OAK RIDGE NATIONAL LABORATORY

Development of an In-Well/Oil/Water Separator (Centrifugal Downhole Separator or CDHS)

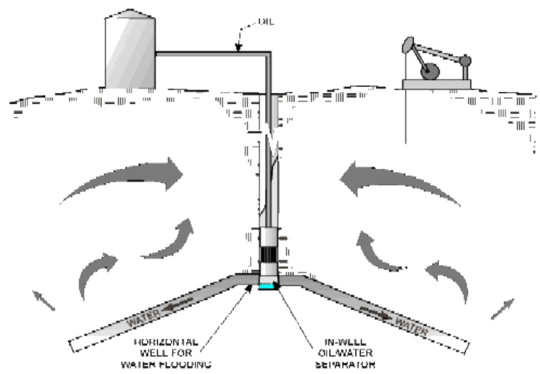

Fig. 1. Schematic of the CDHS.

Fig. 2. The small separator rotor can be scaled in both diameter and size. This unit is 2 inches in diameter and 4 inches tall. We can effectively process 0.4 gpm (14 bbl/day) in this unit.

The Chemical Technology Division at Oak Ridge National Laboratory in collaboration with University of Tennessee is investigating methods for separating oil and water at the bottom of oil wells. This approach would allow for reinjection of water down-hole, thereby eliminating surface separation and treatment processes.

The technology would be very beneficial for off-shore operations that are rapidly moving towards design of large, expensive, high-capacity platforms that cannot accommodate surface treatment of produced water. A schematic of the down-hole separation process may be seen if Figure 1.

The Department of Energy has in the past developed very compact centrifugal separators for organics and water (see Figure 2). These separators consist of a rotating hollow shaft that works as a separator with inherrant pumping action. The oil and water is separated into different streams that are discharged through the centrifugal force in the upper portion of the shaft. To demonstrate the performance of these separators, a light crude from the Gulf of Mexico and a heavy crude from the North Sea were obtained from the oil industry. These oils were combined with synthetic produced water and fed into the separator.

The goal of Oak Ridge National Laboratory’s project is to completely separate oil and water and to investigate the performance according to industry-established criteria. The table below shows the criteria supplied by industry, our achievements, and has links to more details about our results.

Industry supplied criteria	Achieved	Comment
Flow Rate: 2,000 to 10,000 bbl/d	15 bbl/d	The small unit used in the laboratory can be scaled in both diameter and length. The current labscale unit is just 2 inches in diameter and 4 inches tall. A computer program developed for design of separators will be used to scale up units.
Diameter: 6 inches for 7-inch well	2"D x 4"H	
Temperature: 100 to 180°F	75-150°F	The effect of temperature on the separation was studied using the North Sea heavy crude. Increasing the temperature improved performance.
Water-to-oil ratio: 1:10 to 10:1	1:19 to 10:1	The bench-scale separator unit has been operated through the whole regime without decrease in performance.
Gas processing: Can it be done?	Yes	Gas entrapped in the oil water does not interfere with the separation efficiency. We have studied gas levels of up to 21% (v/v).
Solids: 0-3% (sand to clay)	3% sand	3% sand was processed through the application of a hydrocyclone for solids separation followed by oil-water separation in the CDHS

		separation in the CDHS.
Product quality: <2000 ppm (0.2%)	<0.2%	The separation efficiency can be adjusted through replacement of the aqueous weir.
Reliability: 18 months between failure	27 mo.	The failure rate of separator units has been determined previously by DOE.

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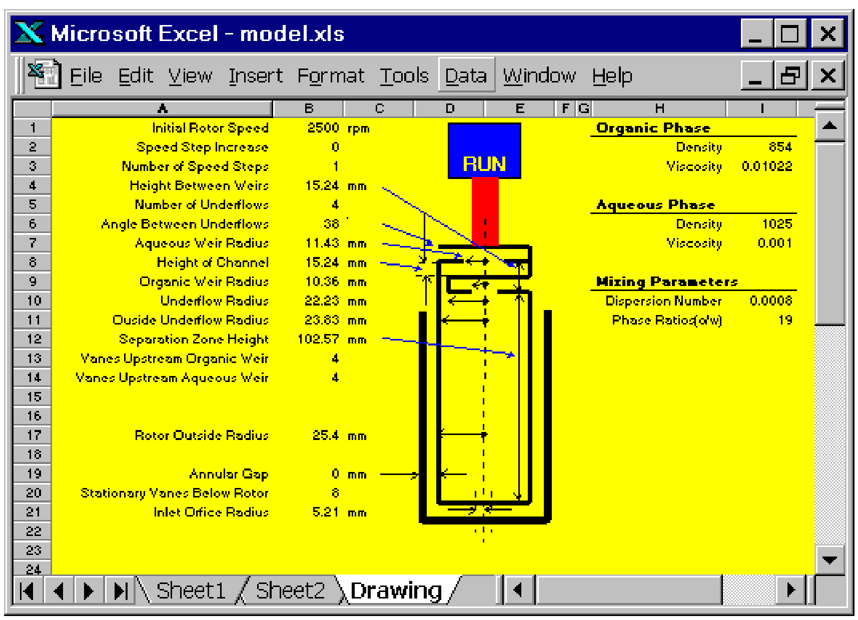
OAK RIDGE NATIONAL LABORATORY

Development of an In-Well/Oil/Water Separator (Centrifugal Downhole Separator or CDHS)

The small laboratory unit is very efficient in separating oil and water.

The laboratory unit has a rotor that is only 2 inches in diameter and 4 inches tall, and can typically process 14 bbl/day (0.4 gpm). The rotor speed is variable; however, we have found that for our system it does not effect the separation efficiency to the extent one would think. Most of what you see in the photo is the experimental setup to allow for pumping and mixing of oil and water before separation. The stream is introduced in the bottom of the system and the separated streams exits horizontally. The separated streams are then combined and introduced back into the system. Using this approach we avoid waste generation.

The computer program is coded in FORTRAN but is used through a Visual Basic module in Excel making it user-friendly. The computer model is used to scale laboratory data to field units. Current estimations predicts that a separator unit with a diameter of 4.5 inches and 16 feet tall can process 4200 bbl/day of a stream consisting of 5% water in oil.



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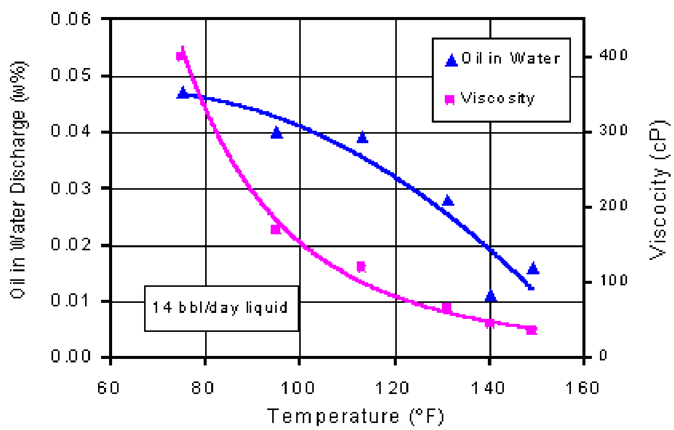
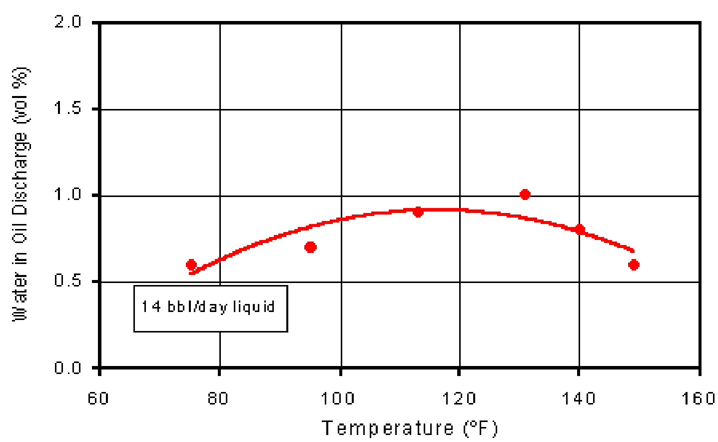
Studies performed with North Sea heavy crude oil at higher temperatures indicate that the performance of the system improves with temperature, resulting in a cleaner water stream.



As is noted to the left, the viscosity of the crude oil decreased as the temperature increased. This results in an improved separation of the oil droplets from the water. Although we did not extend the studies to higher temperatures, it is likely that the trend will remain the same.

The separation of water droplets from the oil was, for all practical purposes, not affected by the temperature.



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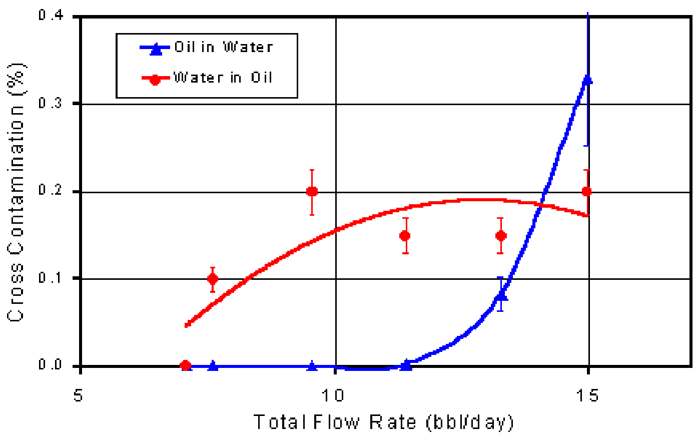
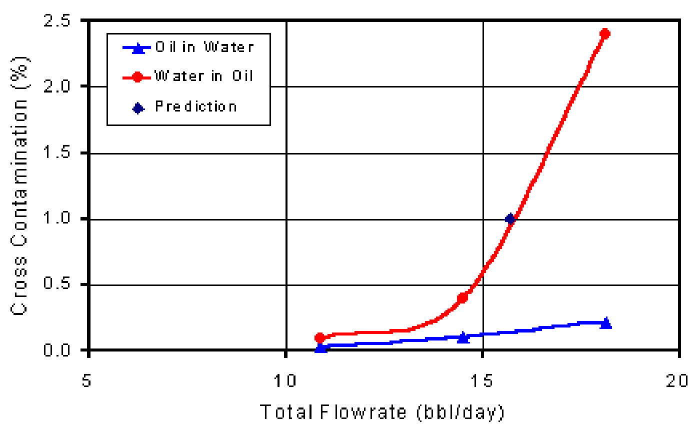
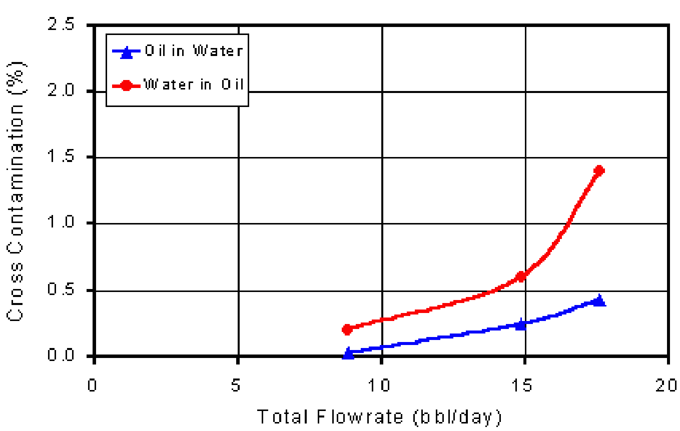
The bench-scale separator unit has been operated over oil-to-water ratios of 19:1 to 1:10 (including the transition region) without decrease in performance. The goal is to have less than 0.2% oil in the water. The operation at all phase ratios was 2500 rpm.



We have studied the performance at a variety of water-to-oil ratios. The target is to be able to separate oil and water to the exent that only 0.2% of oil remains in the water stream. The amount of water in the oil is less important. To the left you see results from the study made with a phase ratio of 1:19 (water:oil). As is noted the oil content in the water remained under 0.2% for flow rate of <14 bbls/day.

These are results from a study made with a phase ratio of 1:1 (water:oil). In the figure, the prediction of 1% cross-contamination using the computer model has also been included.





These are results from a study made with a phase ratio of 10:1 (water:oil).

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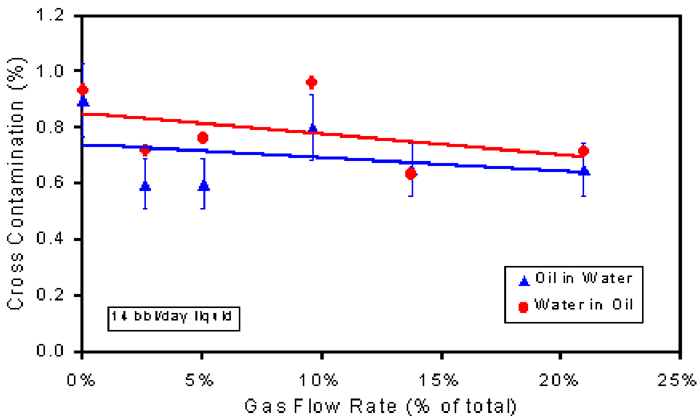
The centrifugal separator can also separate gas in a three-phase feed.



Gas in the inlet stream did not change the performance of the system, regardless of the gas content. Thus, we are confident that entrapped gas in the oil well will not cause problems.

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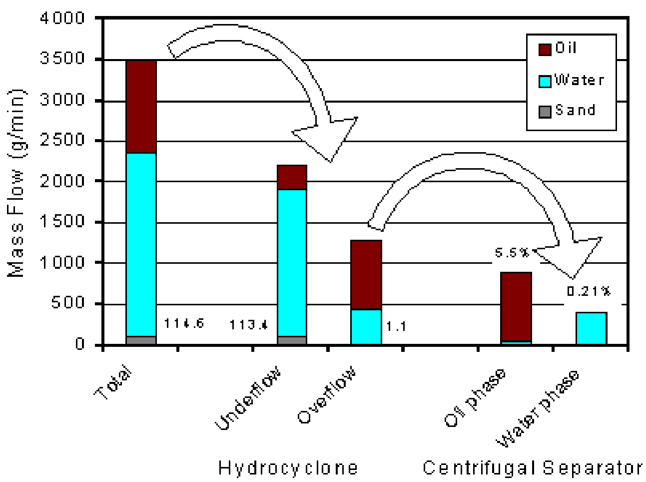
Development of an In-Well/Oil/Water Separator (Centrifugal Downhole Separator or CDHS)

The centrifugal separator in combination with a hydrocyclone can also separate solids in a three-phase feed (sand/oil/water).



The CDHS can handle very little solids, but solids in the influent stream can be removed by coupling the separator with a hydrocyclone. Here you see results of a stream of sand/oil/water flowing through a hydrocyclone, and then the overflow from the hydrocyclone is fed into the separator. The values next to the bars in the left-hand side of the figure correspond to the mass flow of sand (in g/min). The values next to the bars on the right-hand side correspond to the cross-contamination in the separator (in %). As is noted, the hydrocyclone separated out in excess of 99% of the sand. The subsequent processing of the stream from the hydroclone was able to get down to 0.21% oil in the water.

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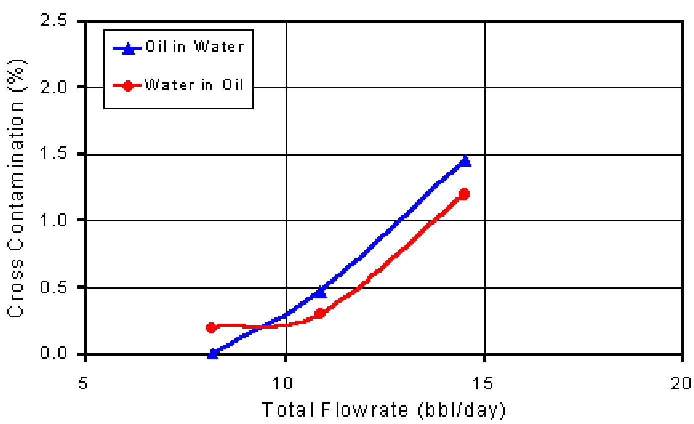
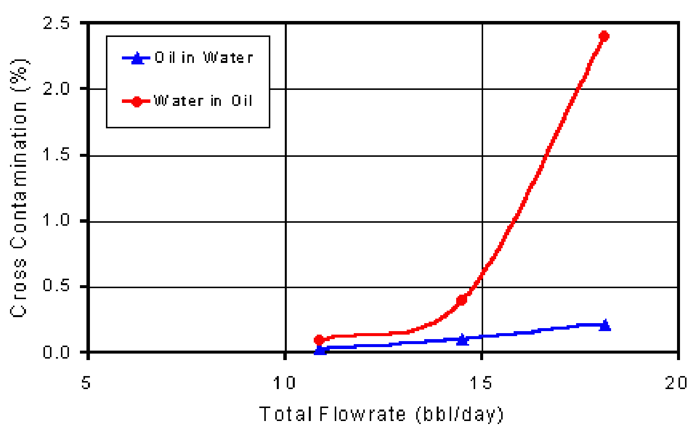
The separation efficiency can be adjusted with the aqueous weir.

A large selection of aqueous weirs (rings in left figure) is available to optimize the separation efficiency. One of these weirs is mounted in the top of the separator rotor (right) before use. A larger-diameter weir means that more oil will end up in the aqueous stream. For our purposes we may select a conservative smaller-diameter weir to make sure that this does not happen since changing weir size down-hole is not feasible.



To the left you see the results obtained with a weir size of 0.975 inches. The cross-over contamination is about equal in both streams and the separator is running close to optimized.

To the right, you see what happens when you decrease the weir size to 0.95 inches. The aqueous stream becomes cleaner and more of the water is found in the oil stream. This is the operating condition we seek since our objective is to have a very clean water stream.



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