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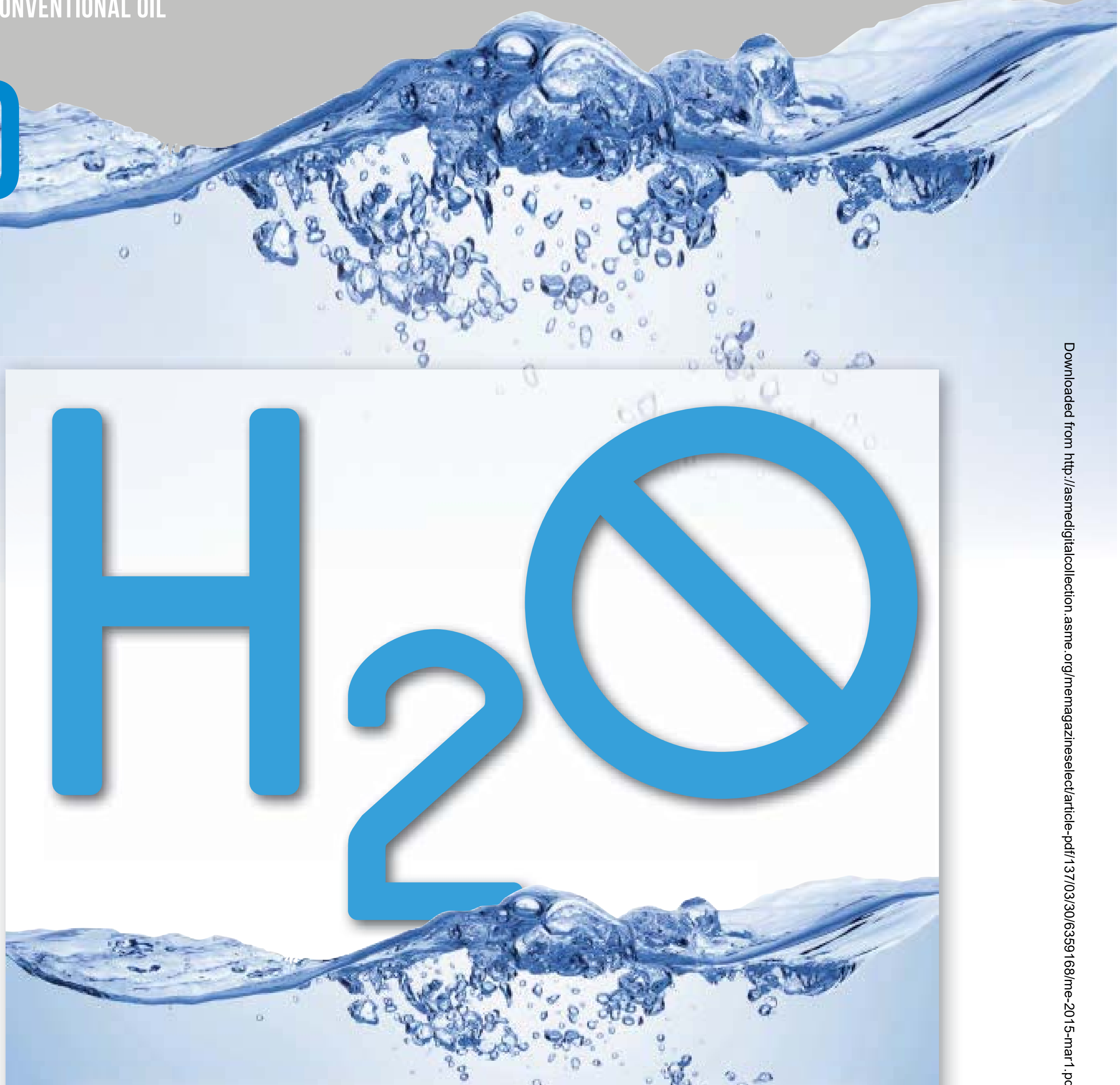

TAKING THE HYDRO OUT OF HYDRAULIC FRACTURING

BY MARK CRAWFORD

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WATERLESS METHODS AIM TO MAKE UNCONVENTIONAL OIL AND GAS WELLS MORE ENVIRONMENTALLY FRIENDLY.

A waterless fracturing operation in progress. Such methods may reduce the perceived environmental impact of "fracking."

THE DROP IN OIL PRICES BELOW $50 A BARREL this winter has been credited to many factors – economic struggles in China, the reduction in turmoil in North Africa, and greater fuel efficiency in automobiles among them. But undeniably, the surge in U.S. oil production had a major effect. In 2014, the United States produced around 3 billion barrels of oil, the most it has produced in a generation and a more than 60 percent increase over its production levels of just a few years before.

That surge is due to unconventional drilling and completion technologies that encompass a number of methods, but which is usually shorthanded as hydraulic fracturing or "fracking." In hydraulic fracturing, explosive charges shatter oil- and gas-bearing strata and then fluids pumped at high pressure force apart the fissures and insert fine grains to prop open the cracks to enable the petroleum to flow out.

The growth in hydraulic fracturing has not been met with universal praise. Indeed, in December, New York State banned the practice on health concerns. Generally, those concerns all come back to water.

First, the water use is immense. A typical hydraulic fracturing job requires between 2 million and 5 million gallons per well. This poses risks for depleting groundwater resources, especially in arid regions where water is scarce and important to other industries, such as ranching and agriculture.

Also, before the water is pumped down the drill hole, a proprietary mixture of chemicals is added to reduce friction, corrosion, and bacterial growth. Local landowners may be concerned that nearby fracking activity could contaminate the aquifers they rely on for drinking water, worries that are not alleviated by the secret nature of the chemical brew.

Fracturing's water problems have led some companies to look at other ways to "frack." Instead of using water as the main downhole fluid, these companies are developing new technologies that

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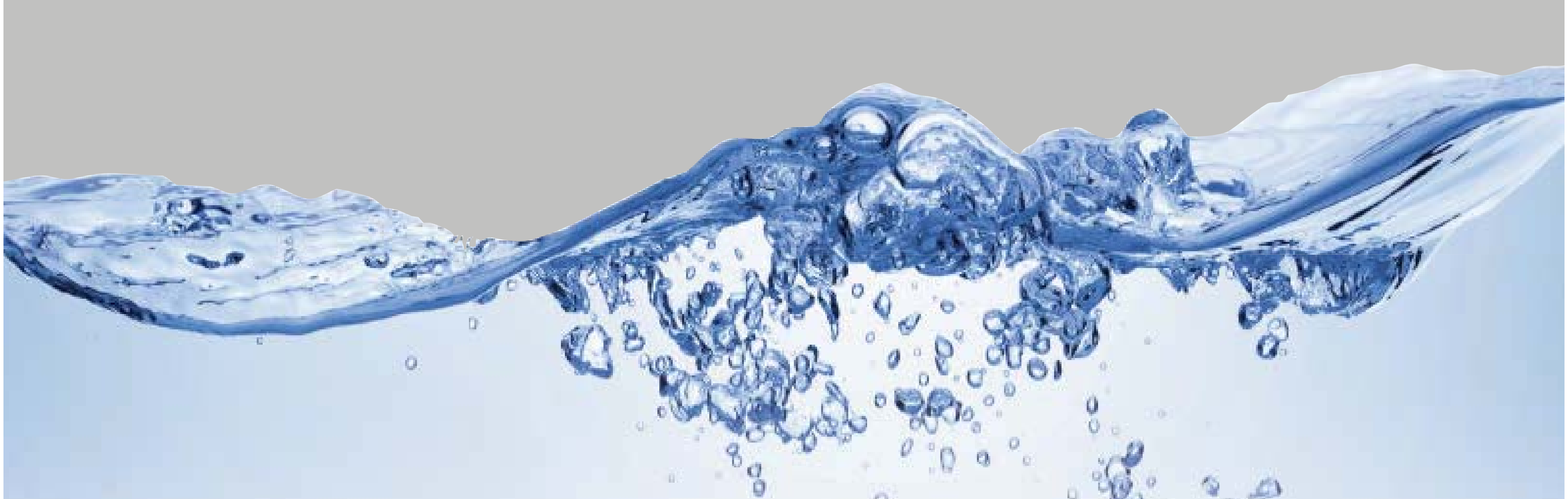

WHAT ARE THE MAIN DIFFERENCES BETWEEN WATERLESS FRACTURING METHODS?

Albert B. Yost II, senior management/technical advisor for the U.S. Department of Energy's Strategic Center for Natural Gas and Oil in Morgantown, W. Va., ran through the options with us.

- **NITROGEN-BASED FOAM FRACTURING** uses a drill fluid that is mostly nitrogen, surfactants, and 8-25 percent water. Compressed nitrogen and a foaming agent are added to a water-based fracture fluid and injected under pressure. According to Yost, "Foam fracturing is highly suitable for low-pressure, tight gas formations that are sensitive to water."
- **CO_2-BASED FOAM FRACTURING** is similar to nitrogen-based foam fracturing but uses compressed carbon dioxide instead of nitrogen. This process can be limited by the availability of carbon dioxide within reasonable trucking, rail, and pipeline distances of well sites. Chesapeake Energy recently tested carbon dioxide foam fracturing on a well site in Ohio.
- **CO2/SAND FRACTURING** uses only sand and carbon dioxide, with no water. A closed-system blender augers sand out of a pressure vessel, which is then mixed and transported with liquid CO_2 down the wellbore. CO_2 is pumped as a supercritical liquid instead of a gas and no other additives are used. This process has been used successfully on hundreds of wells, mostly in Canada.
- **STRAIGHT NITROGEN- OR CO_2-BASED FRACTURING** has been used as an alternative to water-based hydraulic fracturing in shale formations that absorb water and swell, restricting gas flow. The gas is pumped without surfactants or proppant (sand). "This application has also been successful where the horizontal stress differences make proppant less important, or blockages from previous fracturing fluids need to be removed to restore production," Yost said.
- **GELLED-LPG FRACTURING** uses liquefied petroleum gas (LPG) and sand in a closed-system blender. The system has been used successfully in South Texas and western Canada. The gelled propane turns into a gas and exits the well along with the natural gas or oil stream produced, eliminating the need for water to be pumped into a well.

use far less water or, in some cases, no water at all.

Several hydraulic fracturing technologies have been developed over the past few decades that use little or no water. In general, waterless fracturing accounts for less than 3 percent of fracturing jobs in the U.S.

"Even though some of these fracturing methods have been available since the 1970s, they still simply represent a niche share of the market," said Albert B.Yost II, senior management/technical advisor for the U.S. Department of Energy's Strategic Center for Natural Gas and Oil in Morgantown, W.Va.

But to move into places that are unsuitable for–or skeptical of–traditional hydraulic fracturing, these waterless methods need to be brought into the mainstream.

GETTING ENERGIZED

While waterless fracturing is still relatively rare in the U.S., it is more common in operations north of the border. About 25 percent of the fracturing jobs in Canada use waterless techniques, and as many as 40 percent of Canadian horizontal shale wells employ what's called "gas-energized" (foamed) fracking. The method involves using a foamed fluid consisting mostly of carbon dioxide, nitrogen, or methane to deliver both pressure and the proppant into the underground shale formation.

Water is still part of the foamed fluid, however, but it typically is only about 10 to 15 percent of the fluid.

Gas-energized fracturing has a significant advantage over traditional water-based methods: It requires less proppant, which saves money, and it can can double oil and gas recovery from a well. That economic case has led to a surge in interest in foam-based fracturing in the U.S.

Expansion Energy, based in Tarrytown, N.Y., has developed an innovative gas-energized technology that relies on a cryogenic, non-liquid fluid phase of natural gas—also known as cold compressed natural gas. Short for "Vandor's Refrigerated Gas Extraction," Expansion's VRGE process brings in a mobile cryogenic plant to a drill site to produce the CCNG from natural gas from

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nearby wells or from the targeted formation itself. CCNG is very dense and can be pumped like a liquid.

The CCNG is pumped to high pressure with a cryogenic natural-gas pump and then vaporized via heat exchangers into high-pressure compressed natural gas. It is then blended with a proppant-carrying slurry and foaming agent and sent down the well.

This process creates, extends, and holds open fissures in the underground formation. When the pressure is reduced, the proppant holds open the fissures, releasing oil and gas.

Using low-weight hydrocarbons allows operators to recycle fluids in fracturing.

"Instead of relying on complex chemistry like water-based fracturing does, VRGE relies primarily on mechanical processes such as CCNG production (compression and refrigeration), cryogenic pumping, slurry blending and pumping, and fluid phase shifts," said Jeremy Dockter, co-founder and managing director for Expansion Energy.

"By using a hydrocarbon to produce a hydrocarbon," Dockter continued, "VRGE avoids the need for most chemical additives and biocides. Other gas-energized technologies, like CO_2 and N_2, introduce non-hydrocarbon substances into the product stream, which then must be captured and removed, driving up costs and adding logistical complexity. With VRGE, once the well begins to produce, the natural gas simply returns to the surface via the wellbore and can be sold to the market or re-used."

Overall, Expansion Energy says its VRGE process can reduce total completion costs by as much as $2 million per horizontal well versus standard water-based fracturing.

CARBON RECYCLING

Praxair, a supplier of industrial gases based in Danbury, Conn., has developed a system that relies on a different liquefied gas. Its DryFrac technology relies on liquid carbon dioxide that is mixed with sand and sent down the hole under high pressure.

The CO_2 can also be captured as it returns to the surface.

A key challenge that Praxair solved with this technology is the ability to blend the liquefied carbon dioxide and sand at precise concentrations, customizing it to the shale formation being fractured. Carbon dioxide is delivered and stored on the well pad. DryFrac blenders are delivered to the site with the blender vessel in a horizontal position, which is then hydraulically lifted to the vertical operating position and locked in place.

"Once all the piping to and from the blender is connected, sand is pneumatically conveyed into the blender vessel," said Mark Weise, business development director of oil and gas services for Praxair. "We then add liquid carbon dioxide to cool down and pressurize the vessel and sand in preparation for pumping."

After a safety check, completed in coordination with the service company and the operator, CO_2 begins pumping down hole at the specified rate. Praxair's blender delivers the preset concentrations of sand over the course of the stage. Once the sand has been fully pumped, the job is completed and the system can be disassembled and moved to the next well pad.

According to Weise, DryFrac has been used successfully on several jobs. Initial results have shown up to double the production over wells in the same formation that were fractured with water.

"These results are generating an interest within the industry and we expect to see more operators using our technology over the next six to nine months," Weise said.

UNDER THE HOOD

Another waterless method of fracturing wells relies on low-weight hy-

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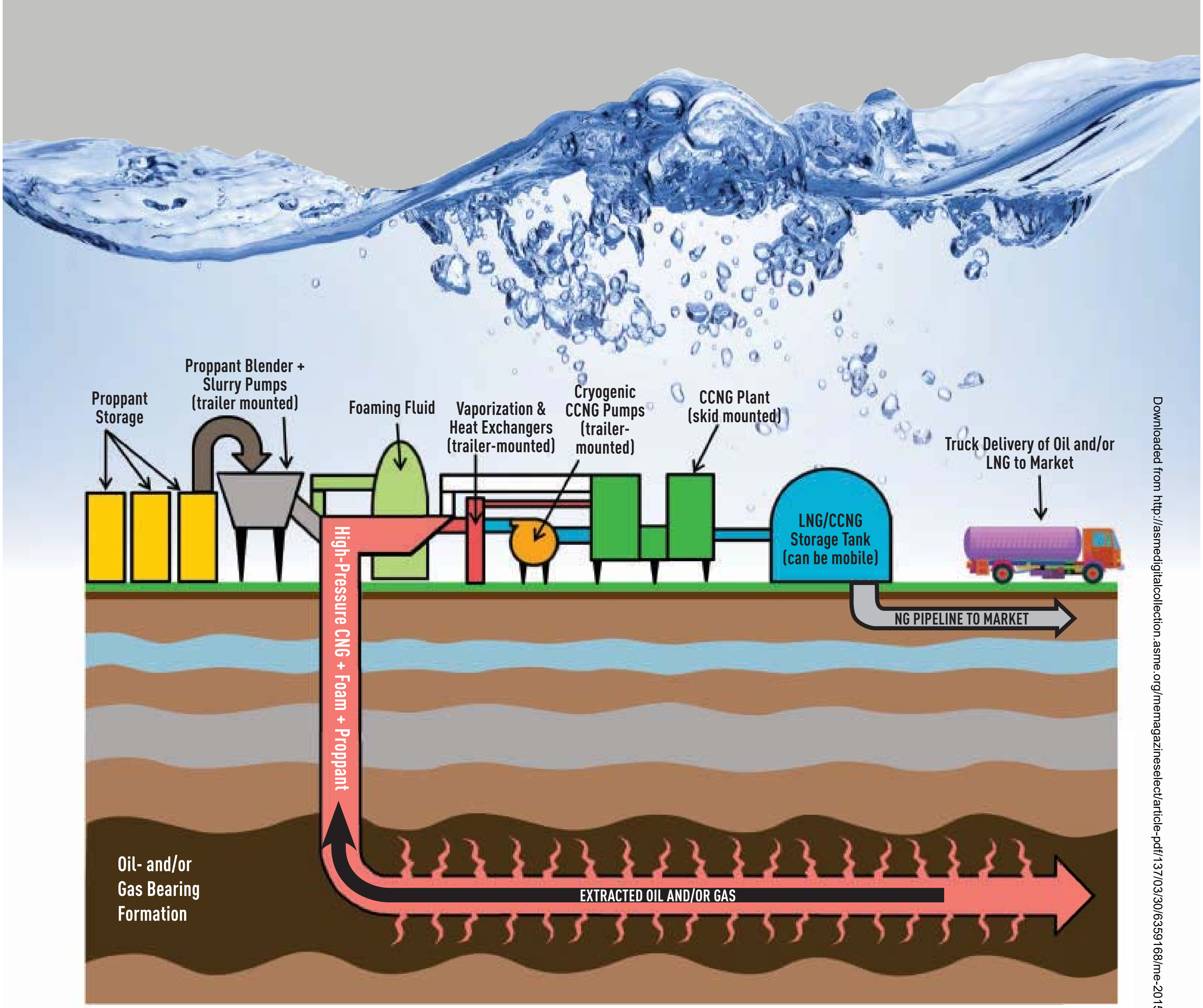

drocarbons such as propane or butane. When the earliest versions of this technology were developed in the 1960s, however, using low-weight hydrocarbons to recover oil was considered to have more safety risks because flammable compounds were being used under high pressure.

To reduce this risk, GASFRAC Energy Services of Calgary has developed a technology to convert these hydrocarbons to a low-flammability gel. The gels are also more effective than water for distributing sand into fractures.

"The unique design of our equipment allows us to safely pump fluids that no one else in the industry can pump," said Greg Brown, director of engineering for GASFRAC.

"We hold multiple patents on the equipment that we utilize for our LPG and HRVP (high Reid vapor pressure) fracturing fluid systems, which represent significant mechanical innovations," Brown said.

"Our ability to custom-engineer properties of the fracturing fluid, such as surface tension and viscosity, allows us to match the same properties of the reservoir fluids, at reservoir conditions," Brown said. "This way we provide the customer with a fracturing fluid that is custom-tailored to their specific reservoir, enhancing hydrocarbon production."

GASFRAC recently received a patent for its new vapor hood, which enables a fracturing crew to pump RVP fluids up to 8 psi. The hood is a modification to a conventional tub-style blender where a sealed assembly sits on top of the blender tub.

"This modification creates a closed system that allows explosive vapors generated by the fluid during pumping to be directed away from equipment to a safe area, where they can be managed effectively," Brown said. "This process allows operators to use recycled fluids previously thought to be too volatile for use as a fracturing fluid."

To date GASFRAC has performed more than 2,000 well completions using this technology. BlackBrush Oil and Gas is currently using this process for some of its wells in South Texas and plans to expand its use in other regions.

CHOOSING WELL

The biggest challenge for waterless fracturing technologies is to consistently deliver improved oil and gas recovery across a range of reservoir con-

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ON THE HORIZON: CRYOGENIC NITROGEN

Engineers at the Colorado School of Mines in Golden have been working hard to develop "cryogenic fracturing"—a waterless fracturing method that uses liquid nitrogen as the drilling fluid. Chilled to temperatures below -321 ˚F, liquid nitrogen is pumped down the hole at high pressure. When the super-cold nitrogen hits the warmer host rock, the rock shatters.

The biggest benefits of cryogenic fracturing are environmental—no water or chemicals are used in the process, and the nitrogen evaporates underground. Initial lab results are promising, with field testing at a drill site planned in 2015.

Two key challenges, however, remain:

1) overcoming liquid nitrogen's lack of energy capacity for carrying sand;

2) keeping the nitrogen cold, both on site and as it travels thousands of feet to the target formation.

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ditions, at an affordable cost.

"Choosing which technique is best for a specific well should be based on economics, environmental impacts, and technical and safety considerations," Yost said. "Any new fracturing process must also overcome the technical and economic barriers of competition from previously capitalized processes, demonstrate improved economic rates of production, and be able to meet the anticipated operational schedules expected by the oil and gas industry.

Brown agreed.

"The biggest research and development challenge facing waterless fracking is the fact that, when a new concept is developed for a fracturing system, companies are typically required to work with manufacturers to develop the equipment for testing and extraction as well," Brown said. "New systems are often incompatible with current equipment, so in order to test it or use it, new equipment has to be custom manufactured. This often becomes very time-consuming and costly, so it represents a major hurdle in new developments."

Even so, in places where hydraulic fracturing's water use is becoming a real constraint to exploiting shale formations, it's likely that petroleum companies will find that it's worth it to make the commitment to waterless fracturing. **ME**

MARK CRAWFORD is a geologist and independent writer based in Madison, Wis.

Some waterless fracturing methods have shown about double the production compared to wells fractured with water.

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