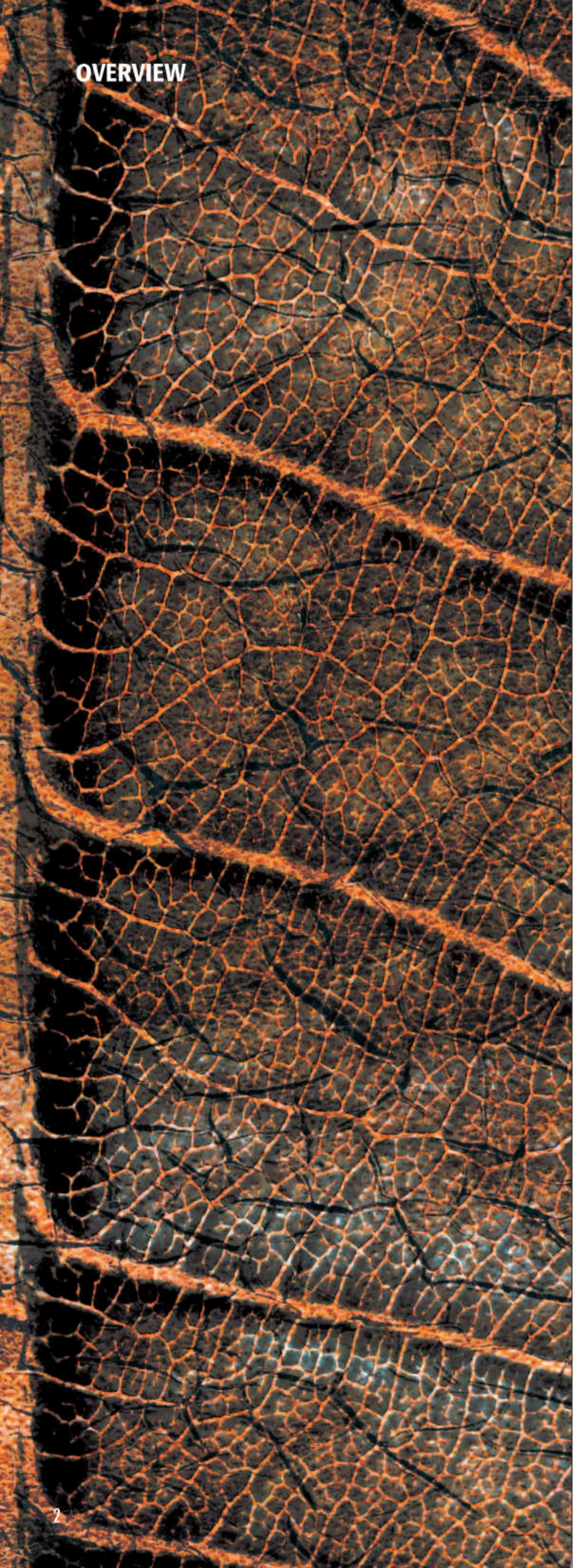


Hydraulic Fracturing

Game-changing advances in stimulation and production technology are improving well economics.

By Kelly Gilleland, *Contributing Editor*

For more than 60 years, hydraulic fracturing has helped bring oil and gas to the surface from wells that otherwise would be classified as uneconomical. Currently used in an estimated 90% of all land-based wells in North America, hydraulic fracturing will remain a mainstay in the operator's bag of tricks, as development of lower-quality reservoirs becomes the rule rather than the exception. Worshipped by some and feared by others, fracture stimulation technology continues to evolve to better meet the needs of producers and environmentalists, not only in North America, but on a global scale.

"We are beginning to see the increase in the focus on unconventional developments in many areas of the world outside of North America, such as Argentina, Eastern Europe, China, and the Middle East," said Ted Lafferty, vice president of stimulation services, Schlumberger. "Currently, due to higher prices of oil, we are seeing a moderate shift in activity in North America from the dry gas reservoirs toward the reservoirs that have more liquid content (condensate and oil), like the Bakken and Eagle Ford. Unconventional reservoirs require hydraulic fracturing to be economic today, so the advances in fracturing technology have contributed to making some of the key activity areas today viable that would not have been economically viable even 10 years ago."

As the use of fracture technology increases, "one size fits all" no longer applies, and ongoing technology development is the name of the game. Today's drillers perform sophisticated analyses of formation properties from core samples taken from individual wells to determine the precise formulations of the frac fluids needed, workable proppant-fluid-pressure combinations, and ideal frac orientation. Proppants now come in a variety of formulations, shapes, and sizes, each with their own advantages and disadvantages, and partial monolayer technology is evolving so that one layer of sand can offer the same conductivity as 10 layers of proppant.

Fracture treatments now use high-resolution seismic to determine natural fault locations in shales so that the man-made fractures reach those crucial pathways, or, alternately, to avoid those natural faults or karsts that will suck the life out of the production stream. Microseismic and tiltmeter mapping can relay frac information in real time so that geohazards are avoided and the maximum reservoir area is accessed successfully. Additionally, fracmapping services have been used to confirm that hydraulic fracs do not grow so far out of the target zone as to contaminate aquifers and surface water resources. Kevin Fisher, general manager of Pinnacle, a Halliburton service, points to data from thousands of fracs in the Barnett, Marcellus, and Woodford shales

where Pinnacle's microseismic mapping services verify fracture height containment with measurements showing they remain a mile or more below any potable water sources.

Environmental stewardship has given rise to a plethora of new fluids technology, including new drilling mud and fracturing fluid formulations, and it has also spurred such innovations as the development of a portable closed-loop system for recovering reusable oil-based fluid. New water-based drilling fluids have been used successfully in shale plays such as the Haynesville, which has the dual challenge of extremely high bottomhole temperatures, and in Canada's Bakken Shale, where a crosslinked fracture fluid that works with flowback and production water is being used successfully. Thermal evaporation systems to treat and reuse frac water are being developed and tested, providing not only ecological benefits but cost savings as well.

Challenges and solutions

Even with all the advancements in stimulation and production technology, the industry still faces challenges regarding fracturing operations. One specific challenge, Lafferty said, is in the efficient optimization of the number of frac stages to maximize performance of the horizontal well. "Increased use of production logs is still required to provide a quantitative evaluation of the performance results of various technology and process choices," he noted.

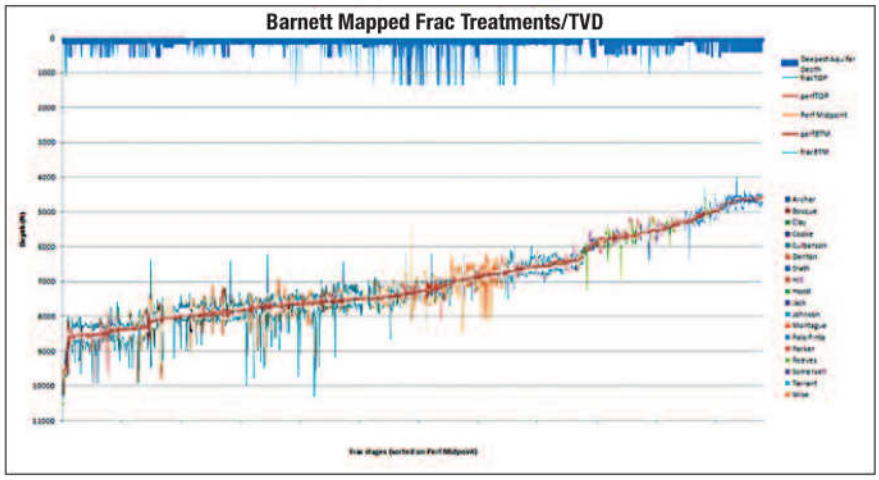
Fracturing can comprise a significant percentage of total well completion costs, so getting an optimal stimulation treatment is critical to the success of the program. Nearly all fracturing takes place in low-permeability rocks such as tight sands and, increasingly, shale, which comes with a set of operational challenges beyond the frac procedure. And even if a company successfully finds and manages to produce significant quantities of hydrocarbons from such reservoirs, environmentalists and other energy industry outsiders continue to look at fracturing as a highly suspicious activity.

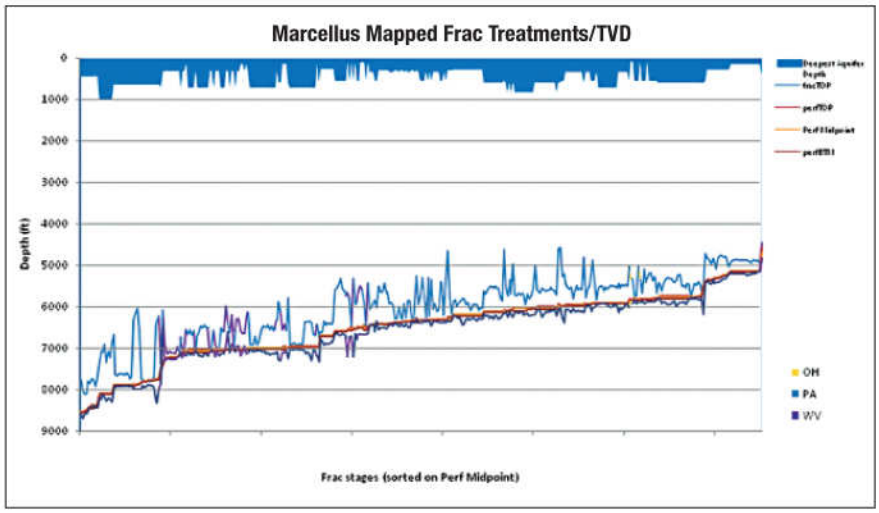
"One gentleman I spoke to compared fracing operations to a whole slew of government-related conspiracy theories like hiding aliens in Area 51," one geoscientist said. "I'm not sure how fracturing got so mysterious – I guess because it happens downhole and you can't see the effects from the surface – but the whole fear of fracturing being the source of groundwater contamination is really a non-issue."

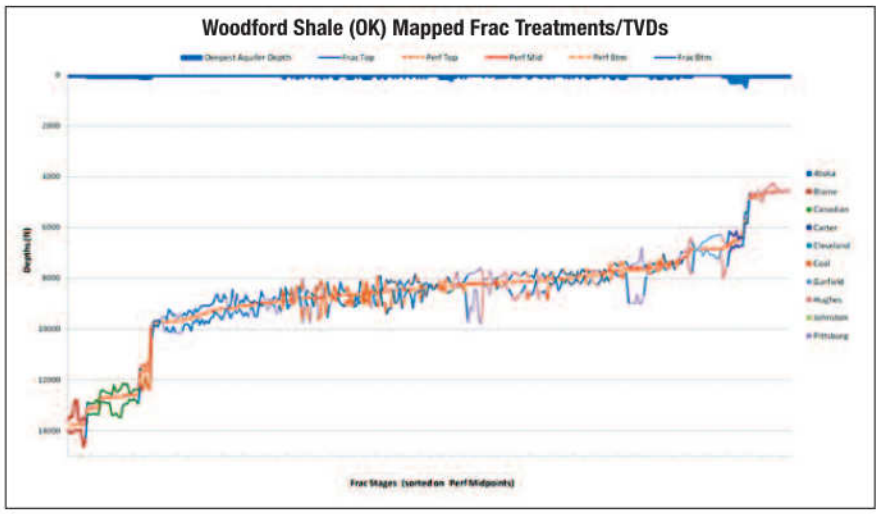
To combat the allegations, several companies are disclosing information about the makeup of their frac fluids. Halliburton now is providing the public with information related to the identity and common uses of the additives and constituents generally involved in the hydraulic fracturing process – additives that typically comprise less than one-half of 1% of the total water-and-sand-based solution.

"Halliburton has just made available new web pages to emphasize our forthright disclosure of the additives and constituents that

Service companies expect the increasingly intense scrutiny by regulators and the public to lead to hydraulic fracturing operations on smaller locations, with less traffic on sensitive lease roads and with more environmentally responsible fluid systems. *(Photo courtesy of Baker Hughes)*







Figures 1-3 show Pinnacle fracmapping data on all fracs mapped in the past decade in the Barnett, Marcellus, and Woodford shales. The frac top and bottoms are shown and sorted from deepest to shallowest completions in these three reservoirs. The frac top and bottoms are contrasted with the deepest aquifers in the counties where the fracs occurred as listed on the USGS website. *(Images courtesy of Pinnacle; data source: USGS)*

are used for several typical wells in Pennsylvania," said David Adams, vice president of Halliburton's production enhancement product service line. "We believe this effort represents an important and substantive contribution to the broader long-term imperative of transparency."

While the initial focus of the additive disclosure pages are limited to activities taking place in Pennsylvania, where development of the Marcellus Shale already is well under way, Halliburton said it is committed to continuing to provide hydraulic fracturing fluid disclosure information for every US state in which the company's fracture stimulation services are in use.

Public concerns about oilfield safety and water use are driving regulators' interest in hydraulic fracturing, which increases operators' interest in minimizing HSE footprints. "Even for completely benign fracturing fluid systems, the layers of pre-job disclosure and extensive testing and documentation will change the process of fracture planning and operations," said Lindsay Link, Baker Hughes' president for pressure pumping.

Even as fracturing experts address concerns about the relatively small volumes of chemicals pumped downhole in hydraulic fracturing, well cementing will become increasingly scrutinized for its ability to isolate water and hydrocarbon zones.

"Cementing will necessarily become linked with safe, effective hydraulic fracturing, so engineers will design cement systems that not only achieve good bonds, but also control gas migration control and withstand stimulation and geological stresses expected for the life of the well," Link said.

Service providers are not the only ones ready to talk about fracs, although some argue this is just a thinly veiled effort to head off tighter scrutiny and federal government regulation. In early 2010, ExxonMobil announced it would be willing to disclose what chemicals were being used in its wells across the US. According to a filing the company made with the SEC, "ExxonMobil supports the disclosure of the identity of the ingredients being used in fracturing fluids at each site. While we understand the intellectual property concerns of service companies when it comes to disclosing the proprietary formulations in their exact amounts, we believe the concerns of community members can be

alleviated by the disclosure of all ingredients used in these fluids."

To help alleviate the confusion, hydraulic fracturing companies are not only ramping up their press campaigns, they are enhancing their product lines. Fisher said the fracing sector is making huge strides in filtration methods as well as formulating safer fracturing chemicals. "Things are safer now than they were five years ago," he said. "I think all of the operating companies are extremely safety-cognizant these days, and not just because safety and environmental issues are regulated."

Halliburton recently announced a new line of frac fluids called CleanStim that are composed entirely of food-grade chemicals. CleanStim, an integral part of the company's new CleanSuite line of products, is the first fracture fluid to source its components entirely from the food industry.

"The safe and efficient use of this technology has never been more important or in greater demand than it is right now," Adams said. "With the CleanSuite line, we believe we've effectively set a new standard for how unconventional resources may be accessed and produced in the future."

The line is composed of:

- CleanStim fracturing chemicals;
- CleanStream, a service that uses ultraviolet light instead of chemical additives and biocides to control bacteria that can blossom and kill well conductivity and cause viscosity instability in fracturing gels; and
- CleanWave, a wellsite wastewater treatment system that allows wastewater to be reused and recycled by the operator, significantly reducing the need for freshwater.

"Halliburton is a recognized industry leader, and takes safety and the environment very seriously," Fisher added.

Schlumberger also has prioritized safety in its operations and technology development. "We have introduced many advances that impact our ability to keep our operations and our people safe," Lafferty said. "Some of these have come in the form of equipment modifications that reduce risk exposure, others in the form of process improvements that identify and eliminate or better manage risks. These advances have allowed us to manage the increase of our clients' activity, while reducing HSE incidents at the same time."

In June, Schlumberger introduced a step change in fracturing technology with the commercialization of its HiWAY flow-channel hydraulic fracturing service, which delivers increased production with 45% less proppant. "Some of the challenges today in fracturing revolve around the scale of the fracture operations and the amount of equipment and volumes of proppant and fluids required," Lafferty added. "Significant advances will come through technologies that deliver improved production results with less equipment and materials."

Weatherford International's focus on safety was highlighted in its first frac job completed in Egypt. "This area was well known for its tight formations – permeabilities on the order of three millidarcies – and a relatively high fracture gradient. These conditions make failure of the fracturing operation a distinct possibility," said Mostafa Amin Amer, regional operations manager of reservoir stimulation and well services for Weatherford's Middle East and North Africa business unit.

The company brought a new fleet of equipment and state-of-the-art fluid technology to the region. In an effort to ensure safe, streamlined frac operations, other Weatherford equipment was incorporated into the project as well, including well-completion technology, engineered chemistry, and wellhead-control valves.

"Our commitment to safe operations is what prompted us to install a safety restraint system on the wellhead," Amer said. "In the event of any overpressure of the pumping line or wellhead, the restraint system limits movement of the equipment, making the operation safer for workers in the field." According to Amer, this safety requirement is so important to the company that the use of a restraint system is mandated in the company's safety policies.

Innovations in fracturing, stimulation

Hydraulic fracturing and stimulation treatments to restore or enhance well productivity are performed in all types of formations and reservoir environments and are critical components of well economics. Production can be maximized not only by creating highly conductive reservoir flow paths, but by selecting the appropriate treatment for each environment. According to Schlumberger, its matrix stimulation and hydraulic fracturing techniques are designed to repair and improve the natural connection of the well bore with the reservoir. "Matrix acidization treatments are used to mitigate the effects of formation damage, the biggest hindrance to productivity in highly permeable reservoirs," according to the company. "Better reservoir knowledge and increasingly sensitive technologies are making production of unconventional gas economically viable and more efficient. This efficiency is bringing tight gas, coalbed methane, and gas hydrates into the reach of more companies around the world."

One innovative technique being used by many frac companies is "simul-fracs," or "zipper fracs," in which two or more parallel wells are drilled and then perforated at alternate intervals along the well bores and fractured at the perforations. This creates a high-density network of fractures between the wells that increases production in both wells. By holding frac pressure on one well while the adjacent well is being fraced, the fractures tend to avoid each other because of the stress pattern set up in the pressured-up well. In the zipper technique, the alternating stages are fraced in sequence, resulting in a maximum of new reservoir rock exposed.

As the industry increases its technological might, challenges that seemed insurmountable just a few years ago are being mastered and put into practice. And although gas shales have captured the most attention for the last several years, the relative price of oil and condensates is driving interest in oil shales and a different fracturing paradigm.

"The challenge in getting better results," Lafferty said, "lies in the process of identifying and integrating the combination of technologies that will deliver improved performance for the specific well and reservoir conditions." ■