

Department of Petroleum Engineering  
PE 8623: Reservoir Engineering II  
Unit - IV

② Write a neat diagram show the phase behaviour of fluids on pressure Vs Temperature plot, indicating all parameters involved in it.

When hydrocarbon contacts water, the two components separate into two phases in which the mutual component solubility is less than 1.0 mole% at ambient conditions.

This splitting of phase affects almost all treatments of mixed water and hydrocarbon systems and is caused by the different molecular attractions within water and hydrocarbons.

Hydrocarbon molecules have a weak, noncharged attraction for each other, while water attracts other water molecules through a strong, charged hydrogen bond.

Because hydrogen bonds are significantly stronger than those between hydrocarbon molecules hydrocarbon solubility in water (and that of water in hydrocarbons) is very small. Hydrogen bonds are responsible for most of the unusual properties water displays.

- water's very high heat of vaporization
- which absorbs large amount of heat & buffers many hydrocarbon reservoir temp
- very high normal boiling point water has relative to its molecular weight.

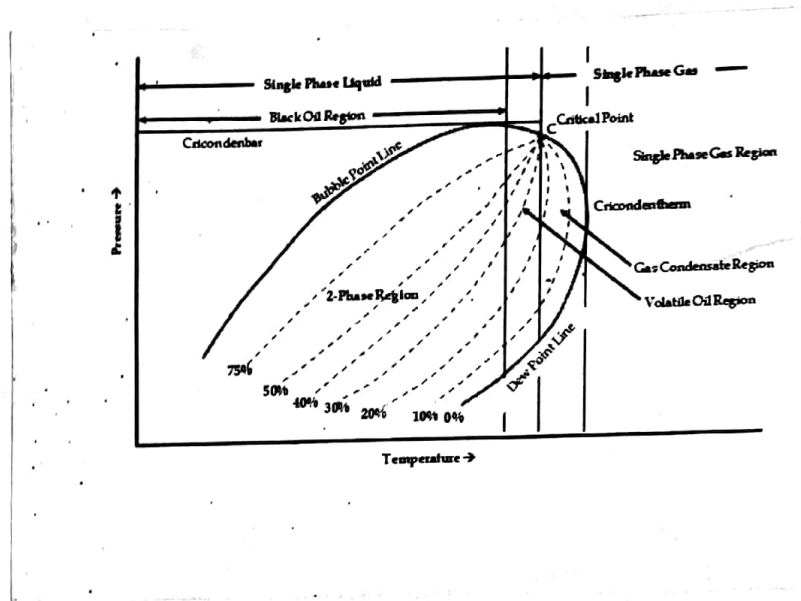
Phase behaviour of water and hydrocarbon system is divided into three main categories.

Gibbs phase rule which are used to define the problem. Only the two most common concerns are treated in this.

Equilibrium of water & hydrocarbon system without hydrates. It goes on cover the simplest case that of a water & hydrocarbon mixture when all phases are fluid.

as vapour and/or liquid and without hydrate formation.

This water and hydrocarbon equilibrium without hydrates exists at high temperature or low pressure or when only large hydrocarbon components present.



Importance of hydrates in water and  $H_2$  equilibrium  
 Equilibrium of water and hydrocarbon system with  
 hydrates deals with systems containing small  
 hydrocarbon molecules that form hydrates with  
 water.

Hydrates are the most common solid  
 phase problem in flow assurance.

③ Discuss gas condensate reservoir engineering in detail.

Gas condensate is a single phase fluid at original reservoir conditions. It contains methane and other short hydrocarbons, but it also contains long chain hydrocarbons termed as heavy ends.

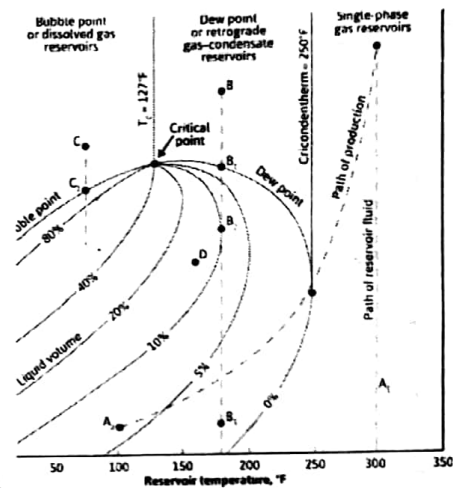
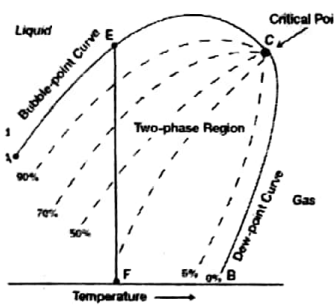
A gas condensate reservoir can choke on its most valuable components. Condensate liquid saturation can build up near a well because of drawdown below the dewpoint pressure ultimately restricting the flow of gas.

Conditions for gas condensate reservoir engineering.

The rule of thumb that a gas condensate system exists when the gas/liquid ratio exceeds  $5,000 \text{ cu ft bbl} [200 \text{ bbl/MMscf}]$  and the liquid is higher than  $50 \text{ degree API}$ .

A more accurate representation of the composition of gas condensate fluids is provided by fractional analysis of the streams coming from the reservoir.

The viscosity of a gas condensate system is of interest in various reservoir calculations, particularly with respect to cycling operations and representation of such reservoir in computer model.



Whenever possible, viscosity of the vapour phase at reservoir conditions should be measured directly. Viscosities of separate gas and liquid phase at the surface conditions usually encountered can be obtained by the direct measurement.

Empirical correlation for determining the viscosity is a fn of pres, temp gas-liquid ratio & gas composition.

⑤ How is material balance method used in calculating water influx?

To find out the volume of gas cap

we can introduce a parameter 'm' to find out the ratio between gas and oil.

$$m = \frac{\text{Initially volume of gas cap}}{\text{Volume of oil initially in place}}$$

$$m = \frac{G \cdot B_{gi}}{N \cdot B_{oi}}$$

$$\boxed{G \cdot B_{gi} = m \cdot N \cdot B_{oi}}$$

$B_{gi}$  - Initial gas formation volume factor  
ft<sup>3</sup>/STB

$B_{oi}$  - Initial oil formation volume factor  
ft<sup>3</sup>/STB

The total volume of hydrocarbon system can be given as,

$$\begin{aligned} &\text{Initial oil volume} \\ &+ \\ &\text{Initial gas cap volume} \end{aligned} = \text{pore volume}$$

$$N_{Boi} + G_{Boi} = PV (1 - S_{wi})$$

$$N_{Boi} + m N_{Boi} = PV (1 - S_{wi})$$

$$N_{Boi} (1 + m) = PV (1 - S_{wi})$$

The generalized material balance equations can be written as

$$\left[ (PV \text{ occupied by oil initially @ } P_i) \right]$$

+

$$\left[ (PV \text{ occupied by gas cap initially @ } P_i) \right]$$

$$\Rightarrow \left[ (PV \text{ occupied by remaining volume of oil at } P) \right]$$

$$+ (PV \text{ occupied by remaining volume of water influx @ } P)$$

+

$$(PV \text{ occupied gas cap @ } P)$$

+

$$(PV \text{ occupied by evolved solution gas at } P)$$

+

$$(change \text{ in } PV \text{ due to connate water gas at } P)$$

+

$$(PV \text{ occupied injected water at } P)$$

+

$$\left[ (PV \text{ occupied injected @ } P) \right]$$

PV occupied by oil in place @  $P_i = N B_{oi}$

PV occupied by gas cap @  $P_i = m N B_{gi}$

PV occupied by remaining volume of oil @  $P = (N - N_p) B_o$

PV occupied by water in place @  $P = (W_e - W_p) B_w$

PV occupied by gas cap @  $P = \frac{m \cdot N \cdot B_{oi}}{B_{gi}} B_g$

Volume of evolved solution gas = [ (Volume of gas initially in solution) - (Volume of gas produced) - (Volume of gas remaining in solution) ]

Vol. of evolved soln gas =  $[ N R_{oi} - N_p R_p - (N - N_p) R_s ] B_g$

Change in PV due to connate water =  $N \cdot B_{oi} (1+m) \frac{S_{wi} C_w + C_g}{1 - S_{wi}} \Delta P$

PV occupied by injected gas & water @  $P = G_{inj} B_g + W_{inj} B_w$



⑥ What is retrograde gas condensate reservoir? How their depletion performance studied?

Gas condensate is single phase fluid at original reservoir conditions. It contains methane and other short hydrocarbons, but it also contains long chain hydrocarbons termed as heavy ends.

A gas condensate reservoir can choke on its most valuable components. Condensate liquid saturation can build up near a well because a drawdown below the dew point pressure, ultimately restricting the flow of gas.

A rule of thumb that gas condensate system exists when the liq/gas ratio exceeds 5000 cu ft bbl (200 bbl/MMscf) and liquid is lighter than 50 degree API.

The viscosity of a gas condensate system is of interest in various reservoir calculations, particularly with respect to cycling operations and the representation of such reservoir in computer models.

Whenever possible, viscosity of the vapor phase at reservoir conditions should be measured directly.

Viscosities of separate gas and liquid phase at the surface conditions usually encountered can be obtained by direct measurement.

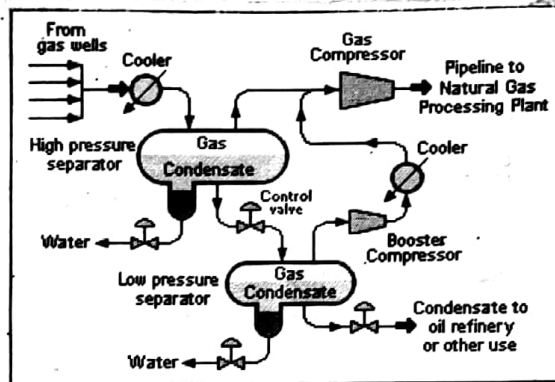
Empirical correlations for determining the viscosity by direct measurement are a function of

✓ Pressure

✓ Temperature

✓ Gas-Liquid Ratio

✓ Gas composition



The condensate reservoir that is the topic under discussion is therefore first a hydrocarbon reservoir. Due to the composition and the production of the individual hydrocarbons in the mixture, the content is gas phase at the temperature and pressure of the reservoir.