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Technical Bulletin

Residual Oil Testing

The Single Well Chemical Tracer (SWCT) test is a method for measuring fluid saturations in oil producing reservoirs. The method has been used to measure residual oil saturation (S_{or}) for more than 30 years. More than 400 reservoirs worldwide have been tested during that period.

The test is normally performed on watered out wells. If the target well produces a substantial oil cut, water can be injected to water out the zone. After water injection, the well will produce 100% water, and will be ready for S_{or} testing. SWCT testing is non-destructive; after testing for S_{or}, the well can be returned to oil production status.

Figure 1 illustrates a test zone cross-section in a perforated or open-hole completion.

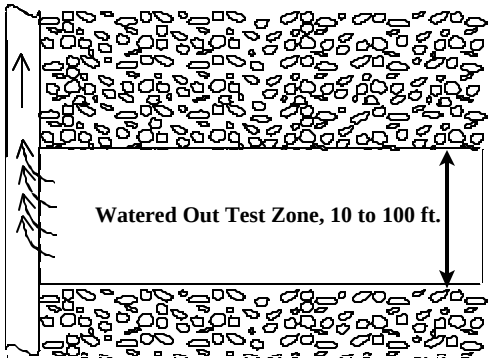


Figure 1
Test zone with 100% water cut production.

The SWCT test for S_{or} is carried out by injecting a volume of water containing about 1% by volume of a partitioning ester into the target zone of the test well. A larger volume of water that does not contain ester pushes the ester bank until it reaches a position ten to fifteen feet into the reservoir. The total volume injected is typically labeled with a suitable non-reactive, non-partitioning (material balance) tracer. Figure 2 illustrates the ester position after the injection step.

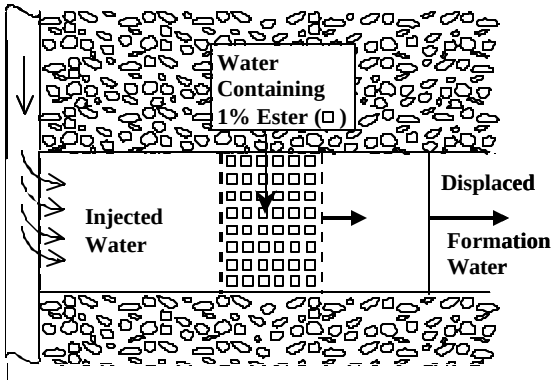


Figure 2
Ester injection and push

During a shut-in period of one to ten days, a portion of the ester reacts with the reservoir water and forms the secondary or product tracer in-situ. The product, an alcohol, is virtually insoluble in the

residual oil. The shut in period is designed to allow a measurable amount of the alcohol to form. Typical ester to alcohol conversion is from 10% to 50%. At the end of the shut-in step, the unreacted ester and the product alcohol tracers are superimposed and located about 10 to 15 feet from the test well bore, as shown in Figure 3.

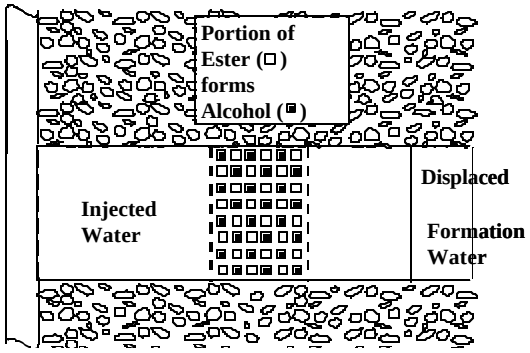


Figure 3
Shut-in (reaction) step. Some of the ester reacts with water to form a new alcohol tracer.

After the shut-in period, the well is produced. The produced fluid is periodically sampled at the wellhead and immediately analyzed for content of the un-reacted ester, the product alcohol, and the material balance tracer.

Figure 4 shows how partitioning of the un-reacted ester tracer between the immobile residual oil phase and the mobile water phase separates the ester from the product alcohol during back-flow to the test well. The product alcohol tracer is not delayed, and flows back to the well at very near the same speed as the water.

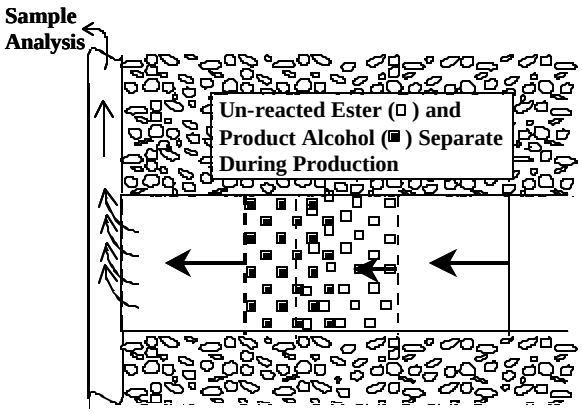


Figure 4
Production Step

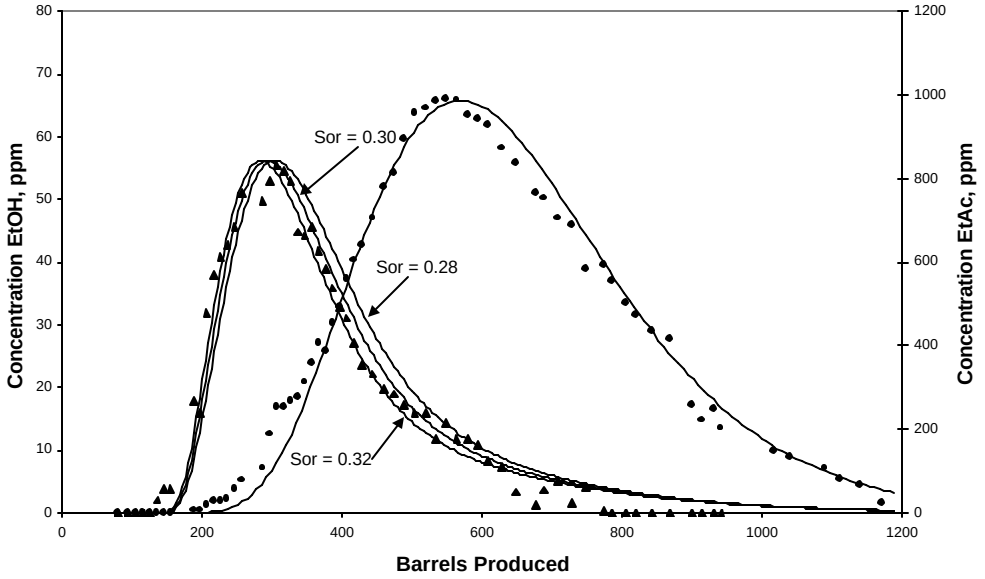
The chromatographic separation of the ester and the secondary alcohol tracer is observed in profiles of tracer concentrations vs. produced volume, as shown in Figure 5.

SWCT test results from high S_{or} cases show a large separation between the product alcohol and ester. Test results from low S_{or} cases show a small separation between the product alcohol tracer and ester. This separation, combined with the laboratory measurement of the ester oil/water partition coefficient, is the basis of the S_{or} measurement.

In ideal cases, the S_{or} results can be calculated directly from field measured tracer concentration vs. produced volume profiles by measuring the degree of separation between the secondary tracer and ester. A more rigorous interpretation is made through mathematical modeling. Simulated SWCT production profiles are compared to field SWCT production profiles, as seen in Figure 5. S_{or} is obtained from the best-fit simulation model. For the test shown, the interpreted S_{or} is 30 ± 2 %.

Figure 5

SWCT test production profile with simulations



Simulation also allows the interpreter to compensate for complications, such as ester reaction during the flow period and flow irregularities encountered during the test.

SWCT tests are non-destructive; after the production step, the formation is returned to its original condition. The test procedure can be repeated on a given completion as many times as needed without altering the fluid content of the pore space investigated. This non-destructive feature allows oil saturation measurements before and after an EOR injection from a single well. This test-inject-test strategy has been performed dozens of times to evaluate recovery processes such as surfactant-polymer, lignin-surfactant-polymer, caustic-polymer, CO_2 and miscible hydrocarbon. This IOR evaluation is called a one-spot IOR pilot. The one-spot IOR pilot is completed in about one month on an existing producing well. See the "One-Spot IOR Pilot Technical Bulletin", also available from CTI.

A tracer-derived in-situ S_{OR} value provides the reservoir engineer with the end point for oil relative permeability and quantifies potential IOR targets. Combined with good material balance data, an accurate S_{OR} value can help identify the presence of bypassed oil in a water-flooded formation, which may justify infill drilling and/or sweep efficiency improvements.

Contact Charlie Carlisle at CTI (307) 742-0418, cell (307) 351-3629 or visit our website at www.chemtracers.com for more details on this unique in-situ tool.