Vanishing
TEMPORARY PRESENCE: Baker Hughes' entire SPECTRE plug, including the body, IN-Tallie anchoring grip system and packing element, is designed to completely disintegrate downhole.

Downhole completion tools that disintegrate on prolonged contact with wellbore fluids or at certain temperatures save time and money by reducing post-frack steps. Jennifer Pallanich finds out about the evolution of dissolvable technology and some big ideas for new ways to apply it.

As operators sought increased stage counts in their horizontal wells, they also sought downhole tools that would not need to be drilled out.

Disintegrating frac balls save operators money by preventing ball debris problems and reducing drillout and circulating costs. Dissolving frac plugs, the newest completion tools in the market, go a step further by eliminating the need for milling operations, clean out trips, and coiled tubing or wireline runs.

"One of the things about the unconventional market is it's still fairly young in the grand scheme of things. We're still doing a lot of trial and error to improve the production and efficiency of these wells," says Jim Sessions, Baker Hughes' vice president of completions technology. "There are very few barriers to trying new technologies, and it's easier to prove things out."

Sessions says dissolvable technology is an answer to the larger question of how the industry can become more efficient.

"The vision of having anything disappear in the first place was a step change," Sessions says. "Once we identified a means to have dissolvable items in the wellbore, it opened our eyes to what it could do for the industry."

Dissolvable technology started with metals, but now tools can also be made with polymers, which may provide cost advantages, Sessions says.

Brian Doud, chief operating officer of Tervis, says: "Baker Hughes really paved the way for dissolvable technology. They've been pushing dissolvable technology since 2011."

Nothing left behind.

IN-Tallie, the disintegrating ball, was Baker Hughes' first step in the dissolvables market. From there, the service company introduced the SHADOW frac plug, which eliminated the
post-frack intervention phase of plug-and-perforation completions.

Unlike traditional composite plugs, SHADOW is designed to stay downhole during production but lets operators bypass coiled tubing intervention to speed up completion times. It has a large flow-through inside diameter and uses IN-Tallic disintegrating frac balls.

Applications for SHADOW include unconventional oil and gas wells, staged plug-and-perfor completions, horizontal wellbores and extended reach wellbores.

The SPECTRE frac plug is "a generational improvement on SHADOW" that "does not leave anything in the hole," Sessions says. "We went from leaving a large inside diameter to leaving zero restrictions."

The long length of laterals in shale plays can make drill-outs problematic, Sessions says. Baker Hughes' aim with SPECTRE was to provide an alternative to composite frac plugs that would eliminate drill-outs and provide a full bore.

According to the service company, the entire SPECTRE frac plug — including the body, IN-Tallic slip system, and packing element — fully disintegrates downhole in the presence of wellbore fluids, leaving behind no spare parts or metal debris.

SPECTRE also provides additional options for later refracks and workovers because eliminating the drill-out eliminates worries about scoured casing. Applications for SPECTRE include unconventional oil and gas wells, multistage plug-and-perf completions, extended reach wellbores, remote developments and depleted wells.

The unconventionals market has adopted the dissolvable technology more heavily than other markets, Sessions says.

With a few years of field use, dissolvable technology is "less of a voodoo science project and more of a reliable tool."

**Now you see it**

Halliburton jumped into the dissolvable plug market with Illusion, a fully dissolvable frac plug. The service company says the 10,000 psi-rated product can shorten the time to production by eliminating the need to mill-out plugs after fracturing. Illusion frac plugs can be installed at any position in the wellbore and dissolve completely to leave an unrestricted bore for production, the company says.

"The hard part was to get something that dissolved itself," says Greg Vargas, Halliburton's product manager, drillable tools — unconventional completions.

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"We tried looking at plastic materials that would dissolve over time, but the question remained, would they hold that pressure for the duration of the frack?"

Greg Vargus, Halliburton

ON LOCATION: Running the Halliburton Illusion frack plug.

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Ultimately, Halliburton turned to metals. Temperature, pressure, wellbore fluid and salinity all factor into how quickly the dissolvable tools disintegrate. “The cooler it is, the longer it takes,” Vargus says. Halliburton is working on dissolvable tools for lower temperatures for places such as the US Marcellus shale, where temperatures can be as low as 120 degrees Fahrenheit (48 degrees Celsius).

“We want something that will perform as well there as for someone running something in the Eagle Ford at the 200 to 250 degrees Fahrenheit (93 to 120 degrees Celsius) range.”

The Illusion frack plug is made of multiple individual components, and as those components dissolve they may become small enough to travel

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in the flowback before complete dissolution. Halliburton therefore set a maximum design criterion of no pieces larger than one inch being allowed as a remnant size during the dissolution process.

"The plug dissolves over time. It's not an instantaneous dissolution. It's going to dissolve from end to end and the outside in," Vargus says.

For example, he says, the Illusion plug is predicted to dissolve in about a month at 200 degrees Fahrenheit and with a salinity of 3% potassium chloride. "The more plugs we run, the more data we gather, we'll get a better picture."

Commercialised in 2015, the Illusion plug comes in 4 1/8-inch and 5 3/4-inch regular weight casing sizes, and the service company is developing the same sizes for heavyweight casing. Early this year, Halliburton expects to commercialise the heavyweight casing versions, which will meet the requirements for the North American completions market.

The service company is looking at different compositions and materials that can operate at temperatures above 250 and 300 degrees Fahrenheit but still function at a pressure rating of 10,000 psi. Other considerations are for high-pressure, high-temperature applications up to 20,000 psi and 400 degrees Fahrenheit.

Halliburton has run Illusion plugs in the US Eagle Ford, Bakken and Woodford shale plays, and recently carried out a field trial in Argentina. The plug is applicable anywhere plug-and-perf technology is used, so Halliburton is courting markets in China, Argentina, Australia and Saudi Arabia. "Interest is growing globally," Vargus says. "There's a lot of opportunity for new developments and how to apply it to different wellbores across the globe."

**Heat is on**

Magnum Oil Tools, based in Corpus Christi, Texas, took its first dissolving tool — a frack ball called Fastball — to field trial in 2012. The company has since commercialised Fastball and added a dissolvable frack plug to its product line.

The seed of Fastball was planted at a 2011 trade show when Magnum executives met with a vendor selling biodegradable polymer, and later germinated when the company decided to pursue a high compressive strength biodegradable polymer in ball form.

The idea, says Derrick Frazier, Magnum Oil Tools' product line manager, was to replace standard G10 balls, which can shear if they land badly on the ball seat. The balls also have to be flowed back to surface, otherwise they can block the flow of the well. Working with Kureha Corporation, Magnum created dissolving balls that would achieve 10,000 psi rating on specific ball seats. Fastball's first field trial was in late 2012 in Alaska. Full production began in 2013.

As Frazier points out, a dissolving material is one that is soluble with water and undetectable after it dissolves, with no difference in viscosity. Degradation, he continues, results in particles, whether small or large. Frazier says clients initially worried that the dissolving tool would create sludge or leave behind particles in the well. "We were able to prove that this wouldn't create sludge or particles in the well," Frazier says. "(Fastball) does not degrade, it dissolves."

Fastball, available in sizes from 0.5-inch to 4.75-inch outside diameter, works anywhere sliding sleeve systems or composite
frack plugs are effective. The temperature affects how quickly the ball dissolves.

"The ball can and will degrade in room temperature, but it will take up to three months at ambient temperature," Frazier says. "It's very predictable. We can basically tell you exactly when that plug or that ball will fully dissolve" based on wellbore medium and temperature.

At 175 degrees Fahrenheit, he says, it takes seven to nine days for Fastball to dissolve. That time drops sharply as temperatures approach the upper operational limit of 375 degrees Fahrenheit.

"We put the ball in water under pressure at 300 degrees, and left it for 48 hours, not knowing what to expect. We took the test caps off and there was absolutely nothing there. There wasn't even dust. It was like dissolving sugar into coffee," Frazier says.

When the company launched the Magnum Vanishing Plug (MVP) in late 2014, the company's aim was to eliminate the steps typically taken after a plug is run. Removing those steps, Frazier says, would make it possible to bring wells into production quicker and reduce costs and the amount of water needed for the well.

The MVP is based on the same material used in Fastball, but with more tensile strength. The Fastball has "simple geometry" but the plug has "lots of different angles and strength requirements," Frazier says.

"The critical thing was the sealing element," he says, noting that standard seals were not fully dissolvable.

Magnum worked with a vendor to develop a dissolvable seal. MVPs are designed to dissolve in the wellbore in temperatures between 180 and 350 degrees Fahrenheit and withstand pressures to 10,000 psi.

During testing, Magnum set the MVP in a piece of casing, pressured it to 10,000 psi, added water and left the test to run under pressure for 48 hours. "We took off the test caps and there was nothing there but the cast iron slips," Frazier recalls. "It was the most perfect test result we could have seen."

In an Eagle Ford field trial in 2014, an operator ran 27 MVPs in a long horizontal well with a 5.5-inch inside diameter and 23 pound per foot casing. According to the company, all plugs dissolved at the 235 degree Fahrenheit bottom-hole temperature without requiring drill-out or clean-out runs. Magnum claims this reduced the well's time to production by 90%

Since the tests and the field trials, the company has sold about 7000 MVPs.

**Planned corrosion**

In 2013, Ohio-based Terves received an unusual client request. "Someone asked us to make a piece that would corrode on command," Doud says.

Terves drew on an alloy it had developed about a decade before to help a client who needed a lightweight solution.

What was considered a liability — a tendency to corrode — turned out to be a solution for the oil and gas market.

Within three days, Terves had a prototype, and field trials followed. Terves has seen three generations of production since the 2013 request started the ball rolling. "We found a market for something that was considered a problem for magnesium," Doud says.

"Corrosion has always been a problem and turning that into a solution was an interesting challenge to solve, to control corrosion at a faster rate. Corrosion science is fairly well understood. For materials such as steel and aluminum, it's almost a black art. There is no knob you can turn to actually control corrosion."

However, Terves found a way to control the degradation of the alloy and keep that consistent across batches, Doud says.

"Every single batch of alloy we do the degradation and mechanical testing on, we can track it back," he says. "We can assure that it is going to work the way it's supposed to every time."

Doud, a ceramic engineer, has multiple patents pending on Terves's "Our materials dissolve in the solution. There's very little residue left," Doud says. In the case of a pound ball, most would dissolve and filter it out, he says. "There would not be a pound of residual left. A significant portion dissolves into the saltwater."

The ideal is for 100% of the tool to completely dissolve with zero residue. In acid environments, Doud says, a magnesium alloy-based technology can come very close to dissolving.

The metal alloy is lighter and stronger than aluminum and is engineered for controlled disintegration when exposed to completion fluids at downhole temperatures. Terves offers five alloys as balls and tubulars or rods up to 20 feet long, from which the company or its customers can machine specific components.

According to Terves, the magnesium alloy frac ball maintains its shape and does not start degrading in the ball drop system but effectively actuates sleeves or seal frac plugs at pumping pressures that can exceed 10,000 psi. Once deployed, the balls respond to a combination of completion fluids and bottom-hole temperatures of 85 to 200 degrees Fahrenheit to degrade into soluble micron-sized particles that easily circulate out of the well. Within one to five days after the frac completion, tools are completely disintegrated, leaving an

"We believe that dissolvables can replace drillable composite technology."

*Brian Doud, Terves*
raw material: Nine-inch by 30-inch TervAlloy castings ready for extrusion.

unobstructed wellbore, without requiring coiled tubing drill-out operations, the company says.

As of the end of 2015, more than 1000 of its second-generation TervAlloy engineered disintegrating frac balls have been successfully deployed in horizontal frac completions in North America since their introduction in 2014.

The main application for TervAlloy has been dissolvable frac balls used with sliding sleeve completions, but the alloys are now being used for other tool designs. “We are designing a suite of designable alloys so tool engineers can go out there and design downhole tools to their hearts’ content with dissolvable tools,” Doud says.

Terves is scheduled to launch two new alloys and three new coating options for the TervAlloy line. Beyond that the company has its eye on the offshore market, which tends to use heavy brines and salt solutions.

“We are developing new alloys that perform in those environments,” Doud says. “The conditions that you have to survive in and degrade in offshore are different from typical onshore wells.”

Big potential
Other companies are staking a place in the market, including Schlumberger, which released its Infinity dissolvable plug-and-perf system in early 2015. Infinity uses fully degradable fracture balls and fully degradable seats instead of plugs to isolate zones during well stimulation. According to the company, the full bore interventionless plug-and-perf system eliminates the need for milling operations and leaves nothing behind in the wellbore.

The service company says a customer in South Texas deployed the Infinity system in a seven-well project that began with partial wellbores and, after early successes, moved onto full wellbore completions.

Schlumberger deployed the system under extreme conditions, with temperatures up to 320 degrees Fahrenheit in laterals up to 8000 feet. In these wells, more than 135 stages were completed without any stages skipped or any type of mechanical intervention required, according to the company.

The companies selling dissolvable tools see a future full of possibility for the technology. “It’s an emerging technology that came out of backroom brainstorming,” Sessions says.

For now, dissolving technology is used primarily in a few completions components, but Sessions sees the possibilities for the technology in the overall completion. “Where does it go from here? Do we look at fully dissolvable completions technology?” he asks. “The possibilities are just endless. Every day we find a new application or niche we can apply it to.”

Vargus says: “Ideally, we’ll get to the stage where a full wellbore will be a common practice.”

Doud says: “Dissolvable technology is still in its infancy, and we believe it’s going to take over more of the available market because of the savings it enables. We believe that dissolvables can replace drillable composite technology. Some say dissolvables will replace coiled tubing, which is partly true, but our goal is to replace all drillable technology.”

Frazier believes dissolvables could replace metals in some applications. “I think that the market and technology is there to move full steam ahead with these dissolvables.”
Flexible solution for pilot hole project

Pilot hole drilling is standard industry procedure in areas where shallow gas deposits pose a risk. In an industry first, however, Centrica took a cue from the civil engineering sector to devise a safe and money-saving method to drill a pilot hole at the Butch field, as Russell McCulley reports.

Centrica's Butch discovery lies in a well-developed sector of the Norwegian continental shelf, north of Ekofisk and east of the Ula field. It is an area known to contain pockets of pressurised gas just below the seabed, which can present a blowout risk if encountered while drilling.

Traditional seismic interpretation cannot rule out the presence of shallow gas. Before exploration or production drilling can proceed, operators must ensure that an area is safe by first drilling a small-diameter pilot hole, which can be quickly brought under control and killed if necessary.

The failure to detect shallow gas early in a field development may lead to lengthy and expensive project delays down the line. If shallow gas is encountered once development drilling is under way, work stops and the drilling rig and subsea infrastructure must be moved to an alternate location.

"We have a lot of shallow seismic here and have done a lot of interpretation, but since we were not able to conclude from that whether we had no risk of shallow gas, or a very low risk, we had to make sure we weren't taking on extra risk later in the project," says Espen Kopperud, Centrica Norway's project manager for the Butch pilot hole.

The Butch drilling campaign will likely not begin before 2018. "But at this stage we had to check out the location for shallow gas to be sure that this was a feasible location for development."

When Centrica began market screening for the pilot hole in 2014, rigs were in demand and dayrates were high. Kopperud and his colleagues were familiar with a recent project Island Offshore had completed in Norway using coiled tubing and a light well intervention vessel to drill core samples for the Rogfast subsea road tunnel. Could a...