# ESP FLOWSHEET SIMULATION

## APPLICATION BRIEF

## Downhole Oil/Water Separation

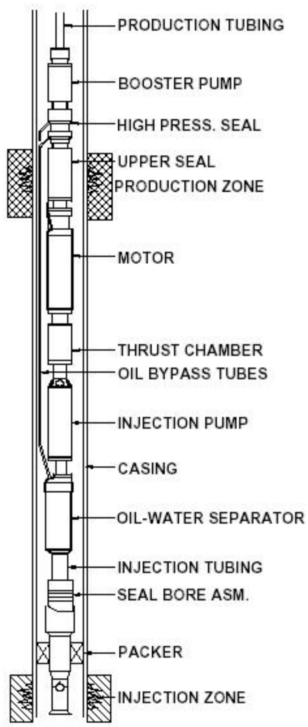


**Figure 1 Schematic drawing of a Hydrocyclone Oil/Water Separator**

The largest volume waste stream associated with oil and gas production is **produced water**. Water to gas ratios of 10 to 1 are common and treatment followed by disposal of produced water leads to significant costs for operators. A relatively new technology, downhole oil/water separators (**DOWS**), has been developed to reduce the cost of handling produced water.

DOWS separate oil and gas from produced water at the bottom of the well and reinject some of the water into another formation or another location within the same formation. Since most of the produced water is not pumped to the surface the cost of handling produced water is greatly reduced.

A secondary benefit of DOWS is that the risk of contaminating underground sources of drinking water is minimized since reinjection from the surface is reduced.

**Contents**

# The Application

For this application we use a simplified producing oil well as an example. The oil is in contact with formation fluids and minerals. The first application simulates the movement of the oil and brine up the well to the separator without the use of a DOWS. The second application simulates the same fluids using a DOWS installed below the production zone. Finally, the two produced waters are compared.

## Fluid Compositions – Oil Phase

The oil phase flows to the well bore at a rate of 208 barrels per day (bpd) at 250 $^oF$ and 300 psia. The oil composition is shown in the Table 1:

**Table 1 Oil analysis**

| Fraction | API Gravity | Mol. Wt | Volume % |
|---|---|---|---|
| C1-C4 | | | 1.7 |
| C5-175 $^oF$ | 78.8 | 97 | 7.3 |
| 175 $^oF$ - 250 $^oF$ | 59.8 | 111 | 8.1 |
| 250 $^oF$ - 375 $^oF$ | 50.8 | 136 | 14.2 |
| 375 $^oF$ - 530 $^oF$ | 40.2 | 184 | 16.3 |
| 530 $^oF$ - 650 $^oF$ | 34.5 | 246 | 10.0 |
| 650 $^oF$ - 1050 $^oF$ | 2.7 | 425 | 31.8 |

## Fluid Composition – Brine Phase

The brine phase flows to the well bore at a rate of 1290 bpd at 250 $^oF$ and 300 psia. The brine composition is shown in Table 2:

**Table 2 Brine composition**

| Cation | mg/L | Anion | mg/L |
|---|---|---|---|
| $Mg^{+2}$ | 2387 | $Cl^{-1}$ | 23059 |
| $Na^{+1}$ | 3679 | $SO_4^{-2}$ | 23.4 |
| $Ba^{+2}$ | 33.5 | $HCO_3^{-1}$ | 6.3 |
| $Ca^{+2}$ | 3382 | $OH^{-1}$ | 2.1 |
| $K^{+1}$ | 4904 | $CO_3^{-2}$ | 0.3 |
| | | | |
| **Neutral** | **mg/L** | **Properties** | |
| $CO_2$ | 0.7 | pH | 6.8 |
| | | Density (g/mL) | 0.973 |

## *Application 1: No DOWS Installed*

Using ESP, we first simulate a simplified well with no downhole oil/water separator installed. The fluids detailed above are mixed at the well bore. A small pressure drop of 100 psi is assumed. This fluid is sent to the well head/separator. Any solids that may form are entrained until reaching the separator. The separator is operated at 100 $^oF$ and 50 psia.

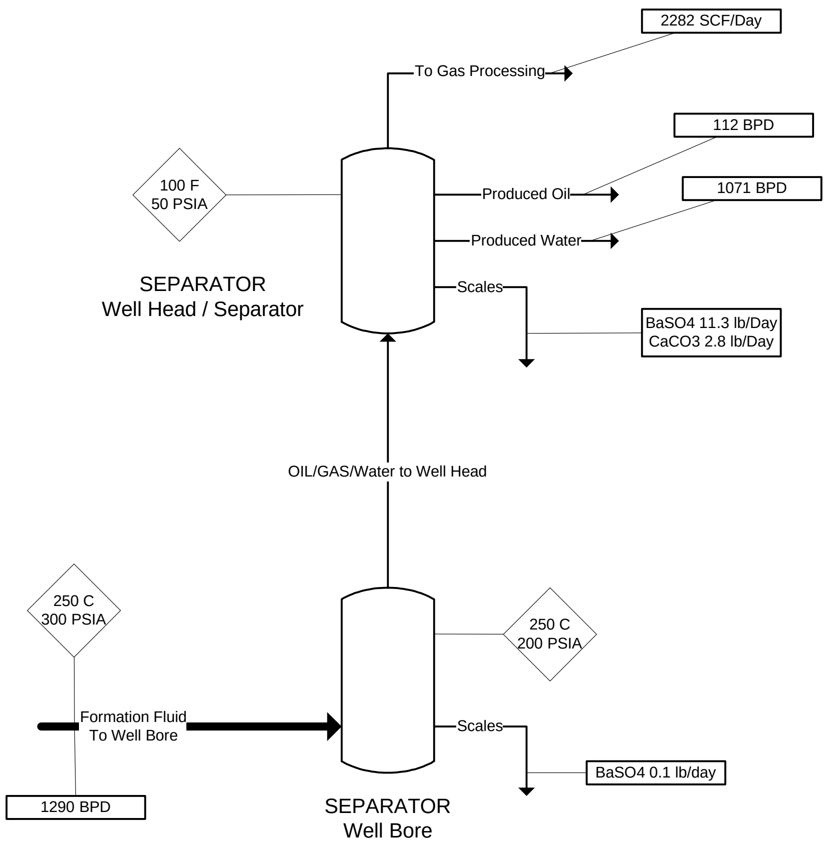


**Figure 2 Non-DOWS configuration – ESP flowsheet**

The predicted phase flows from the separator are listed in Table 3 below:

**Table 3 Non-DOWS configuration flows**

| | |
|---|---|
| Gas | 2282 scf/day |
| Produced Water | 1071 bbl/day |
| Oil | 112 bbl/day |
| Scale Formation | |
| $BaSO_4$ | 11.3 lb/day |
| $CaCO_3$ | 2.8 lb/day |

The water – oil ratio is 9.6 which is typical for an aged producing well. Some solid formation is to be expected although this simulation can't predict where in the well the scales will form.

## *Application 2: DOWS Installed*

Next, we simulate a well with a downhole oil/water separator installed. For this example a hydrocyclone oil/water separator is installed below the producing zone in the well. Hydrocyclones have been used for many years above ground for the separation of oil, gas and water. Hydrocyclones have no moving parts and separate substances of different density by centrifugal force. A liquid/liquid hydrocyclone is used in DOWS technology. The denser aqueous solution moves to the outside of the hydrocyclone and moves down the cyclone to be reinjected in the formation. The lighter fluids remain in the center of the cyclone and flow upwards in the well.

Separation is incomplete in hydrocyclones. Oil is entrained in the water fraction, sometimes as high as 500 ppm. Also, some brine is entrained in the oil fraction where 10 to 15 weight percent is frequently encountered.

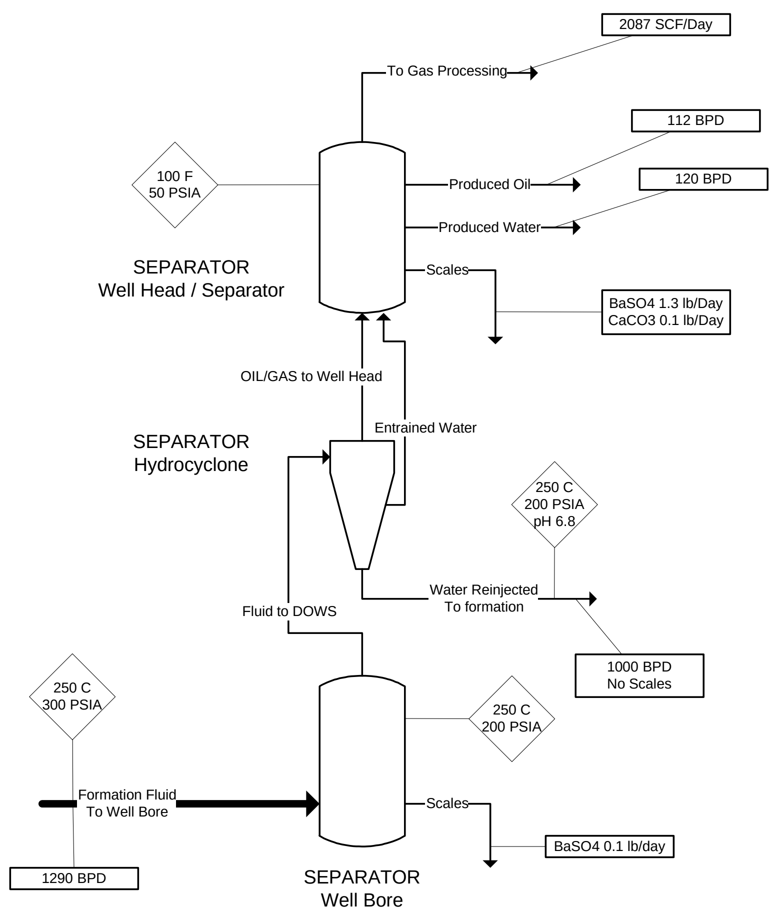


**Figure 3 DOWS configuration – ESP flowsheet**

In this application a hydrocyclone separator is placed between the well bore and the well head/separator units. The hydrocyclone is specified to entrain 500 ppm oil in the reinjectate and to have 15 weight percent brine entrained into the oil phase. The gas phase is allowed to pass through the separator without entrainment. The hydrocyclone separator can handle 1000 bpd with the remaining fluid bypassing the hydrocyclone. A 100 psi pressure drop is assumed across the hydrocyclone.

The conditions at the well bore and at the well head/separator are the same as in the first application.

The phase flow results for this simulation are listed in Table 4 below:

**Table 4 DOWS configuration flows**

| | |
|---|---|
| Gas | 2087 scf/day |
| Produced Water | 120 bbl/day |
| Oil | 112 bbl/day |
| Scale formation | |
| $BaSO_4$ | 1.3 lb/day |
| $CaCO_3$ | 0.1 lb/day |

The predicted water/oil ratio is 1.1. Some solid formation is expected. However, this simulation can't predict where in the well the scale will form. The reduced produced water flow is very desirable since we have approximately a 10 fold decrease in volume. Also, note that there is a reduction in the amount of scales that can be formed.

## *A Concern...*

There is a concern that since there is 14 times more scale in the non-DOWS configuration that excess scaling species are present in the reinjectate. These solids may scale out and plug the formation. For this reason, the reinjectate is injected well below the production zone or very far away from the well bore in the production zone.

A final simulation mixes the formation fluid (see Table 1 and Table 2) with the predicted reinjectate fluid from the non-DOWS simulation (see Table 3). The reinjectate fluid has the following composition:

**Table 5 Reinjected brine composition**

| Cation | mg/L | Anion | mg/L |
|---|---|---|---|
| $Mg^{+2}$ | 2830 | $Cl^{-1}$ | 22970 |
| $Na^{+1}$ | 3675 | $SO_4^{-2}$ | 13.9 |
| $Ba^{+2}$ | 33 | | |
| $Ca^{+2}$ | 3370 | | |
| $K^{+1}$ | 4832 | | |

| | | | |
|---|---|---|---|
| | | | |
| **Neutral** | **mg/L** | **Properties** | |
| $CH_4$ | 126 | pH | 6.8 |
| Oil | 485.9 | Density (g/mL) | 0.972 |

Of particular note is that the carbon dioxide and carbonate ions seem to be missing from this analysis. These species are soluble in oil and went up the well with the oil.

The fluid that flows to the well bore at 1290 bpd is mixed with the reinjected brine flowing at 1000 bpd. The streams are mixed at 250 $^oF$ and 300 psia. The results of the mix are:

**Table 6 Production zone mixed fluid composition**

| **Cation** | **mg/L** | **Anion** | **mg/L** |
|---|---|---|---|
| $Mg^{+2}$ | 2139 | $Cl^{-1}$ | 20642 |
| $Na^{+1}$ | 3302 | $SO_4^{-2}$ | 12.5 |
| $Ba^{+2}$ | 30 | $HCO_3^{-1}$ | 2.5 |
| $Ca^{+2}$ | 3028 | | |
| $K^{+1}$ | 4343 | | |
| | | | |
| **Neutral** | **mg/L** | **Properties** | |
| $CH_4$ | 498 | pH | 6.8 |
| Oil | 36890 | Density (g/mL) | 0.972 |
| | | $BaSO_{4(s)}$ | 3.1 mg/L/day |

Table 6 shows that for the most part, injecting the brine back into the production zone decreases the concentrations of the ions slightly. The production of barite ($BaSO_4$) solid is predicted to be 3.1 mg/L per day. This may be of concern for formation damage. Unfortunately, this model can't tell us where the damage will occur.

## *Conclusions*

These ESP simulations demonstrate the following:

- Using DOWS technology can result in reduced produced water
- Scaling problems on the surface can be minimized
- Formation damage can be predicted

A more complete description of the production zone chemistry and the injection zone chemistry would allow for more accurate simulations. Also, a more complete description of the DOWS configuration under consideration would allow for a more accurate assessment of the technology.