University of Mosul

College of Petroleum & Mining Engineering

Department of Petroleum & Refining Engineering

Petroleum Reservoir Engineering

Third Year

Lecture 5

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Gas reservoirs

If the reservoir temperature is above the critical temperature of the hydrocarbon system, the reservoir is classified as a natural gas reservoir. On the basis of their phase diagrams and the prevailing reservoir conditions, natural gases can be classified into four categories:

- Retrograde gas-condensate
- Near-critical gas-condensate
- Wet gas
- Dry gas

1- Retrograde gas-condensate reservoir:

If the reservoir temperature T lies between the critical temperature T_c and cricondentherm T_{ct} of the reservoir fluid, the reservoir is classified as a retrograde gas-condensate reservoir. The typical phase diagram of a retrograde gas-condensate system is shown in Figure 1.

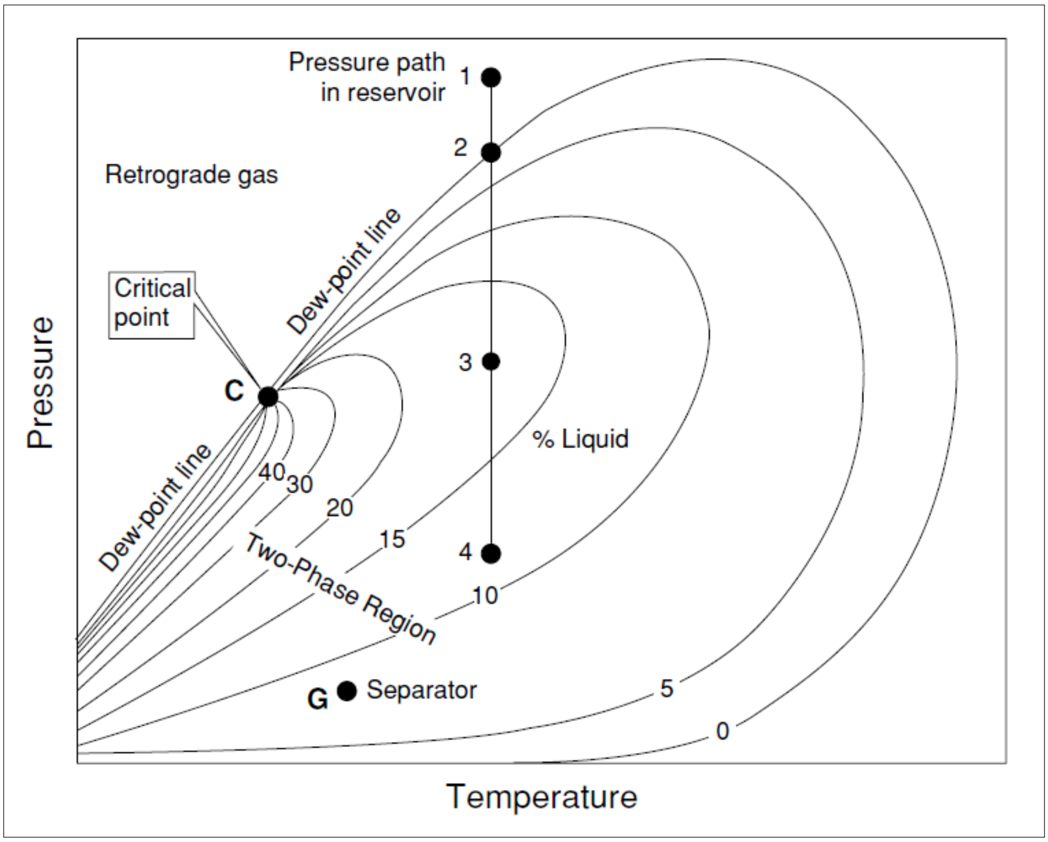

Figure 1: A typical phase diagram of a retrograde gas-condensate reservoir.

Consider that the initial condition of a retrograde gas reservoir is represented by point 1 on the pressure-temperature phase diagram of Figure 1. Because the reservoir pressure is above the upper dew-point pressure, the hydrocarbon system exists as a single phase (i.e. vapour phase) in the reservoir. As the reservoir pressure declines isothermally during production from the initial pressure (point 1) to the upper dew-point pressure (point 2), the attraction between the molecules of the light and heavy components causes them to move farther apart. As this occurs, attraction between the heavy component molecules becomes more effective; thus, liquid begins to condense.

This retrograde condensation process continues with decreasing pressure until the liquid dropout reaches its maximum at point 3. Further reduction in pressure permits the heavy molecules to commence the normal vaporization process. This is the process whereby fewer gas molecules strike the liquid surface, which causes more molecules to leave than enter the liquid phase. The vaporization process continues until the reservoir pressure reaches the lower dew-point pressure. This means that all the liquid that formed must vaporize because the system is essentially all vapours at the lower dew point.

The typical liquid shrinkage volume curve for a retrograde gas-condensate reservoir is shown in Figure 2. The curve is commonly called the **liquid dropout curve.** In most gas-condensate reservoirs, the condensed liquid volume seldom exceeds more than 15% to 19% of the pore volume. This liquid saturation is not large enough to allow any liquid flow. It should be recognized that around the wellbore where the pressure drop is high, enough liquid dropout might accumulate to give two-phase flow of gas and retrograde liquid.

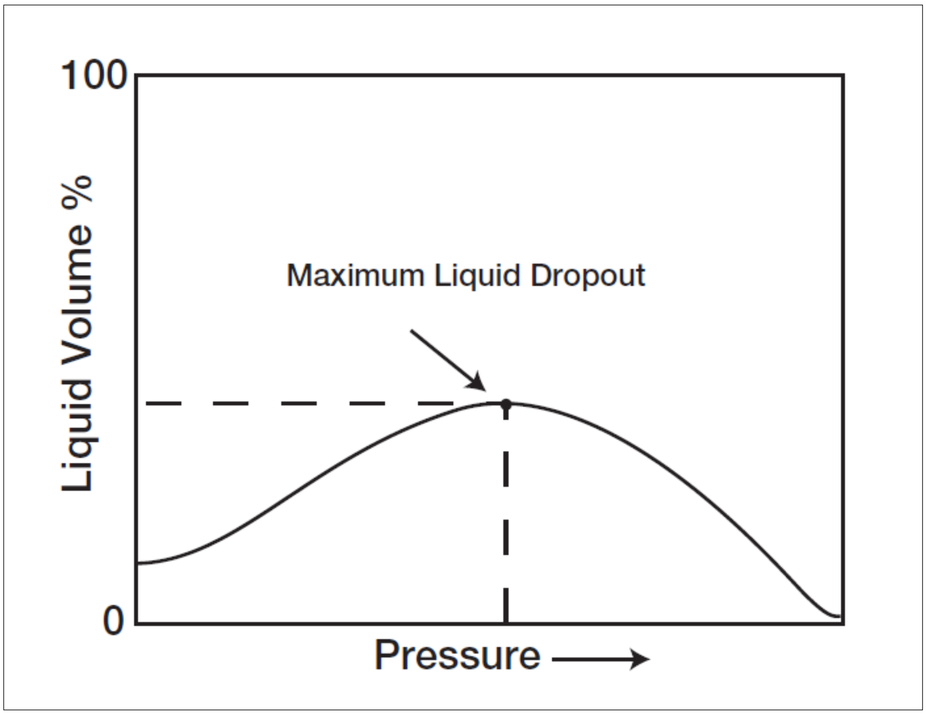

Figure 2: A typical liquid shrinkage volume curve for a retrograde gas-condensate reservoir.

The associated physical characteristics of this category are:

- Gas-oil ratios between 8,000 and 70,000 scf/STB. Generally, the gas-oil ratio for a condensate system increases with time due to the liquid dropout and the loss of heavy components in the liquid.
- Condensate gravity above 50° API.
- Stock-tank liquid is usually water-white or slightly coloured.

2- Near-critical gas-condensate reservoir:

If the reservoir temperature is near the critical temperature, the hydrocarbon mixture is classified as a near-critical gas-condensate, (Figure 3). The volumetric behaviour of this category of natural gas is described through the isothermal pressure declines as shown by the vertical line 1-3 in Figure 3, and also by the corresponding liquid dropout curve of Figure 4.

Because all the quality lines converge at the critical point, a rapid liquid buildup will immediately occur below the dew point (Figure 3) as the pressure is reduced to point 2.

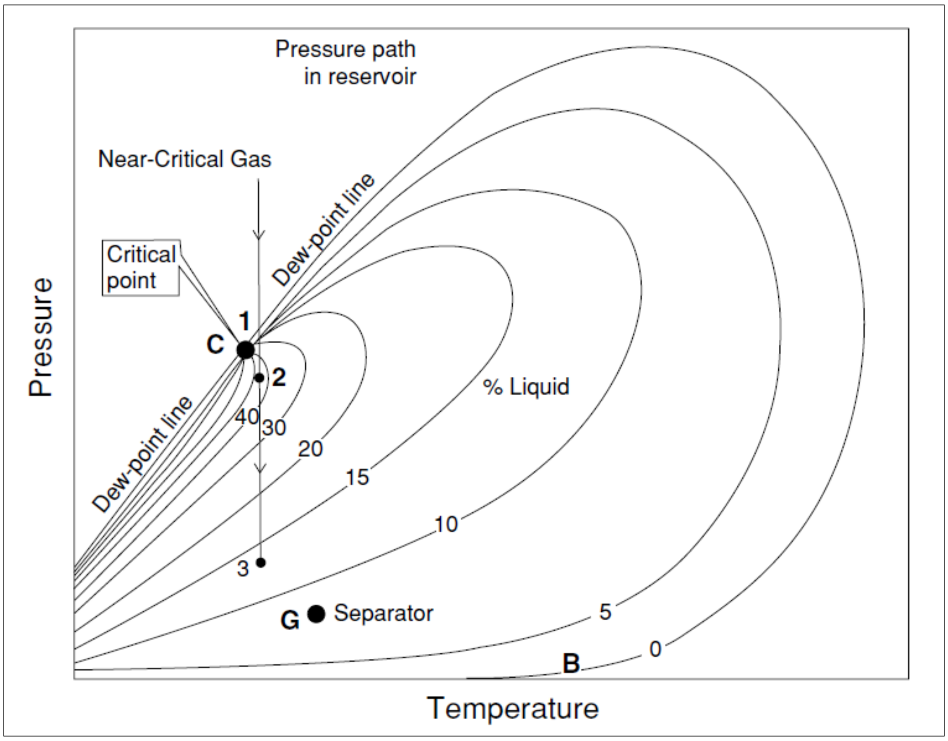

Figure 3: A typical phase diagram for a near-critical gas condensate reservoir.

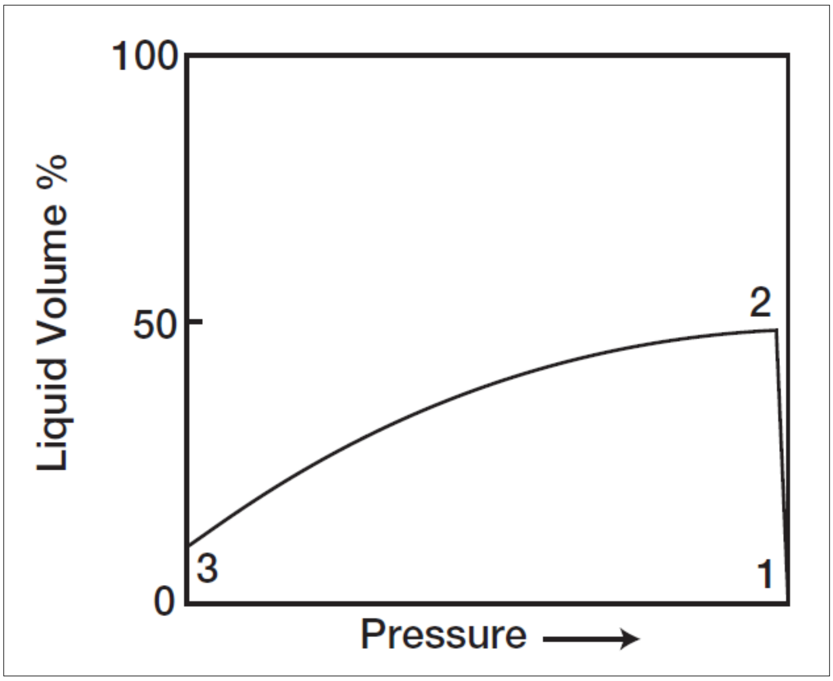

Figure 4: Liquid-shrinkage curve for a near-critical gas-condensate system.

3- Wet-gas reservoir:

If the reservoir temperature is above the cricondentherm T_{ct} of the hydrocarbon mixture, the reservoir is classified as a wet gas. A typical phase diagram of a wet gas is shown in Figure 5.

Because the reservoir temperature exceeds the cricondentherm T_{ct} of the hydrocarbon system, the reservoir fluid will always remain in the vapour phase region as the reservoir is depleted isothermally, along the vertical line A-B (Figure 5).

Wet-gas reservoirs are characterised by the following properties:

● Gas oil ratios between 60,000 and 100,000 scf/STB.

● Stock-tank oil gravity above 60^o API.

● Liquid is water-white in colour.

●Separator conditions, i.e. separator pressure and temperature, lie within the two-phase region.

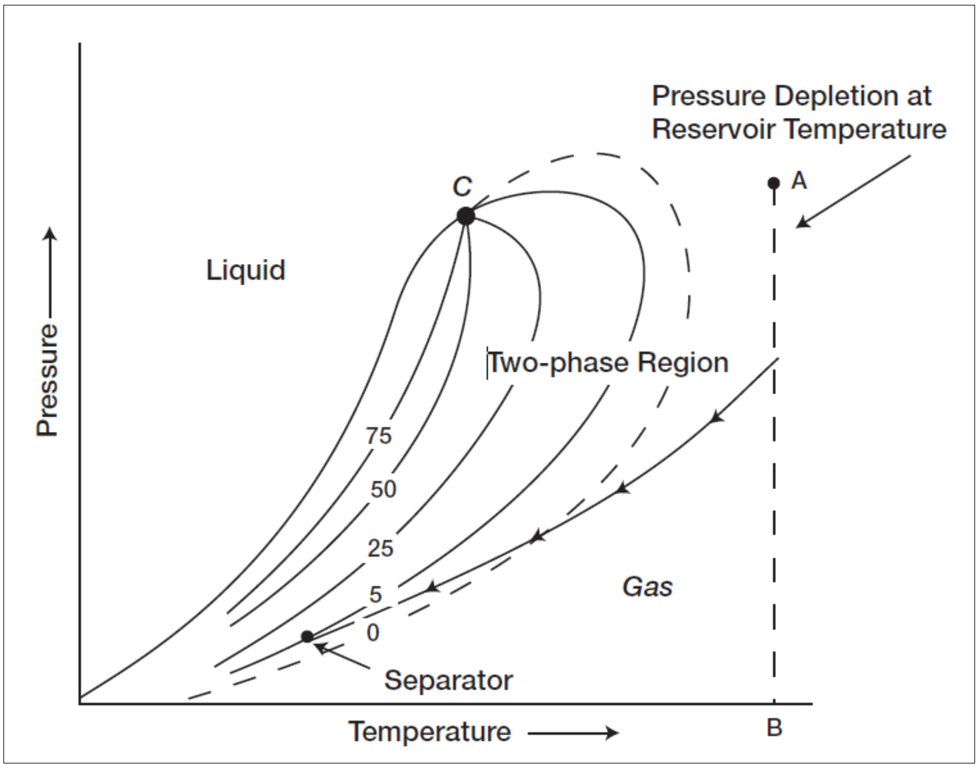

Figure 5: Phase diagram for a wet gas reservoir.

4- Dry-gas reservoir:

The hydrocarbon mixture exists as a gas both in the reservoir and in the surface facilities. The only liquid associated with the gas from a dry-gas reservoir is water. A phase diagram of a dry-gas reservoir is given in Figure 6. Usually a system having a gas-oil ratio greater than 100,000 scf/STB is considered to be a dry gas.

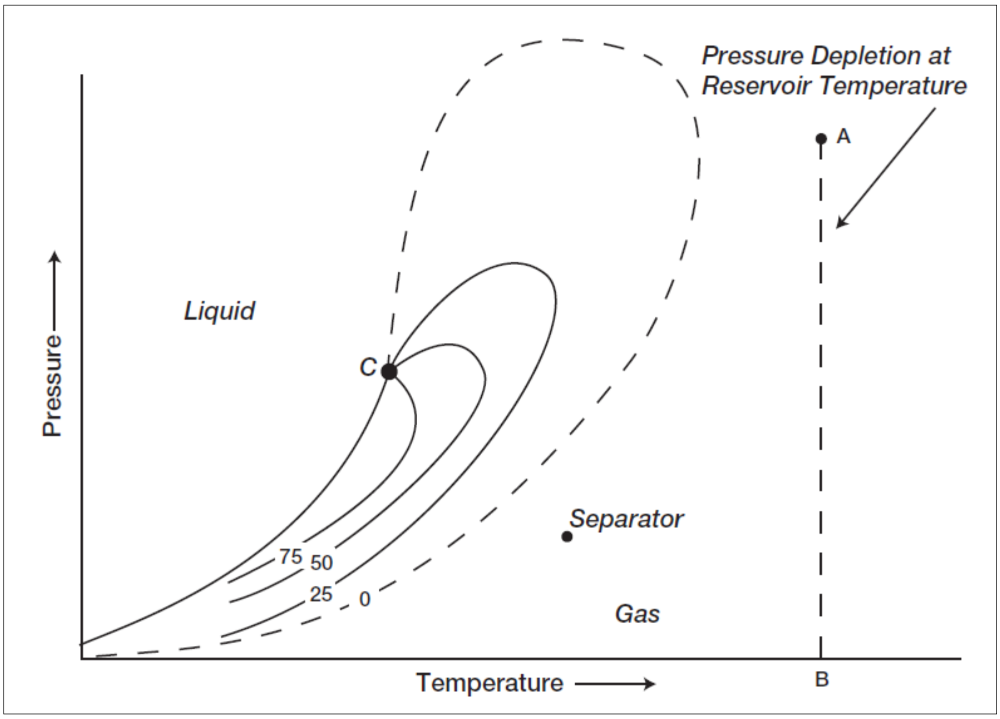

Figure 6: Phase diagram for a dry gas reservoir.