

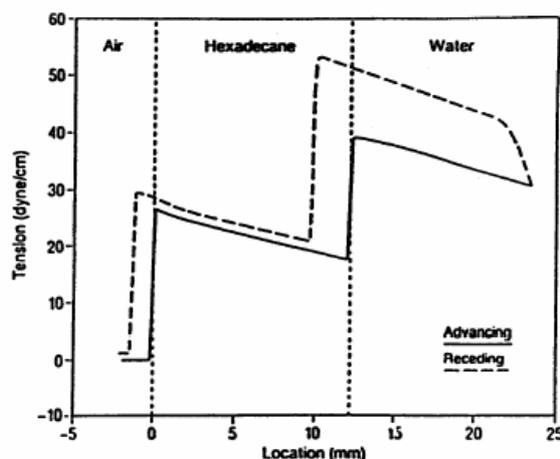
## Wettability: Research in Oil Recovery Science

One of the most important objectives for a chemist or engineer in oil recovery science is to increase the yield of extractable oil from a reservoir that is trapped during the normal drilling operation. To accomplish this goal, a number of techniques have been developed to go back into a reservoir again to remove trapped oil with a variety of so-called "tertiary oil extraction techniques". In one such method known as water-flooding, an aqueous brine solution is pumped into the well to "extract" the additional trapped oil from the reservoir rock by impacting the oil/brine/rock interfaces in such a way as to force the oil out of the rock and into the well where it can be collected.

Unfortunately, no two wells are alike in that the type of rock formation in the well can vary significantly from one well to the next. In addition, there are an infinite variety of oil types and grades with properties that vary from well to well to complicate matters even further. Fortunately, there is a way to help predict the wettability "preferences" of an oil field before a large investment of time and money is committed to the tertiary recovery efforts.

The Dynamic Contact Angle technique is ideally suited for this early investigative work to predict the success of a tertiary oil technique before it happens. Dr. Dale Teeters, a professor of Chemical Engineering at the University of Tulsa (Tulsa, Oklahoma) and Dr. Mark Anderson (Amoco Oil Company) have successfully applied this technique and published results that prove the applicability and utility of this method. In a series of classical wettability experiments in which model systems were used to simulate the wetting conditions prevalent in the reservoir, several distinct types of wetting behavior were observed.

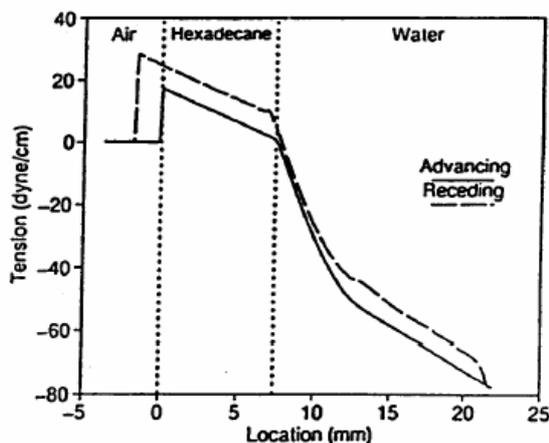
For example, in Figure 1, a so-called "water-wetting" system is portrayed in which the test solid (in this case a glass plate) was immersed through a hexadecane/water interface and the water was found to displace the hexadecane at the interface.



**Figure 1**

*Hexadecane/water/glass wetting cycle "water wetting" behaviour". Source: Reference1)*

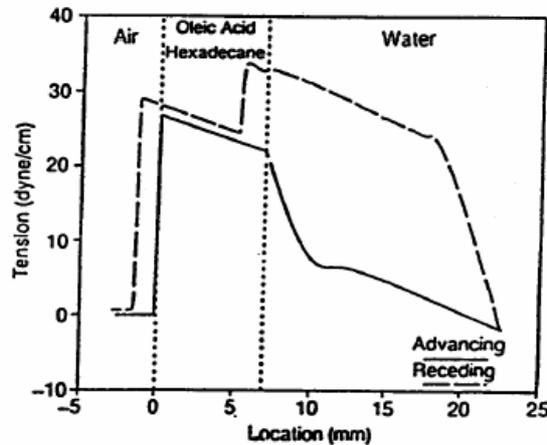
In this "model system", hexadecane is used to simulate the oil phase and water to simulate the aqueous brine phase. Glass was chosen for this illustration to demonstrate what would happen if the reservoir rock was constructed of a highly water wettable material such as glass. In this case, at the hexadecane/water interface the glass plate was wet better by the more polar aqueous phase than the less polar oil phase. The oil phase was therefore displaced from the surface of the glass plate by the aqueous phase, thus the classification "waterwetting system" is appropriate. In Figure 2, another situation is modeled. In this case, the glass plate is replaced by a non-wetting solid- PTFE (polytetra fluoroethylene) to simulate a non-polar surface. In this case, the aqueous phase fails to displace the oil phase from the PTFE surface. This is logical because PTFE is a low energy surface that is wet better by a low surface tension or non-polar liquid. This type of system is classified as an "oil-wetting system" because the solid surface is preferentially wet by the oil phase.



**Figure 2**

*Hexadecane/water/PTFE wetting cycle exhibiting "oil-wetting behaviour". (Source: Reference 1)*

In Figure 3, a "hybrid wetting system" is shown. This is a particularly interesting case in which the wetting of the glass plate is different going in (advancing) than it is on the way out (receding). In other words, the wetting in this case is a hybrid of an oil wetting and a water-wetting system.



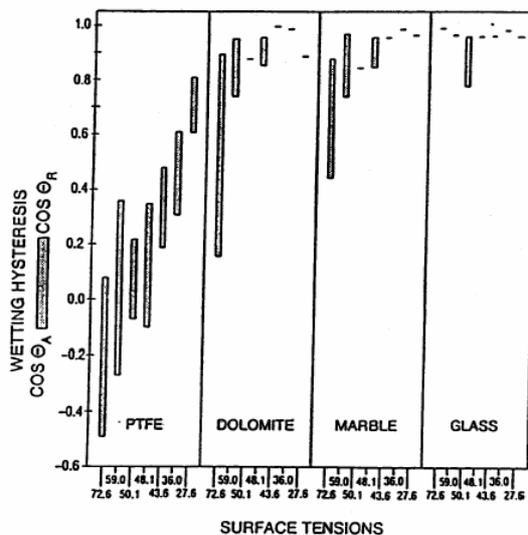
**Figure 3**

*Hexane-oleic acid/water/glass wetting profile exhibiting "hybrid-wetting behavior". (source: Reference 1)*

In addition to the "model" systems illustrated in Figures 1-3 above, it is also possible to test actual crude oil/brine solutions and study the wetting properties of these fluids against samples of dolomite or marble that more closely resemble the reservoir rock material.

Another technique also being applied by Teeters et al to study interfacial wetting behavior in oil systems was developed by Dr. Lynn Penn in the 1970's. Penn's bar graph technique can be applied to evaluate the surface energy profiles of a number of solid surfaces on the basis of the hysteresis profile (See Figure 4). In this technique, the height of the bar represents the wetting hysteresis for each liquid. The top of the bar represents the receding data, while the bottom of the graph represents the advancing data. This technique results in a fingerprint of each surface that is useful in predicting the wetting behavior of a reservoir well.

By comparing surface energy profiles with wetting preference hysteresis curves for model systems, the intrinsic wetting properties can be fully characterized, and more efficient tertiary oil extraction methods can be developed. The Cahn DCA system is capable of executing both types of experiments, thus it is an ideal compliment to the oil research laboratory instrumentation.



**Figure 4**

Bar graph technique summarizes wetting hysteresis profiles for a series of probe liquids on PTFE, dolomite, marble and glass substrates. (Source: Reference 1)

*Reference 1:* Teeters, D. et al, "Surface Studies Related to the Oil Industry Using the Dynamic Wilhelmy Plate Technique", ACS Meeting presentation, Division of Petroleum Chemistry, American Chemical Society, June 1988.