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Downhole Oil/Water Separators – What Has Happened in the Past Year[1]?

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Abstract

Downhole oil/water separator(s) (DOWS) technology holds great promise for reducing produced water disposal costs and protecting drinking water aquifers. It has, in some instances, increased production of oil from wells in which it has been installed. DOWS technology was gaining acceptance in the industry when oil prices fell to historic lows during 1999. For months, no new DOWS were installed. As oil prices gradually rose to the current comfortable levels, interest in DOWS technology has begun to increase again. This paper reviews the basics of DOWS technology and provides information on what DOWS-related activities have taken place during the past year.

Review of DOWS Technology[2]

DOWS technology reduces the quantity of produced water that is handled at the surface by separating it from the oil downhole and simultaneously injecting it underground. A DOWS system includes many components, but the two primary ones are an oil/water separation system and at least one pump to lift oil to the surface and inject the water. Two basic types of DOWS have been developed: one type uses hydrocyclones to mechanically separate oil and water, and one relies on gravity separation that takes place in the well bore. The technology was described in a 1999 report (Veil et al. 1999a) sponsored by the U.S. Department of Energy (DOE), as well as in conference papers (Veil et al. 1999b) and an *Oil and Gas Journal* article (Veil et al. 1999c).

A hydrocyclone uses centrifugal force to separate fluids of different specific gravity without using any moving parts. A mixture of oil and water enters the hydrocyclone at a high velocity

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[2] Throughout this paper, companies or organizations that have developed DOWS technology or are currently suppliers of DOWS technology are mentioned by name. Reference to these companies does not constitute an endorsement of those companies or provide any indication of their performance capabilities. Inclusion of their names in this report is made for historical reference and for the benefit of potential users of the technology. Omission of any other legitimate vendors of DOWS technology is unintentional.

from the side of a conical chamber. The subsequent swirling action causes the heavier water to move to the outside of the chamber and exit through one end, while the lighter oil remains in the interior of the chamber and exits through a second opening. The water fraction is then injected underground and the oil fraction is pumped to the surface. Hydrocyclone-type DOWS have been designed with electric submersible pumps, progressing cavity pumps, and rod pumps. Most of the development work on this type of DOWS was done through several joint industry projects by a Canadian organization, C-FER Technologies.

Gravity separator-type DOWS are designed to allow the oil droplets that enter a well bore through the perforations to rise and form a discrete oil layer in the well. A gravity separator tool has two intakes, one in the oil layer and the other in the water layer. The gravity separator-type DOWS use rod pumps. As the sucker rods move up and down, the oil is lifted to the surface and the water is injected. The most common gravity separator-type DOWS is the dual-action pumping system (DAPS) developed by Texaco. Over the past year, an improved version that develops greater injection pressure – the triple-action pumping system (TAPS) – has been tested (Wacker et al. 1999). The TAPS achieves greater injection pressure by adding a third, bottom plunger that has a smaller surface area than the middle plunger.

Reasons to Install DOWS

Produced water lifting, treatment, and disposal costs are important components of operating costs. DOWS can save operators money by reducing produced water management costs. In all of the 29 DOWS installations examined by Veil et al. (1999a) that had both pre- and post-installation data, DOWS reduced the volume of water brought to the surface. The percent reduction ranged from 14% to 97%, with most of those installations exceeding 75% reduction in water brought to the surface.
In over half of the North American wells in which DOWS have been installed, the oil production rates increased following the installation. The percent increase in oil production rates ranged from 11% to over 1,100%, although a few wells lost oil production (Veil et al. 1999a). In some cases where surface processing or disposal capacity is a limiting factor for further production within a field, the use of DOWS to dispose of some of the produced water may allow additional production in that field.

DOWS provide a positive but unquantifiable environmental benefit by minimizing the opportunity for underground sources of drinking water to become contaminated through leaks in tubing and casing during the injection process. Likewise, DOWS minimize spillage of produced water onto the soil at the surface because less produced water is handled at the surface.

Economic Considerations

Nearly all of the DOWS installations to date have been made as retrofits to existing wells with standard pumps. Conversion of a well from a regular pump to DOWS technology is a relatively expensive undertaking. Total costs include the cost of the DOWS tool itself and well workover expenses. Veil et al. (1999a) provides limited information on costs, but many of the operators polled by the authors did not provide any detailed cost information.

Costs for the hydrocyclone-type DOWS are high. For example, the cost of an electric submersible pump-type DOWS system is approximately double to triple the cost of replacing a conventional electrical submersible pump; it is often in the range of $90,000 - $250,000, excluding the well workover costs, which can often exceed $100,000. Costs are somewhat lower for the gravity separator-type DOWS, ranging from $15,000 - $25,000. The cost of one complete gravity separator-type DOWS installation was $140,000 Canadian (Veil 1999a).

Performance of Early Trials

Fewer than 100 DOWS have been installed worldwide. Veil et al. (1999a) provides information on the geology and performance of 37 of these installations. The rate of oil production increased in 19 of the trials, decreased in 12, stayed the same in 2, and was unspecified in 4. The top three performing hydrocyclone-type wells showed oil production increases ranging from 457% to 1,162%, while one well lost all oil production. The top performing well improved from producing 13 barrels per day (bpd) to producing 164 bpd. The top three gravity separator-type wells showed oil production increases ranging from 106% to 233%, while one well lost all oil production. The top performing well in this group improved from 3 to 10 bpd. In all 29 trials for which both pre-installation and post-installation water production data were available, the amount of water brought to the surface decreased. The decrease ranged from 14% to 97%, with 22 of 29 trials exceeding 75% reduction.

Problems That Have Been Experienced

Despite the success of many of the early trials, numerous other installations either did not work well from the start or lost good performance within a few weeks or months, necessitating removing the DOWS from the well and repairing it. The problems can be broken down into several major categories, as noted below:

- Some installations were poorly chosen or designed. Some operators didn't want to risk damaging good performing wells with a new device and selected less-than-optimal candidate wells. Particularly in the earliest installations, many of the design flaws had not been worked out. For example, valves failed or narrow-diameter transfer tubes or electrical cables became crimped or broken during installation. Subsequent models avoided some of these pitfalls.

- Some installations did not allow for a suitable difference in depth between the producing and the injection interval. If isolation between the intervals is not sufficient, the injectate can migrate into the producing zone and then short-circuit into the producing perforations. The result is recycling of the produced water, with oil production rates dropping to nearly zero.

- At two installations, incompatible injected fluids contacted sensitive reservoir sands, which plugged part of the permeability and reduced the injectivity.
- Several installations suffered from corrosion or scaling. This problem has resulted from incompatible chemistry between the producing and injection formations.
- Several other installations had problems with excessive sand collection that either clogged the formation or eroded the DOWS.

Current Status of DOWS Technology

At the time Veil et al. (1999a) was released, three companies were actively marketing DOWS tools in the United States: Centrilift, REDA Pumps, and Dresser/Axelson. During 2000, only Centrilift continued to actively market the technology. REDA plans further research and development, but it does not plan to actively market DOWS technology until it believes that at least 80% of installations will be economically successful (Schrenkel 2000). The author was unable to contact a Dresser/Axelson representative to learn of that company's plans to continue marketing DOWS.

In Canada, Quinn Pumps marketed several DOWS tools, but has not had any installations during the past two years. Quinn is still marketing DOWS systems and hopes to have new installations in 2001 (Collins 2000).

Texaco was a leader in developing gravity separator-type DOWS technology. However, during the past two years, Texaco disbanded its core group of DOWS researchers (some have retired and others have been reassigned to different projects). One Texaco well with an installed DOWS system was sold, and the DOWS was removed from the well.

Centrilift has five active installations in the United States, Argentina, France, and China. The Chinese installation is the first offshore trial of DOWS technology. After a successful installation and startup, the unit performance results were poor. Analysis suggested that the injected water had recirculated to the producing zone. After three weeks, the DOWS was pulled from the well. Upon surface inspection, Centrilift found that two pressure port plugs had been omitted. The DOWS is being reassembled and tested before reinstallation in the first quarter of 2001
(Voss 2000).

On a brighter note, the U.S. installation has been running successfully for 20 months, and the French installation has done even better: 25 months of performance. The French installation operates somewhat differently than do typical DOWS operations, in that oil and water are separated downhole, but both streams are separately brought to the surface. The water stream is then reinjected (Voss 2000).

It is interesting to note that although use of DOWS technology started out in North America, many of the new installations and probable installations for the next year or two are in other parts of the world. Some countries (other than those mentioned above) in which DOWS are likely to be tried in the next year or two include Venezuela, Colombia, Ecuador, Austria, Italy, Egypt, Saudi Arabia, Oman, Indonesia, and Australia (Voss 2000).

DOE-Sponsored DOWS Data

In 1998, DOE transferred funds to Argonne National Laboratory to be shared with operators to partially defray the cost of several DOWS installations. In exchange for the DOE funds, operators were to provide performance details on the well for six months following installation. Argonne has had poor success in distributing this federal funding. Through December 2000, only one company was interested enough to complete a co-funded field trial: a TAPS installation on a Texaco well in New Mexico. A final report summarizing the performance of that DOWS, including daily data, was published in May 2000 (Veil 2000a). The data from that report were included in a paper presented at the 2000 Produced Water Symposium (Veil 2000b).

This fall, Argonne signed a contract with Avalon Exploration, an Oklahoma-based independent producer, to co-fund a DOWS installation in Oklahoma. The installation had been scheduled for November 2000, but because of drilling rig availability problems, the installation date was moved back to February 2001. A hydrocyclone-type DOWS will be installed in a new well (most of the previous trials have involved a retrofit). A data report from this installation should be available in 2002.

In late 1998, Unocal installed a DOWS system in a well near Van, Texas. The performance data from this well have never been made publicly available. Argonne and Unocal signed a legal agreement giving Argonne access to Unocal's DOWS performance data in exchange for analyzing the data. As of December 2000, a draft data analysis report was undergoing review. Argonne hopes to publish the data from this well some time during 2001.

In 1999, DOE awarded a large grant to Venoco, Inc., a southern California offshore producer, to conduct a pilot application using downhole water separation units attached to electric submersible pumps. The goal was to improve field economics and minimize water disposal in the South Ellwood Field, offshore from Santa Barbara, California. As of December 2000, Venoco reported that the first phase of the project – reservoir and fracture characterization – is underway. Downhole separation is still at least a year and a half away (Christensen 2000).

What's New in DOWS Technology?

Over the past two years, several other companies have introduced DOWS systems or other related tools. Wood Group ESP, Inc., has developed a two-stage hydrocyclone-type DOWS system but is not marketing the product heavily at the moment. One unit underwent a surface test in Venezuela, but has not been installed in a well yet. A field trial is scheduled for 2001.

According to a representative of the company, its DOWS requires a larger diameter pipe to accommodate the tool, but it is easier to install than some other types of DOWS (Barry 2000).

C-FER Technologies has worked with PanCanadian Petroleum to develop and test a new class of hydrocyclone-type DOWS devices that operate with gas-lift pumps. This technology has strong implications for offshore wells. The first stage of the system separates the free gas from the oil and water. In the second stage, the oil and water are separated through the use of a hydrocyclone. The oil is commingled with separated free gas and lifted to the surface, and the water is injected. The system is designed to process about 2,500 bpd in 7-inch casing and about 15,000 bpd in 9 5/8-inch casing. The design operating conditions are greater than 85% water cut (the proportion of water in the produced fluids) and up to 85% free gas (Alhanati 2000). C-FER has built and tested a full-scale prototype of the system and is now evaluating candidates for a field trial. A recent industry journal provides a diagram and brief description of the tool (JPT 2000a).

Three European companies – Weir Norge A/S, Kvaerner Oilfield Products Norway, and Norsk Hydro – have collaborated to develop a new class of gravity-separation DOWS known as the H-SEP. The design allows gravity separation to take place in the horizontal section of an extended reach well. The downhole conditions allow for rapid separation of oil and water. Oil is lifted to the surface, while water is injected by a hydraulic submersible pump, powered by either water or oil. The hydraulic submersible pump can produce more than enough pressure to fracture the rock in the injection formation. The H-SEP has been pilot-tested at an aboveground testing facility in Norway and is scheduled for a full-scale field demonstration at an offshore well during 2001. The developers of the H-SEP claim their technology can work across the entire spectrum of water cuts (1% to more than 90% water), whereas most of the other DOWS systems work well only when the water cut is high. This feature allows the H-SEP to be installed in new wells. No technical papers on the H-SEP were found. More information can be found at web sites operated by the three partners. The site located at http://www.kvaerner.com/oilgas provides good background information. A brief description and a drawing of the system can be found in an industry journal (JPT 2000b).

The final new technology discussed here is not truly a DOWS, but it involves remote oil/water separation nonetheless. ABB developed a subsea separation and injection system (SUBSIS) that separates the produced fluids from an offshore well at a treatment module located on the sea floor. Because size is not limited to the dimensions of a well bore, SUBSIS is much larger than the DOWS tools previously described. The first pilot tool weighs 350 tons and has a separator module that is 10 meters long by 3 meters in diameter and an injection and pumping module that stands 5 meters high. This pilot device was installed in May 2000 at Norsk Hydro's Troll field, in water at a depth of 350 meters. The initial results indicated that 23,900 bpd of produced fluids were separated into 16,350 bpd of oil and gas and 7,550 bpd of water. The water was injected into a dedicated injection well directly from the SUBSIS unit (Offshore 2000; Wolff 2000).

The last item included in this section is not a specific technology *per se*, but an innovative approach to recover more oil from a field in a shorter amount of time. The so-called π-mode production strategy (Ehlig-Economides and Economides 2000) relies heavily on the use of downhole oil/water separators to reinject water into the same formations from which the fluids originated and maintain formation pressure. This process accelerates the rate of recovering the available oil.

Summary

The market for DOWS technology has been very slow for the past two years. Much of this situation can be attributed to the low price of oil during 1999 and the nervousness of operators to try relatively unproven technology. Many DOWS trials have not proved economically successful, and operators have hesitated testing the waters. Some vendors have ceased actively marketing their DOWS technology for the time being. On a brighter note, oil companies around the world are seriously considering ordering or testing DOWS technology during the next year. The first offshore installation of a DOWS took place in China during 2000. Other offshore trials may follow this year. Several new variations on DOWS and remote separation systems offer exciting potential for different segments of the market. 2001 should be an exciting year for DOWS observers.

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