Optimising production using drag reducing agents in water injection wells

by Jennifer Nelson, ConocoPhillips Specialty Products Inc.

At the beginning of an oil field's production life, primary recovery utilizes the natural energy of the reservoir to cause hydrocarbon to flow into the well bore. After some time, the natural energy of the reservoir utilized in primary recovery is depleted. To continue production some secondary recovery method must be implemented. There are several methods of enhanced oil recovery available with water flooding being the most common method.

In addition, as oil fields mature the amount of produced water increases. Disposal of this produced water needs to be conducted in an economic and environmentally friendly way. The two most common disposal methods are to re-inject the produced water into the producing reservoir and to inject the produced water into an abandoned reservoir or aquifer.

Drag reducing agents (DRA) are used to assist in both of the situations described above. This article will give an overview of drag reduction technology, followed by details on water injection technology and water flooding. A case study is discussed in detail, including the key steps involved in implementation. The additional benefits of using drag reducing agents in water injection systems are also discussed.

Drag reduction technology

Drag reduction was defined by Savins1 as the increase in pumpability of a fluid caused by the addition of small amounts of another substance, such as high molecular weight polymers, to the fluid. Drag reduction is a reduction in the pressure drop over some length of a pipeline when traces of high molecular weight polymer are dissolved in the pipeline fluid.

The key factors governing the amount of drag reduction achievable in a given system are:

- solubility of the polymer in the continuous phase;
- effectiveness in dispersing the polymer;
- molecular weight of the polymer; and
- concentration of the polymer

Good dispersion of drag reducing polymer will lead to optimal dissolution in the pipeline fluid and hence good drag reduction performance. One needs to make sure that the right injection technology is used to ensure full dissolution of the injected product.

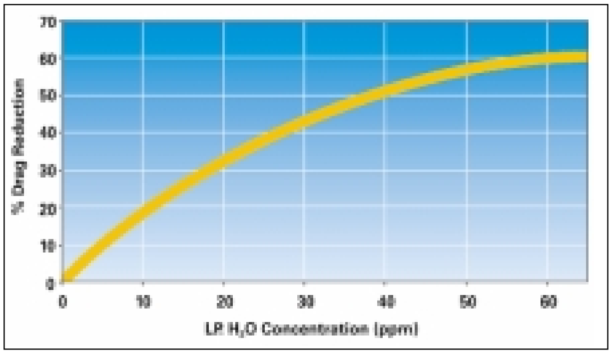

Figure 1. Performance graph.

The polymer molecular weight has a large influence on the drag reduction performance that may be achieved. Generally, the higher the molecular weight of the polymer, the greater the drag reduction performance that may be achieved.

Concentration is also a major factor affecting drag reduction performance in a pipeline: as the concentration of polymer increases, so the resulting drag reduction performance increases.

Water-soluble drag reducers

Typically water-soluble drag reducers are water-in-oil emulsions with ultra-high molecular weight polymers dissolved in the water droplets. When the drag reducer comes into contact with water, the polymer breaks out of the emulsion and is activated in the water phase. The polymer molecules then interact with the water phase in the near wall region of the pipeline to reduce the hydraulic pressure drop.

Figure 1 gives a graphical representation of the standard performance curve for LP H_2O Flow Improver. This performance curve is based on empirical data collected from a number of different applications and so gives a good indication of the likely drag reduction performance.

Water Injection

Water is injected into a reservoir via water injection wells to maintain reservoir pressure and hence maintain or boost oil production levels. In general, the more water that is injected into the formation the more oil that can be subsequently produced, until water breakthrough occurs.

The water is transported using centrifugal pumps usually located on the production platform, and is pumped through small-bore piping (typically 6-8in). The maximum amount of water that may be injected is limited by the capacity of water injection pump(s), the capacity of the injection tubing and the reservoir characteristics. By injecting DRA downstream of the injection pumps, the differential pressure drop in the water injection tubing may be reduced. As a result, the water injection rate may be increased until the maximum allowable operating pressure in the injection system is again reached.

DRA may also be used to increase the rate of water disposal. As oil fields mature the amount of water that is produced increases.

In some cases, this water is disposed of by pumping into an abandoned reservoir or aquifer. By treating this water with DRA, the rate at which the water may be disposed of can be substantially increased.

Water flood

Water flood is the method by which water is injected down injection wells into the oil zone. This creates a vertical flood front, pushing the oil in front of the water toward the producing wells. It is desirable to conduct the water front so as to maximise the sweep efficiency, so that when the water front from the injection wells breaks into the producing wells, a maximum percent of the reservoir volume has been swept by the flood.

For maximum efficiency, the mobility ratio of the driving fluid should be less than the mobility ratio for the driven fluid. The mobility ratio is the ratio of the permeability to the flow of the liquid to the dynamic viscosity of that liquid. The oil and

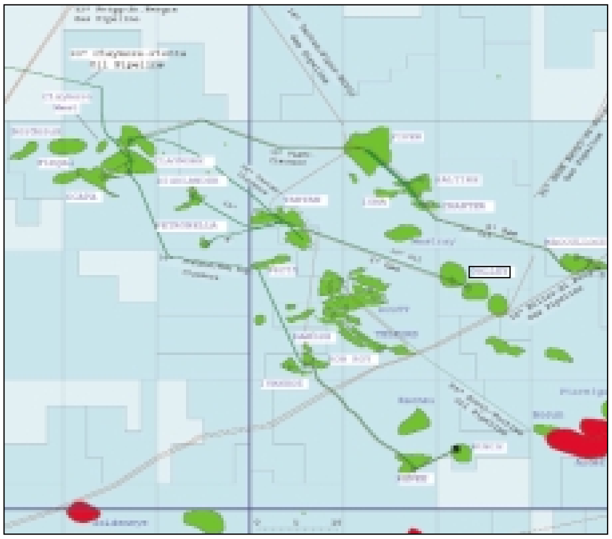

Figure 2. Location of Galley field.

water mobility ratios[2] are:

$$\left(\frac{k_o}{\mu_o}\right) = \text{Oil Mobility Ratio} \qquad \left(\frac{k_w}{\mu_w}\right) = \text{Water Mobility Ratio}$$

where: k_o = Oil permeability
μ_o = Oil dynamic viscosity
k_w = Water permeability
μ_w = Water dynamic viscosity

If the mobility ratio of the driving fluid is greater than the mobility ratio of the driven fluid, the driving fluid will tend to channel or finger through the hydrocarbon, tending to bypass the hydrocarbon in the smaller permeability channels leaving it behind in the reservoir. Typically, the water mobility ratio is greater than the oil mobility ratio.

The effect of treating flood water with drag reducing agents is to increase the viscosity of the water and thus reduce the effective water mobility ratio to a value lower than the oil mobility ratio. Therefore, the oil is more likely than the water to be driven towards the well bore, resulting in enhanced oil recovery.

The above drag reduction technology has been successfully applied in many different locations worldwide. Following is a detailed discussion of the application of LP H_2O Flow Improver to an offshore water injection system located in the UK North Sea.

Case study one: ChevronTexaco Galley

The Galley field is situated 145km east-north-east of Peterhead, Scotland, in block 15/23a of the UK sector of the North Sea (*Figure 2*). The field is operated by Petrofac (UK) Ltd using the *Northern Producer* floating production facility.

The Galley reservoir has an estimated 57.5 million barrels and 80.4Bcf in place and recoverable reserves of 28mmbbl and 40.2Bcf. The field is Upper Jurassic age sandstone and the API gravity of the crude is 44°.

Oil is exported via pipeline to the Flotta Terminal, while the gas is piped to St Fergus Frigg processing plant, both onshore Scotland. Field production began in 1998 and peak production of 43,000boe/day was reached in 2000.

The water injection system consists of approximately 2.2km of 6in tubing from the platform to the sub-sea manifold, situated 150m below the platform. The injection tubing from the sub-sea manifold to the injection well has an ID of 4.8in and a measured depth of 5500 metres. The bottom hole flowing pressure is 430bar and the injectivity index is 73.8m^3/d/bar.

Seawater is injected at a baseline flow rate, without Flow Improvers, of around 29,000b/d. At this water injection rate, the average oil production rate is 39,000b/d.

In late 2000, the pressure in the Galley reservoir was seen to be falling, resulting in reduced oil production rates. To maintain oil production rates, the reservoir needed to be re-pressurised. To achieve this, it was decided to increase the water injection rates. It was estimated that by increasing the water injection rate to 40,000b/d, re-pressurisation could be achieved. Galley personnel chose to investigate the use of DRA to increase the water injection rate as follows:

Predictive performance calculations

Based on information provided on the characteristics of the injection system and water, it was possible to complete hydraulic simulations using ConocoPhillips' in-house simulation model to give an indication of the likely performance of drag reducing agents in the Galley water injection system.

The results of the predictive performance calculations showed that it would be possible to achieve the required 40,000b/d water injection rate by injecting approximately 45ppmv, or 75USG/d, of drag reducing agent. It was also shown that the water injection rate could be further increased to about 45,000b/d by increasing the DRA injection rate.

Laboratory core analysis

Core analysis tests were conducted confirming that DRA has no adverse effect on production operations. A core of the reservoir was taken and its permeability measured while flowing water through the core. This permeability test was conducted for untreated water and for water with 100ppmv DRA concentration. The small reduction in permeability seen with DRA was well within the acceptable limit set by ChevronTexaco.

Bottle tests were also carried out to confirm the compatibility of DRA with all process chemicals, including corrosion inhibitor, oxygen scavengers, biocides, antifoams, etc. DRA was observed to have no effect on any of the process chemicals tested.

Field performance test

A positive displacement pump with Coriolis mass flow meter was used to inject DRA into the water injection tubing via a small injection port in the tubing.

A test was conducted to ascertain the drag reduction and resulting flow rate increase that could be achieved in the Galley water injection system. By injecting DRA at three different concentrations – 10ppmv, 30ppmv and 45ppmv – a drag reduction performance curve for the system was attained. This drag reduction performance curve is included in *Figure 3*.

From this performance curve it can be seen that DRA performed better than expected. The increased water injection rate of 40,000b/d required was achieved by injecting 40ppmv, or

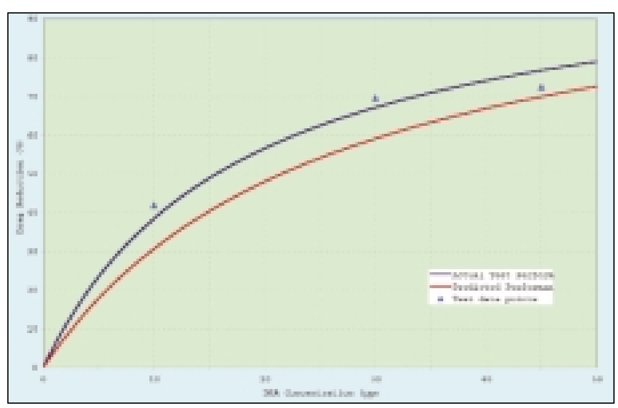

Figure 3. Drag reduction performance, Texaco Galley water injection system.

67USG/d. This improved performance is likely due to better dissolution rates and higher water temperature. The test also confirmed that the water injection rate could be further increased to a maximum of around 45,000b/d by injecting DRA at 65ppmv, or 123USG/d.

Final implementation

ChevronTexaco decided that DRA was the preferred option to increase the water injection rate in the Galley field. A permanent DRA injection installation was provided, similar to that used for the test, and installed immediately. Since its introduction in 2000, ChevronTexaco has continued to use DRA to operate the Galley field.

As a result of the increased water injection rate, ChevronTexaco was able to re-pressurise the reservoir and to continue operation at 39,000b/d.

In addition, the expected life of the reservoir has been extended by three years and the total amount of recoverable reserves is now estimated to be 29.5 million barrels, 1.5 million barrels above the initial estimate of 28 million barrels. This increase in recoverable reserves equates to a $16.5 million NPV over the anticipated production life of the Galley field.

Other benefits

The use of these chemicals over time have shown a number of additional benefits, such as:

- Extensive testing has shown that DRA has no souring effect on crude oil.
- DRA reduces the effect of corrosion by up to 30%.
- DRA is a good reservoir management tool for optimal distribution of the water injected.
- Produced water contains small quantities of oil and traces of heavy metals that may be potentially harmful to the sea. By re-injecting this water, discharges to the environment can be kept to the strict minimum.
- By using DRA, less energy is required to drive the water injection system.
- By reducing the energy consumption needed for water injection, DRA reduces the CO_2 and NO_x emissions to air.
- DRA reduces the number of water injection wells needed.

Conclusions

DRA can bring a number of substantial benefits to maturing oil fields, as follows:

- increase water injection rate;
- increased oil production rates;
- extension of field production life;
- increase overall recoverable reserves;
- cost effective way to increase water injection rates;
- energy savings;
- environmental benefits (Silver Classification under DTI Environmental Classification); and
- reduction in corrosion.

It is important to note that each production field and water injection system has its own characteristics and hence the performance of drag reducing agents will vary from field to field. It is always recommended to conduct an in depth evaluation of drag reducing agents to a particular application before final implementation.

References

[1] Savins, J.G., 1964, Soc. Pet. Eng. J., 4, 203 (1964)
[2] Boatright, K.E., 2002.Basic Petroleum Engineering Practices, 9.6.