RESTRACK™

# Oil Saturation from Single Well Chemical Tracer Tests

Restrack offers oil saturation measurements in near-well regions, using a Single Well Chemical Tracer Test. The method works by injecting a reacting partitioning tracer (ester) that produce a non-partitioning tracer (alcohol) in-situ. Oil saturation in the test-zone is directly related to the lag of the partitioning vs. the non-partitioning tracer during back-production.

The single-well chemical tracer test (SWCTT) is a non-intrusive test to measure oil saturation in the near-well region. The test is based on injection of an ester into the reservoir. Some of the ester hydrolyses during a shut-in period, and subsequent production of the well, yield tracer production curves of the ester and the alcohol produced during shut-in that can be used to determine oil saturation.

Commonly utilized esters in SWCTTs are propyl formate and ethyl acetate. For example, the hydrolysis reaction for ethyl acetate is

$$CH_3COOCH_2CH_3 + H_2O \rightleftarrows CH_3CH_2OH + CH_3COOH \quad (1)$$

i.e.

$$Ester + water \rightleftarrows alcohol + acid \quad (2)$$

In a water-flooded area close to residual oil saturation oil flow rates may be negligible compared to the water flow rates. In such cases oil saturation can be determined by differences in retention times of a partitioning and non-partitioning (passive) water tracer. Oil saturation is given by the simple expression

$$S = \frac{(t_2 - t_1)}{(t_2 + t_1(K - 1))} \quad (3)$$

Here $t_1$ and $t_2$ are the retention times of the non-partitioning and partitioning tracer, respectively, $S$ is the residual oil saturation, and $K$ is the partition coefficient of the ester tracer. $K$ is measured in the lab and the residual oil saturation is calculated from the measured difference in the arrival times between the non-partitioning and the partitioning tracer.

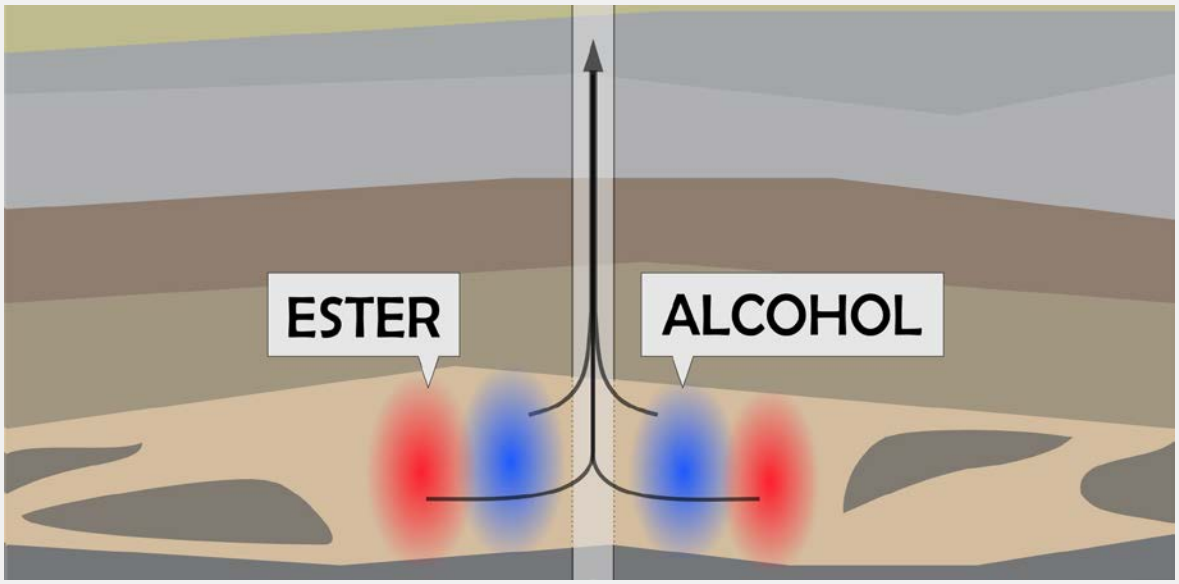


*Figure 1. Illustration of the single-well chemical tracer test (SWCTT) principle. During a SWCTT, ester is injected into the formation. Parts of the ester react with water (hydrolyze) to form alcohol. During back-production (see illustration) the partitioning ester lags behind the alcohol and the time-difference is directly related to oil saturation in the formation.*

*Figure 2. SWCTT location on the Heidrun platform.*

## SWCTT OPERATION IN THE HEIDRUN FIELD

The operator (Statoil) of the Heidrun field in the Norwegian Sea wanted to measure oil saturation in the near-well region of one of the producers in the field. For safety reasons, the SWCTT chemicals had to be placed in a remote location on the platform (see Figure 2 above) with Arctic mid-winter weather conditions. Detailed planning in close collaboration with the operator was necessary to ensure a secure and effective operation in the challenging conditions. Frequent sampling and continuous on-site analysis secured reliable tracer curves that were afterwards interpreted to determine saturation values.

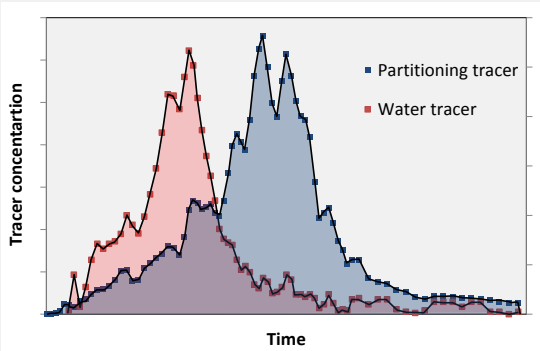


*Figure 3. The time lag of the oil/water partitioning tracer in a production well used to estimate oil saturation.*

The tracer concentration curves from the on-site analysis (Figure 3) and the partitioning coefficient of the ester tracer, measured on oil and water samples from the field, was used to estimate a saturation in the near-well zone using Equation (3) above.

## PLANNING & INTERPRETATION USING ARTSIM TRACER SIMULATION

Previously simulation of SWCTT required complex reactive transport modeling tools to handle the hydrolysis reaction (Equation 1), and could not be done with black-oil simulators (such as Schlumberger's Eclipse simulator). Restrack's in-house ARTSim tracer simulator solves this challenge and makes SWCTT simulation possible using existing black-oil simulation cases.

To achieve this, ARTSim exploits the fundamental property that tracers do not affect the fluid transport (but are affected by it). ARTSim reads fluid simulation output from Eclipse and calculates tracer reaction and transport separately.

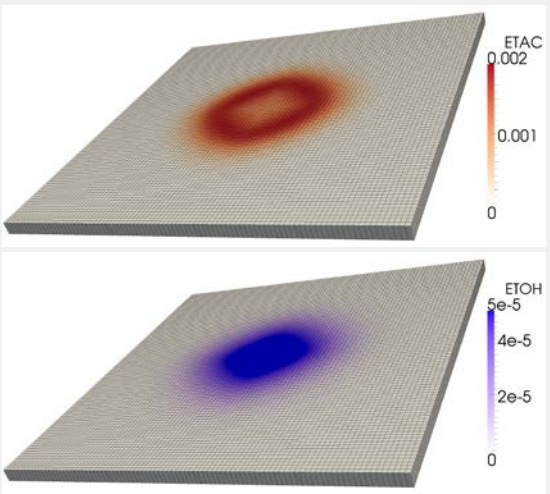


*Figure 4. Simulation results for ethyl acetate ester (EtAc) and ethanol (EtOH) concentrations, obtained on an Eclipse simulation case using the SWCTT option in Restrack's ARTSim tracer simulator. During back-production, the EtOH water tracer moves faster towards the producer in the center than the partitioning tracer EtAc.*