Laboratory Measurement of Capillary Pressure

by

Dr- Eissa Shokir

PE 363
LABORATORY METHODS FOR MEASURING CAPILLARY PRESSURE

- Porous diaphragm method
- Mercury injection method
- Centrifuge method
- Dynamic method

Determination of $P_c(S_w)$ function
POROUS DIAPHRAGM METHOD FOR CAPILLARY PRESSURE

Porous diaphragm method of measuring capillary pressure

- Ultra-fine fritted glass disk
- Core
- Kleenex paper
- Nickel-plated spring
- Neoprene stopper
- Saran tube
- Crude oil
- Scale of squared paper
- Seal of red oil
- Nitrogen pressure
- Brine

Modified from Welge and Bruce, 1947
Capillary pressure using porous diaphragm method.

- Capillary pressure, psi
- Measured data points
- Irreducible wetting phase saturation
- Displacement pressure
- 0 Wetting phase saturation, % 100
COMMENTS ON POROUS DIAPHRAGM METHOD

• Advantages
  – Very accurate
  – Can use reservoir fluids

• Disadvantages
  – Very slow (days, weeks, months)
  – Range of capillary pressure is limited by “displacement pressure” of porous disk
    • Wetting phase of disk should be same as core sample
  • Holes in porous disk act as capillaries, allowing only wetting to flow out until displacement pressure is exceeded
MERCURY INJECTION METHOD FOR CAPILLARY PRESSURE

From Purcell, 1949
COMMENTS ON MERCURY INJECTION METHOD

• Advantages
  – Results obtained quickly (minutes, hours)
  – Method is reasonably accurate
  – Very high range of capillary pressures

• Disadvantages
  – Ruins core / mercury disposal
  – Hazardous testing material (mercury)
  – Conversion required between mercury/air capillary data to reservoir fluid systems
CENTRIFUGE METHOD FOR DETERMINING CAPILLARY PRESSURE

From Slobod and others, 1951
COMMENTS ON CENTRIFUGE METHOD

• Advantages
  – Results can be obtained fairly quickly (hours, days, weeks)
  – Reasonably accurate
  – Can use reservoir fluids

• Disadvantages
  – Complex analysis required can lead to calculation errors
DYNAMIC METHOD OF MEASURING CAPILLARY PRESSURE

From Brown, 1951
COMMENTS ON DYNAMIC METHOD

• Advantages
  – Simulates reservoir flow conditions
  – Can use reservoir fluids

• Disadvantages
  – Very tedious to perform (weeks, months)
  – High cost
AVERAGING CAPILLARY PRESSURE DATA USING THE LEVERETT J-FUNCTION

- The Leverett J-function was originally an attempt to convert all capillary pressure data to a universal curve.

- A universal capillary pressure curve does not exist because the rock properties affecting capillary pressures in the reservoir have extreme variation with lithology (rock type).

- BUT, Leverett’s J-function has proven valuable for correlating capillary pressure data within a lithology (see ABW Fig 3-23).
EXAMPLE J-FUNCTION FOR WEST TEXAS CARBONATE
DEFINITION OF LEVERETT J-FUNCTION

\[ J(S_w) = \frac{C P_c}{\sigma \cos \theta} \sqrt{\frac{k}{\phi}} \]

- J-Function is **DIMENSIONLESS**, for a particular rock type:
  - Same value of J at same wetting phase saturation for any unit system, any two fluids, any values of k, $\phi$
    - $(k/\phi)^{1/2}$ is proportional to size of typical pore throat radius (remember k can have units of length$^2$)
  - C is unit conversion factor (to make $J(S_w)$ dimensionless)
Function moves up and right, and becomes less “L” shaped as reservoir quality decreases.
LEVERETT J-FUNCTION FOR CONVERSION OF $P_c$ DATA

$$J(S_w) = \left[ \frac{C P_c}{\sigma \cos \theta} \sqrt{\frac{k}{\phi}} \right]_{\text{Lab}} = \left[ \frac{C P_c}{\sigma \cos \theta} \sqrt{\frac{k}{\phi}} \right]_{\text{Reservoir}}$$
USE OF LEVERETT J-FUNCTION

• J-function is useful for averaging capillary pressure data from a given rock type from a given reservoir

• J-function can sometimes be extended to different reservoirs having same lithologies
  – Use extreme caution in assuming this can be done

• J-function usually not accurate correlation for different lithologies

• If J-functions are not successful in reducing the scatter in a given set of data, then this suggests that we are dealing variation in rock type