# Lecture Three: Porosity Measurement

## 3.1. Laboratory measurement

### 3.1.3. Pore Volume Calculation

#### 1- Gravimetric

$$V_p = \frac{saturated\ weight - dry\ weight}{density\ of\ saturated\ fluid} \quad \ldots\ldots (3\text{-}7)$$

**Example 1:**

Calculate the porosity of a core sample when the following information is available:

Dry weight of sample = 427.3 gm

Weight of sample when saturated with water = 448.6 gm

Density of water = 1.0 gm/cm3

Weight of water saturated sample immersed in water = 269.6 gm

Solution:

$$V_p = \frac{\text{sat. core wt. in air - dry core wt.}}{\text{density of water}}$$

$$V_p = \frac{448.6\ gm - 427.3\ gm}{1\ gm/cm^3}$$

$$V_p = 21.3\ cm^3$$

$$V_b = \frac{\text{sat. core wt. in air - sat. core wt. in water}}{\text{density of water}}$$

$$V_b = \frac{448.6\ gm - 269.6\ gm}{1\ gm/cm^3}$$

$$V_b = 179.0\ cm^3$$

$$\phi = \frac{V_p}{V_b} = \frac{21.3\ cm3}{179.0\ cm3} = .119$$

$$\phi = 11.9\%$$

**Example 2:**

What is the lithology of the sample in example 1? Is the porosity effective or total? Why?

Solution:

What is the lithology of the sample?

$$V_m = V_b - V_p$$

$$V_m = 179.0\ cm^3 - 21.3\ cm^3 = 157.7\ cm^3$$

$$\rho_m = \frac{\text{wt. of dry sample}}{\text{matrix vol.}} = \frac{427.3\ gm}{157.7\ cm^3} = 2.71\ gm/(cm^3)$$

<u>The lithology is limestone.</u>

Is the porosity effective or total? Why?

Effective, because fluid was forced into the pore space.

**Example 3:**

A carbonate whole core (3 inches diameter by 6 inches length) is placed in cell two of a Boyles Law device. Each of the cells has a volume of 1,000 cc. Cell one is pressured to 50.0 psig. Cell two is evacuated. The cells are connected and the resulting pressure is 28.1 psig. Calculate the porosity of the core.

Solution:

$P_1$=50+14.7= 64.7 psia

$P_2$=28.1+14.7= 42.8 psia

1 inch= 2.54 cm

Diameter= 7.62 cm & length= 15.24 cm

$$V_b = \frac{\pi}{4} D^2 h$$

$$V_b = \frac{\pi}{4} \times 7.62^2 \times 15.24 = 695 \text{ cc}$$

$$V_g = (V_{ref} + V_{cc}) - \frac{P_1}{P_2} V_{ref}$$

$$V_g = (2000) - \frac{64.7}{42.8} \times 1000 = 488.32\ cc$$

$$V_p = V_b - V_g = 695 - 488.32 = 206.6\ cc$$

$$\emptyset = \frac{V_p}{V_b} = \frac{206.6}{695} = 0.2973 = 29.73\ \%$$

## 3.2. Subsurface Measurement of Porosity

Types of logs from which porosity can be derived:

### 1-Density log

Density log measures bulk density of formation by using radioactive source to generate Gamma rays. Gamma ray collides with electrons in formation, losing energy. Detector measures intensity of back-scattered gamma rays, which is related to electron density of the formation. Electron density is a measure of bulk density, the denser the rock the fewer gamma rays reach the detector.

$$\rho_b = \rho_f \emptyset + \rho_g (1 - \emptyset) \qquad \text{...... (3-8)}$$

$$\rho_{bdry} = \rho_g (1 - \emptyset) \qquad \text{...... (3-9)}$$

$$\rho_g = \sum_{i=1}^{i=N} c_i \rho_{gi} \qquad \text{...... (3-10)}$$

$$\emptyset_D = \frac{\rho_{matrix} - \rho_{log}}{\rho_{matrix} - \rho_{fluid}} \qquad \text{...... (3-11)}$$

### 2- Sonic Log

Measures time required for compressional sound waves to travel through one foot of formation. Sound travels more slowly in fluids than in solids. Pore space is filled with fluids. Travel time increases as porosity increases.

$$\emptyset_s = \frac{\Delta t_{log} - \Delta t_{Matrix}}{\Delta t_{fluid} - \Delta t_{Matrix}} \qquad \text{...... (3-12)}$$

### 3- Neutron Log

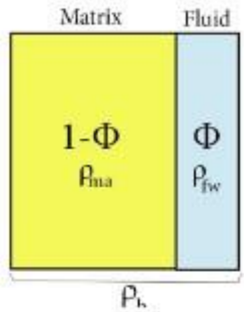
Neutron Log measures the amount of hydrogen in the formation (hydrogen index). In clean, liquid filled formations, hydrogen index is directly proportional to porosity. Neutron log gives porosity directly.

## Example 4:

The bulk density of a clean, sandy interval saturated with water was measured by the density logging tool to be (2.4 g/cm3). Assuming that the density of the formation water is (1.04 g/cm3) and the density of the matrix is (2.67 g/cm3), calculate the density porosity of the formation.

Solution:

$\rho_b = 2.4\ g/cm^3,\quad \rho_{fw} = 1.04\ g/cm^3,\quad \rho_{ma} = 2.67\ g/cm^3 \quad \Phi_d = ??$




$$\Phi_d = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_{fw}}$$

$$\Phi_d = \frac{2.67 - 2.4}{2.67 - 1.04} = 0.166 = 16.6\%$$

## Example 5:

A sonic log measured travel time of 58 µs for a formation. If the formation is primarily limestone (46 µs) and contains oil only (190 µs) compute the rock porosity.

Solution:

$$\Phi_s = \frac{\Delta t_{log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}}$$

$$\Phi_s = \frac{58 - 46}{190 - 46} = 0.083 = 8.3\%$$