CHAPTER 5: FLUID SATURATION

Objective

To measure fluid saturation of rock samples using the retort method.

Introduction

Saturation is the measure of the fluid volume present in the pore volume of a porous medium. By definition, the saturation of a fluid is the ratio of the fluid volume to the pore volume or the rock. Hence, considering the fluids typically present in a reservoir rock:

\[
S_w = \frac{V_w}{V_p} \\
S_o = \frac{V_o}{V_p} \\
S_g = \frac{V_g}{V_p}
\]

\[S_w + S_o + S_g = 1 \quad \text{..........................................................(5-1)}\]

Where \(S_i\) and \(V_i\) \(i = w, o, g\) are the saturations and volumes of water, oil, and gas. The sum of saturation of each fluid phase is equal to unity since the pore space is completely filled with fluids (or at least the effective pore volume). Because the fluids and their saturations in the pore space may vary from point to point and pore to pore, the values of saturation are meaningful only for samples large enough for the porous medium to be considered a continuum.

It is important to consider the saturation change occurring in the core from in-situ to surface conditions. Suppose a core is being recovered while drilling a well with water-based drilling mud. Water from the drilling mud will enter the rock expulsing oil. As the core is lifted, the reduction in pressure will cause the oil to release gas and this will expand expulsing oil and
water out of the rock. Figure 4-1 presents saturation values at different stages of core extraction showing how important the change in saturation can be.

![Figure 4-1](image)

**Figure 4-1.** Saturation values at different stages of core extraction showing how important the change in saturation can be.

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**Retort Method for Saturation Measurement**

The retort method apparatus is shown in Figure 5-2 where the core is heated inside the sample cup causing the fluids to vaporize; oil and water are then condensed in the condensing tube and their volumes measured in the receiving tube.

The procedure is summarized as follows:

- Set the apparatus in a ventilated area, preferably inside a hood.
- Weigh the saturated core.
- Place the core in the sample cup and close it tightly; put the cup inside the heating chamber. Place the graduated receiving tube at the bottom of the equipment as shown in

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**Figure 5-2.** Diagram of the retort method apparatus.
Figure 5-2. Do not close this tube tightly since gases should be vented from the system through the receiving tube.

- Run a steady current of tap water through the water bath and start heating.
- Water and oil will start dropping into the receiving tube. When no more fluids are collected, stop the heating, but continue running the cooling water. After both phases in the collecting tube are clearly separated, read their respective volumes.
- When the system has cooled, disconnect the water and remove the sample cup and the core inside it. Observe the core. A black deposit on it indicates the formation of coke, and a consequent loss of oil in the measurement.

![Retort Apparatus Diagram](image)

**Figure 5-2. Retort Apparatus**

Neither of the measured volumes of oil and water corresponds exactly to the amount of fluids in the core because of losses by vaporization of oil and water, coking of oil and the presence of combined water with free water. Figures 5-3 and 5-4 show typical calibration curves used to correct the readings. Figure 5-3 represents the recovery of water versus time for a particular formation using a particular apparatus. The first plateau (about 16 minutes) represents the volume of free water, which is the value of interest to determine $S_w$. Further heating causes
combined water to be collected; the volume of combined water should be subtracted from the final reading. These curves are valid only for the particular system for which they were performed; since calibration curves for this lab are unavailable the water volume will not be corrected.

Figure 5-3. Water Calibration Curves (Engler, 2003)

Figure 5-4. Oil Calibration Curves (Engler, 2003)

Figure 5-4 shows the observed oil volume versus the original oil volume in the sample; the departure from a straight line at 45° represents losses of the oil. This curve is only valid for the
particular oil for which it was developed. It will be assumed that this curve is valid for the cores studied in lab, and Figure 5-4 will be used to correct the oil volume.

**Laboratory Experiments**

- A Rock saturated with water and a hydrocarbon fluid is supplied.
- Measure the saturation of each phase using the retort method as explained in this chapter.
- Correct the oil saturation using Figure 5-4. No water correction is required.

**References**