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Downhole Oil/Water Separators Offer Lower Costs and Greater Environmental Protection

John A. Veil
Argonne National Laboratory
Washington, DC

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ABSTRACT

Produced water management can be a significant expense for oil and gas operators. This paper summarizes of a study of the technical, economic, and regulatory feasibility of a relatively new technology, downhole oil/water separators (DOWS), to reduce the volume of water pumped to the surface. The study was funded by the U.S. Department of Energy and conducted by Argonne National Laboratory, CH2M Hill, and the Nebraska Oil and Gas Conservation Commission. DOWS are devices that separate oil and gas from produced water at the bottom of the well and reinject some of the produced water into another formation or another horizon within the same formation, while the oil and gas are pumped to the surface. Since much of the produced water is not pumped to the surface, treated, and pumped from the surface back into a deep formation, the cost of handling produced water is greatly reduced. The oil production rate has increased for more than half of the DOWS installations to date.

INTRODUCTION

The U.S. Department of Energy's (DOE's) National Petroleum Technology Office is interested in new technologies that can bring oil to the surface at a lower cost or with less environmental impacts. DOE is particularly interested in technologies that can accomplish both of these goals. Downhole oil/water separators (DOWS) have the potential to reduce operating costs while providing a greater degree of environmental protection. DOE learned of the innovative DOWS technology and funded a team of Argonne National Laboratory, CH2M Hill (a private-sector consulting firm), and the Nebraska Oil and Gas Conservation Commission (a state agency) to conduct an independent evaluation of the technical feasibility, economic viability, and regulatory applicability of the technology. The results of that investigation were published in January 1999 (1) and represent the most complete publicly available reference material on DOWS technology. The full text of the report can be downloaded from Argonne's website at www.ead.anl.gov.

The authors of the DOWS evaluation have published other summaries of the report in widely distributed venues (2, 3). Therefore, to avoid unnecessary duplication, the discussion provided here is general in nature. More detailed text, tables of data, and figures showing the design of various types of DOWS can be obtained from references 1-3.

WHAT IS DOWS TECHNOLOGY?

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 using hydrocyclones to mechanically separate oil and water and one relying on gravity separation that takes place in the well bore.

Hydrocyclones separate fluids of different specific gravity using centrifugal force without any moving parts. A mixture of oil and water enters the hydrocyclone at a high velocity 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 while 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, CFER-Technologies. Some of the hydrocyclone-type DOWS installations have been described in the literature (for example, references 4 and 5).

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 (6), but over the past year, an improved version that develops greater injection pressure, the triple-action pumping system (TAPS) (7), has been tested.

Hydrocyclone-type DOWS can handle oil and water flow volumes up to 10,000 barrels per day (5) while gravity separator-type DOWS can handle up to 1,000 barrels per day (6). Most DOWS installations have been set up with the producing zone above the injection zone.

WHY SHOULD OPERATORS 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 in reference 1 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 (1). 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 can allow additional production in that field.

DOWS provide a positive but unquantifiable environmental benefit through minimization of the opportunity for contamination of underground sources of drinking water 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.

HOW MUCH DOES IT COST TO INSTALL A DOWS?

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 a DOWS is a relatively expensive undertaking. Total costs include the cost of the DOWS tool itself and well workover expenses. Reference 1 provides limited information on costs, but many of the operators polled by the authors of that report 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 and is often in the range of \$90,000 - \$250,000, excluding the well workover costs, which can often exceed \$100,000 (8). Costs are somewhat lower for the gravity separator-type DOWS, ranging from

$15,000 - $25,000 (9-12). The cost of one complete gravity separator-type DOWS installation was $140,000 Canadian (13).

WHAT SHOULD AN OPERATOR LOOK FOR WHEN SELECTING A CANDIDATE WELL FOR DOWS INSTALLATION?

Not all wells or reservoirs are likely to work well with DOWS. Some DOWS installations have been very successful and have paid back their investment cost in just a few months. Some other installations have never worked or have reduced oil production. Knowledge of the reservoir and historical production is important before selecting a DOWS installation. Some of the characteristics of wells that are likely to work well with DOWS are:

- a high water-to-oil ratio

- the presence of a suitable injection zone that is isolated from the production zone

- compatible water chemistry between the producing and injection zones

- a properly constructed well with good mechanical integrity.

ARE DOWS IN COMMON USE?

To date, fewer than 50 DOWS have been installed in North America. Reference 1 provides information on the geology and performance of 37 of these installations. Some of the key findings from those installations are summarized below.

- More than half of the installations have been hydrocyclone-type DOWS (21 compared with 16 gravity separator-type DOWS).

- Twenty-seven installations have been in Canada and 10 installations have been in the United States.

- Of the 37 DOWS trials described in the report (1), 27 have been in four producing areas – southeast Saskatchewan, east-central Alberta, the central Alberta reef trends, and East Texas.

- Seventeen installations were in 5.5-inch casing, 14 were in 7-inch casing, 1 was in 8.625-inch casing, and 5 were unspecified.

- Twenty of the DOWS installations have been in wells located in carbonate formations and 16 in wells located in sandstone formations. One trial did not specify the lithology. DOWS appeared to work better in carbonate formations, showing an average increase in oil production of 47% (compared with an average of 17% for sandstone formations) and an average decrease in water brought to the surface of 88% (compared with 78% for sandstone formations).

- 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 13 to 164 barrels per day. 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 barrels per day.

- All 29 trials for which both pre-installation and post-installation water production data were provided showed a decrease in water brought to the surface. The decrease ranged from 14% to 97%, with 22 of 29 trials exceeding 75% reduction.

The total number of installations in other parts of the world is small. All DOWS installations to date are at onshore wells, although several joint industry projects are attempting to adapt DOWS systems for offshore use.

Throughout the end of 1998 and the first half of 1999, oil prices declined to near historical lows. Oil companies struggled to make ends meet and stopped investing in new technologies. Few DOWS were installed during the first half of 1999. During the summer of 1999, a few new installations were made, but the technology has not yet been widely adopted.

WHY HAVE SOME DOWS UNITS EXPERIENCED PROBLEMS?

Although most of the DOWS installed to date have worked well, some of the installations have experienced problems that have impeded their ability to function properly. 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. Subsequent models avoided some of these flaws.

- Some installations did not allow 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 will be recycling of the produced water, with oil production rates dropping to nearly zero.

- Two installations suffered from low injectivity of the receiving zone; in both cases, incompatible fluids contacted sensitive reservoir sands, which plugged part of the permeability.

- Several installations suffered from corrosion or scaling. This problem may be a result of incompatible chemistry between the producing and injection formations.

- Several other installations had problems with excessive sand collection that either clogged or eroded the DOWS.

REGULATORY ISSUES

Traditional produced water disposal wells are considered to be Class II injection wells under the U.S. Environmental Protection Agency's (EPA's) Underground Injection Control program. EPA's definition of Class II wells is "wells which inject fluids: (1) which are brought to the surface in connection with conventional oil or natural gas production....; (2) for enhanced recovery of oil or natural gas; and ...". In the case of DOWS, the separated produced water is directly injected to a formation near the producing zone without ever coming to the surface. Operators are concerned that the Class II definition might not apply to wells with DOWS and that they might be subject to regulatory requirements for another class of injection wells. This issue has been presented to the EPA and is being studied by a workgroup of EPA regional experts. The workgroup has not yet published final guidance on this matter.

Because the technology is still new, no regulatory requirements for DOWS exist in many jurisdictions. Even though EPA has no specific requirements, five states (Colorado, Oklahoma, Louisiana, Texas, and Kansas) have developed either regulations or administrative guidelines for DOWS. Those states regulate DOWS with requirements comparable to or less stringent than those for regular Class II injection wells.

CONCLUSIONS

DOWS have a great potential to save money and reduce the environmental impacts of managing produced water at the surface. The technology is still in its infancy; not all the bugs have been worked out yet. Some trials have been very successful and have paid back costs in a few months. Other trials have failed. The cost of installing DOWS equipment, including a necessary well workover, is substantial. Assuming that oil prices remain higher than the low prices experienced in early 1999, it is likely that DOWS will play a role in the nation's future oil production. As vendors install more DOWS units, they will continue to improve the technology.

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