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# 'Nanofluidity' Solves Production Issues

By Monte Swan

EVERGREEN, CO.–Almost since the day oil was discovered, the industry has been grappling with common and costly production problems related to paraffin, asphaltene scale deposition and heavy oil. Mechanical, thermal and chemical mitigation methods–ranging from pigging to hot oiling to solvents and inhibitors–have been the primary means of dealing with these perennial problems. However, the industry has long searched for new solutions to improve the effectiveness and reduce the recurring expenses associated with traditional prevention and remediation methods.

A new approach to managing paraffin, asphaltene, scale and heavy oil harnesses the power of physics to optimize the properties of produced fluids at a molecular level, mitigating some of the industry's biggest challenges within the space of a nanometer. "Nanofluidity" technology creates passive downhole energy that stabilizes the micelle structure of crude oil, preventing mineral and paraffin deposition as well as changes in fluid viscosity as a column of oil rises toward the surface. The produced fluids move smoothly and cleanly through tubing, pumps and pipes to continuously minimize and usually prevent asphaltene, paraffin and scale deposition without the need for chemical, thermal or mechanical treatment.

Nanofluidity can be summarized as the behavior of crude oil and produced water at the nanoscale, which at $10^{-9}$ meters is invisible to the human eye and is recognized as a new scientific frontier. Colorado State University is leading academic research efforts into the nanofluidity frontier under the supervision of Amber Krummel, a professor of chemistry and the director of the CSU-based Krummel Research Group and laboratory.

This research team of physical chemists, condensed matter physicists, theoretical chemists and material chemists are working out the details of the physics and chemistry underpinning nanofluidity in oil and gas wells, and continues to analyze the promising results of ongoing field applications of this new class of downhole tools.

One of the key future aspects of the CSU research work is perfecting the ability to measure, tune and focus the downhole tools to address specific problems with fluid stability in oil and gas applications and optimize asset performance. This may expand the ability to target specific molecules, such as barium sulfate, and help to solve even larger problems associated with produced water.

### Composite Material

The downhole tools are made of a composite material that is not magnetic or radioactive. Quartz crystals, rare-earth elements and semiprecious metals fused with aluminum and "charged," produce the energy wave. The tools require no external power source, maintenance or servicing, and have no internal restrictions.

Configured in four designs (tubing sub, rod pump strainer, rod sub and plunger lift), the tools must be installed below the depth of paraffin/asphaltene

**FIGURE 1**

**Venezuelan Well Paraffin Case History**

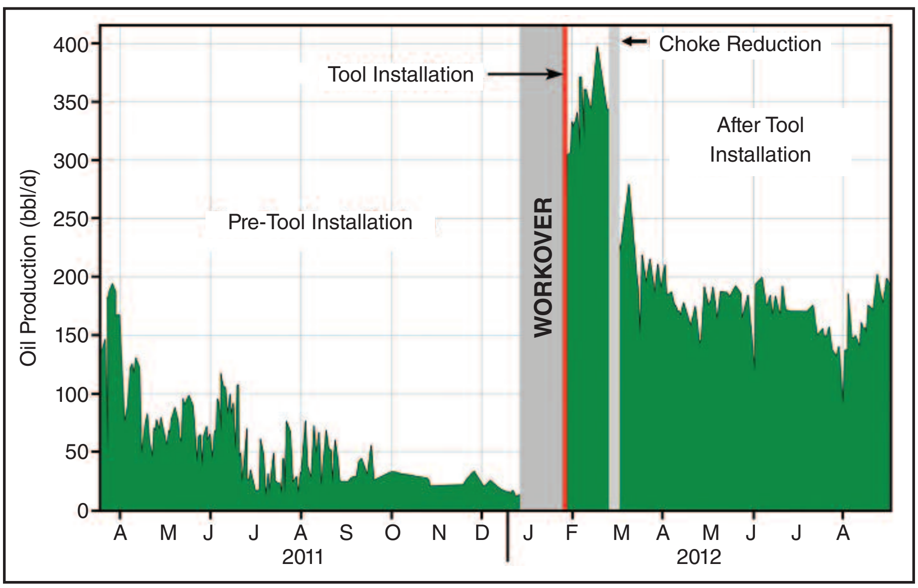
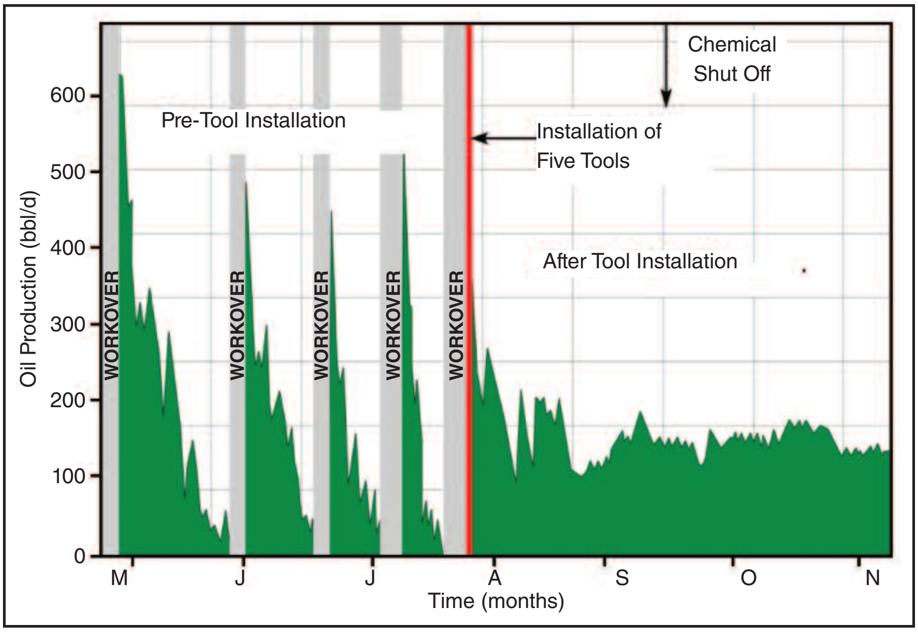


**FIGURE 2**

**Eagle Ford Well Asphaltene Case History**




deposition in a well and the depth at which viscosity begins to increase as the oil moves up the wellbore. For scale problems, depth is not an issue. Multiple tools can be installed in series for increased capacity to accommodate high oil production rates.

The tubing sub tool is designed for downhole installation in the production tubing string of a well. It is installed during a completion operation or workover as an industry-standard, four-foot pup joint that meets required installation specifications. Handling capacities vary by tubing size (e.g., 30 barrels of oil a day for 2⅜-inch tubing, 40 bbl/d for 2⅞-inch tubing, and 70 bbl/d for 3½-inch tubing).

The rod pump strainer, rod sub and plunger lift tools all have the same daily oil capacities: as much as 10 bbl/d for the 12-inch versions, and 15-20 bbl/d for the 28-inch versions. Again, multiple tools can be installed together for higher-producing wells.

The rod pump strainer tool is engineered for downhole installation at the bottom of a rod pump assembly in a producing well. This allows tool installation independent of pulling tubing, making it more cost effective. The rod sub tool is installed when there is a length constraint below the seating nipple. It is installed immediately above the rod pump at the bottom of the rod string. It can be installed whenever the rods are pulled and without pulling tubing.

The plunger lift tool can be installed in a flowing well or in a plunger-lift well. There are two installation options: on top of the seating nipple in a stationary position using an adaptor, or below the seating nipple on the bumper spring assembly. When installed above the seating nipple, a bumper spring assembly is installed by wireline on a slip-stop or collar-stop assembly above the tool.

The tools work in virtually any well that experiences deposition and/or heavy oil viscosity issues, including vertical, directional, horizontal, dual-completions, steam-assisted gravity drainage, water source and water injection wells. They work with free-flowing wells, gas-lifted wells and with nearly any pumping system. Each application is customized for specific wells depending on tubing size and fluid volume. The tools typically are run below the pump intake or above the pump discharge, or in the case of a flowing well, as a tail joint at the end of the tubing string.

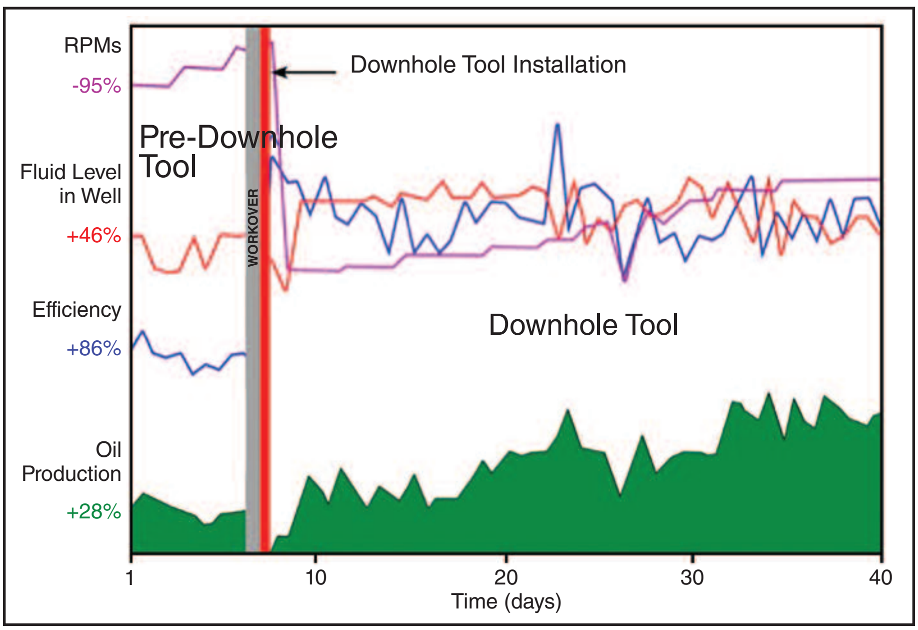
### Well Case Histories

Nanofluidity tools have been applied in diverse geological and reservoir conditions around the world to improve fluid viscosity and effectively combat perennial asphaltene, paraffin, scale, heavy oil-and most recently-bound oil, problems. This improvement has been seen in both low- and high-production volume new wells and stripper wells in mature fields.

Figure 1 shows the "before" and "after" results of installing a series of five tubing sub tools below the depth of initial paraffin crystallization in a free-flowing well in

**FIGURE 3**

**Canadian Well Heavy Oil Case History**



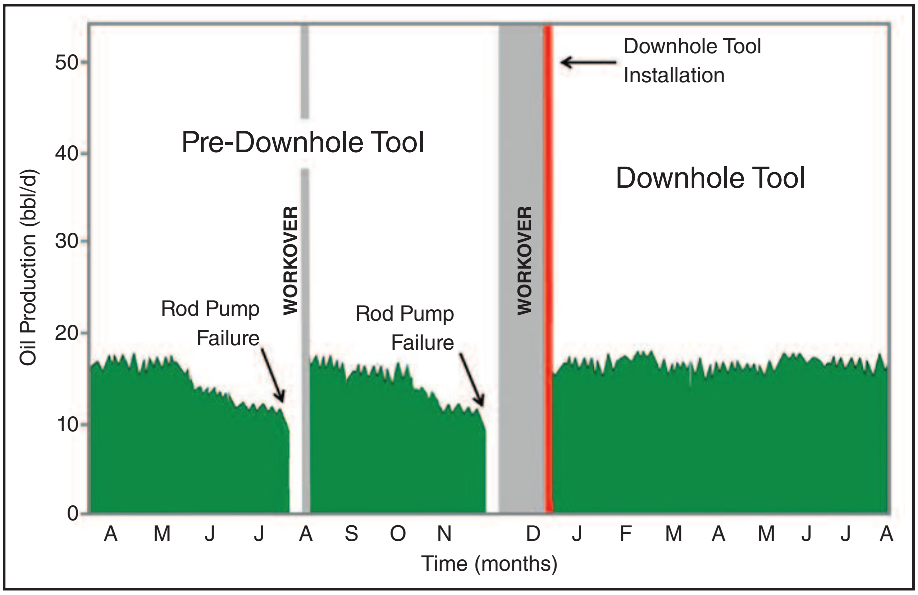
Venezuela. Production rose dramatically after the sub tools were installed. In fact, production from the well increased so significantly that a choke reduction was required following the workover and tool installation. The technology increased paraffin solubility and decreased pour point enough to withstand the up-well decreases in temperature and pressure. This minimized paraffin crystallization and deposition, yielding produced oil higher in paraffin than in samples collected prior to tool installation.

The Eagle Ford Shale well shown in Figure 2 was requiring high-frequency workovers to mediate problems associated with asphaltene and paraffin buildup. Five downhole rod pump strainer tools were installed in the well below the depth of initial paraffin crystallization, and asphaltene flocculation and deposition. The tools continued to stabilize production after the chemical injection system was shut off. The well yielded oil samples that were higher in asphaltene than pre-tool oil samples because of a decrease in asphaltene flocculation and deposition.

In the artificially lifted Canadian oil well shown in Figure 3, a rod pump strainer tool was installed below the depth of initial paraffin crystallization and asphaltene flocculation/deposition. The usual viscosity increase that had occurred as oil flowed upward in the wellbore to lower ambient temperatures was prevented. This caused an 86 percent increase in efficiency, a 28 percent increase in production, a 46 percent fluid level and hydrostatic pressure rise, and a 95 percent drop in rod pump speed and hydraulic pressure.

**FIGURE 4**

**Generic Scale Case History**




Unlike paraffin and asphaltene that require tools to be installed at depth, calcium carbonate mineral scale can be prevented at surface temperatures and pressures as well as down hole. The tool minimizes scale deposition by causing calcium carbonate to tend to crystallize as nonscale-forming aragonite, rather than scale-forming calcite. Aragonite has far less propensity for deposition than calcite. Nanofluidity technology also promotes the release of any calcite mineral scale that was previously deposited on surfaces before tool installation.

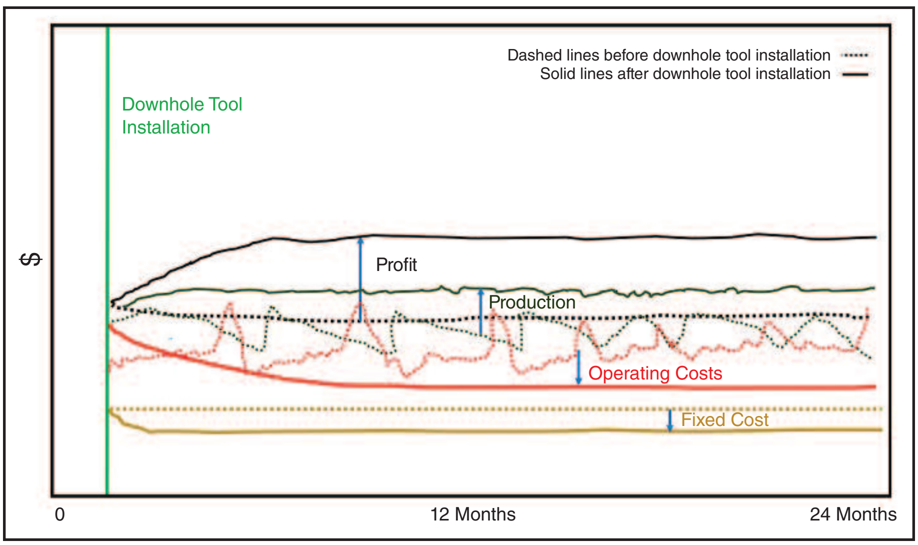
Rod pump strainer tools also have been applied successfully in rod-pumped oil wells in New Mexico below the depth of initial calcite mineral scale precipitation and deposition. Figure 4 is a generic graph that shows typical results of installing a tool in a well with scale problems. Pump failures are what usually shuts down these wells, so the case histories are essentially the same for wells with scaling problems.

The working hypothesis to explain the tool's effect on scale deposition is that calcite and aragonite contain the same ions and have the same charges, but the charges are not distributed the same in each crystal polymorph because of differing crystal structures. Calcite's crystal system is trigonal with three common crystal surfaces: {1014} with a neutral charge and {0112} and {0001}, one being negative and one being positive. Therefore, calcite crystals tend to stick to one another and grow on negatively-charged metal surfaces. Consequently, calcite has a high probability of depositing on itself and on well and pipeline materials, especially metals.

On the other hand, the surface charge distribution of aragonite is positive at the

**FIGURE 5**

**Net Cost Analysis**



tips of its pseudo hexagonal orthorhombic crystals. The spindle-like topography of the crystals with a positive charge only at its tips results in a lowered attraction between crystals and metal surfaces. This results in a high probability of aragonite remaining dispersed in the solution and not depositing on rod pumps, metal surfaces and perforations.

### Economics And Benefits

As all of these field applications demonstrate, nanofluidity technology decreases operating expenses (i.e., workover frequency, refinery time to extract chemicals from oil and water, etc.) and direct costs (i.e., downhole chemicals, hot oiling and knife cuttings, downhole heaters, flowline cleaning, surface facilities maintenance, refurbishment, replacement, vehicle transportation, etc.). In addition, pump and sucker rod life are be extended.

At the same time, production is stabilized and often increases with decreased viscosity, pour point and asphaltene, paraffin and scale depositions. These inverted relationships directly decrease operating expense (Figure 5) The cost reductions resulting from installing a tool can increase well and field life (delaying abandonment), booked reserves and recovery factors.

Therefore, the cost of installing the tool is more than offset by increased production revenues and reduced costs. Moreover, measurable benefits for the environment include decreased environmental disturbances and improved environmental reputation and compliance. If production is doubled, which is possible, the economic result will be the same as if the oil price had doubled.

### The Science Of Nanofluidity

After several initial experiments, CSU researchers theorize that the nanofluidity tool is a type of "bandpass filter," meaning that it allows energy frequencies within certain ranges to pass through, while rejecting or attenuating frequencies outside these ranges. The ambient or resident energy of oil reservoirs is characterized by pressure, temperature and chemical energy gradients. These generate energetic waves such as optical, acoustic or phonon waves. The waves enter on the downhole tool and are filtered or modulated as they move through the tool's material. The resultant waves then travel through the brine in the crude oil emulsion and can be absorbed by the hydrocarbons.

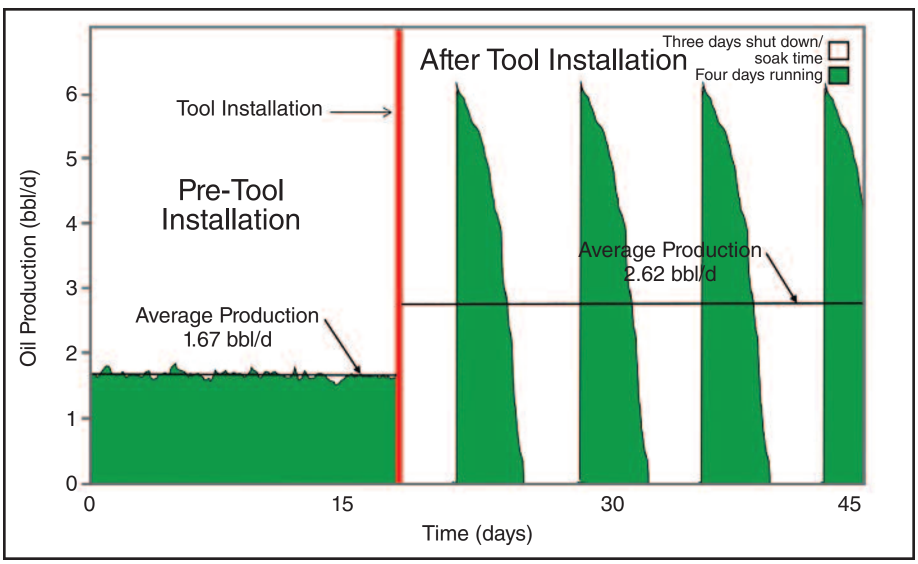
The waves that have passed through the tool's material seem to drive low-frequency molecular vibrations, influencing the molecular interactions that play roles in crystallization, aggregation and flocculation processes. Consequently, physics (kinetics) is driving chemistry. For example, the vibrations affect the hydrocarbon molecules at the nanoscale, which affects molecular characteristics such as solubility, interfacial tension, crystal nucleation and growth, oil gravity, and micelle stability in crude oil.

Many types of molecules in crude oil can move with various degrees of freedom, and as such, can interact with one another in many different ways. This attribute is described by a rough free energy landscape. While in a reservoir under elevated temperatures and pressures, crude oil is stable, although positioned on a "saddle" in the energy landscape. Decreasing temperature and/or pressure and increasing oxidation state as the oil flows out of the reservoir into the well bore and rises toward the surface causes the oil to move off the saddle and down the energy landscape. Thus paraffins crystallize, asphaltenes aggregate, calcite precipitates and the viscosity of the oil tends to increase.

The tool transmits energy to the fluid through the filtered or modulated frequencies emitted. The energy is absorbed by the molecules in the fluid, stabilizing the constituents of the crude oil. This occurs as the oil moves off the energy landscape saddle into an energy landscape minimum, where it is stable and resists movement down the energy landscape as the fluid flows up the well and pressure and temperature decrease while the oxidation state increases. Improved paraffin solubility, oil pour point and asphaltene stability and the nucleation of aragonite crystals instead of calcite crystals maintain the (lower) downhole viscosity of the oil, allowing more oil to be produced from the reservoir.

**FIGURE 6**

**Oklahoma Stripper Well Case History**




### Reviving Mature Fields

CSU is working in a number of mature U.S. oil fields. Operators and owners of mature oil assets face many challenges. Commonly, mature fields are under secondary recovery and often are associated with decades of flat and declining production. The conventional approach to improving the economics of marginal fields is to reduce lease operating expenses, which usually increase over time. Additionally, lower product prices and increased regulatory and environmental pressures create an overwhelming sense of economic hopelessness for many operators and communities.

The downhole tools offer relief to stripper well operators by substantially reducing lease operating expenses while stabilizing (and usually increasing) average production. This results in positive long-term economic changes to many presently uneconomic wells, and can even result in reduced fixed costs. Initial stripper well field trials have been highly successful and have provided surprising results.

A case in point is a stripper well in Osage County, Ok. A rod pump strainer was installed below the depth of initial paraffin crystallization and asphaltene flocculation, scale precipitation and deposition, and increased viscosity. The well was shut down for three days. Pumping then resumed for four days, resulting in a 64 percent increase in total production, as illustrated in Figure 6. The operator also saw decreased electricity consumption and monitoring costs.

In New Mexico, six stripper wells were shut down for a number of months after downhole nanofluidity tools had been installed because of both weather issues and financial constraints. Two of the wells subsequently were opened and flowed on their own. Neither had ever produced without pumping units and chemicals after being shut for such an extended time.

Given the results of these early applications, a stripper well field study program has been initiated to assess the impact of the downhole tools on the economics of mature fields. As part of its ongoing research efforts, CSU is conducting a variety of laboratory tests for the study. In fact, CSU scientists are analyzing oil samples both before and after installing tools in cost-free field trial wells to provide producers with empirical data documenting the technology's affect. This reduces virtually all the economic risk associated with installing a tool on a trial basis.

To date, producers in Wyoming, Utah, New Mexico, Colorado, Kansas, Illinois, Indiana, Kentucky, Ohio and West Virginia have partnered with CSU to deploy test tools. A limited number of new wells and nonstripper wells that produced for a time and then developed paraffin, asphaltene, scale and/or heavy oil problems also will be included in the study, such as Alaska, with the goal of eventually establishing the downhole nanofluidity tools as a core technology in the petroleum industry. In addition, companies in Utah, Illinois, Ohio and Oklahoma are preparing to test the deployment of surface tools on water injection wells.

The results from all of these tests will be presented publicly so that all involved in the oil and gas industry can benefit. The goal of the program is to see if the economics of stripper oil wells that are currently uneconomic can be changed, resulting in increased cash flows into local counties, communities and families, thereby creating jobs and helping to reverse the economic declines seen in many oil-producing regions across the nation. ❒

**MONTE SWAN**

*Monte Swan is chief scientist at Revelant, which has developed the patent-pending Enercat™ nanofluidity tools, and is involved in Colorado State University's research partnership to investigate and document field applications of the technology. Based in Evergreen, Co., Swan also co-founded MagmaChem, an international research and exploration consulting company that developed risk-lowering mineral and petroleum exploration technologies. He holds a B.S. in geological engineering from Michigan Technological University and an M.S. in geology from the University of Arizona.*