Sand production has the ability to damage equipment, impact on performance and, in some cases, even stop production. Produced sand has the potential to cost the oil and gas industry billions of dollars annually and can pose a safety and environmental risk.

There are a number of methods for controlling and managing sand, however, the introduction of ICDs to that list adds a further, credible option. Traditionally used as an inflow balancing technology, it is clear that ICDs can also be deployed effectively to assist the control of sand production. They are a proven addition to the reservoir optimisation mainstream and offer new options for cost-effective completion designs.

The Authors:

Duncan Harper, is the Sand Control / Inflow Control Product Line Manager for Tendeka and has worked in the oilfield industry for over 16 years. Mr. Harper has vast operational experience. His career he has included supervising complicated sand control operations including horizontal gravel pack, standalone multi – zone ICD, and frac pack completions, offshore and onshore.

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