University of Mosul

College of Petroleum & Mining Engineering

Department of Petroleum & Refining Engineering

Petroleum Reservoir Engineering

Third Year

Lecture 4

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Pressure – Temperature Diagram

Figure 1 shows a typical pressure – temperature diagram of a multicomponent system with a specific overall composition. This multicomponent pressure-temperature diagram is used to:

● Classify reservoirs.

● Classify the naturally occurring hydrocarbon systems.

● Describe the phase behaviour of the reservoir fluid.

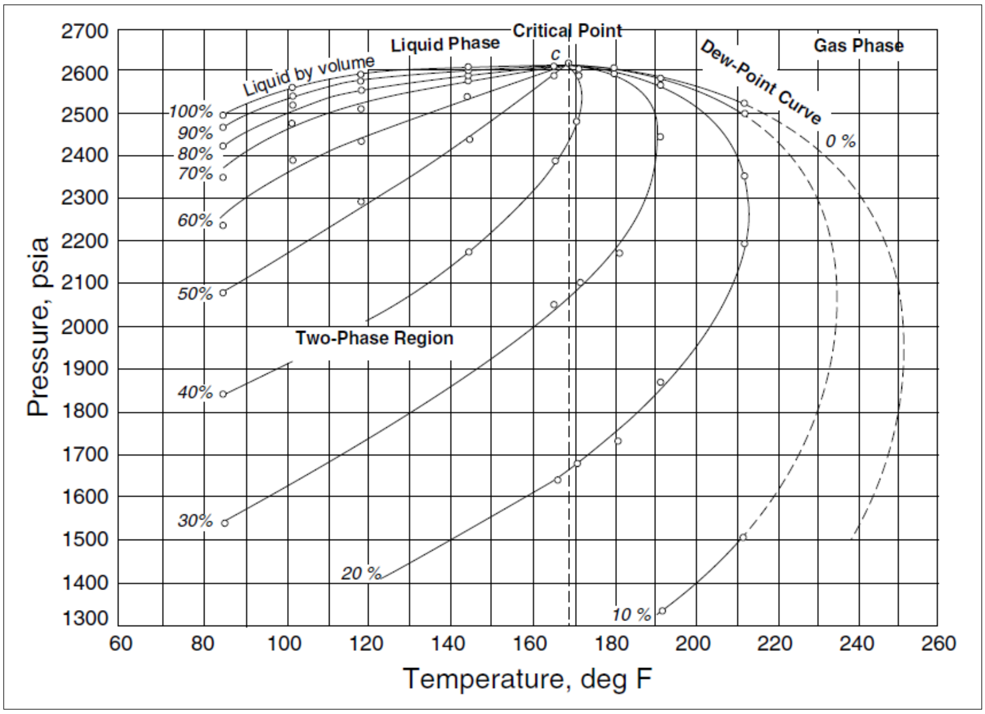

Figure 1: Typical P-T diagram for a multicomponent system.

To fully understand the significance of the pressure-temperature diagrams, it is necessary to identify and define the following key point on these diagrams:

Critical point: The critical point for a multicomponent mixture is referred to as the state of pressure and temperature at which all intensive properties of the gas and liquid are equal.

Bubble-point curve: The bubble-point curve is defined as the line separating the liquid-phase region from the two-phase region.

Dew-point curve: The dew-point curve is defined as the line separating the vapour-phase region from the two –phase region.

Phase envelope (two-phase region): The phase envelop is defined as the region enclosed by the bubble-point curve and the dew-point curve, wherein gas and liquid coexist in equilibrium.

Cricondentherm (Tct): The Cricondentherm is defined as the maximum temperature above which liquid cannot be formed regardless of pressure.

Cricondenbar (Pcb): The Cricondenbar is the maximum pressure above which no gas can be formed regardless of temperature.

Quality lines: The quality lines are the dashed lines within the phase diagram which describe the pressure and temperature conditions for equal volumes of liquids. Note that the quality lines converge at the critical point.

Classification of petroleum reservoirs:

Petroleum reservoirs are classified into two broad classes:

1- Oil reservoirs:

If the reservoir temperature (T) is less than the critical temperature (T_c) of the reservoir fluid, the reservoir is classified as an oil reservoir.

The critical temperature is defined as the highest temperature at which two phases (for example oil and gas) could coexist.

2- Gas reservoirs:

If the reservoir temperature is greater than the critical temperature of the hydrocarbon fluid, the reservoir is considered as gas reservoir.

Oil reservoirs:

Depending upon initial reservoir pressure pi, oil reservoirs can be sub-classified into the following categories:

a- Undersaturated oil reservoir:

If the initial reservoir pressure pi is greater than the bubble-point pressure p_b of the reservoir fluid, the reservoir is labelled an undersaturated oil reservoir.

The **bubble point pressure p_b** of a hydrocarbon system is defined as the highest pressure at which a bubble of gas is first librated from the oil.

b- Saturated oil reservoir:

When the initial reservoir pressure is equal to the bubble-point pressure of the reservoir fluid, the reservoir is called a saturation oil reservoir.

c- Gas-cap reservoir:

If the initial reservoir pressure is below the bubble-point pressure of the reservoir fluid, the reservoir is termed a gas-cap or two-phase reservoir, in which the gas or vapour phase is underlain by oil phase.

Crude oils are commonly classified into the following types:

1- Ordinary black oil

2- Low-shrinkage crude oil

3- High-shrinkage (volatile) crude oil

4- Near-critical crude oil

The above classification is based upon the properties exhibited by the crude oil, including physical properties, composition, gas-oil ratio, appearance, and pressure-temperature phase diagram.

1- Ordinary black oil:

The typical pressure-temperature phase diagram for ordinary black oil is shown in figure 2. Following the pressure reduction path as indicated by the vertical line EF on Figure 2, the liquid shrinkage curve, as shown in Figure 3, is prepared by plotting the liquid volume percent as a function of pressure. The liquid shrinkage curve approximately a straight line except at very low pressures.

When produced, ordinary black oils usually yield gas-oil rations between 200 and 700 scf/STB and oil gravities of 15^o to 40^o API. The stock tank oil is usually brown to dark green in colour.

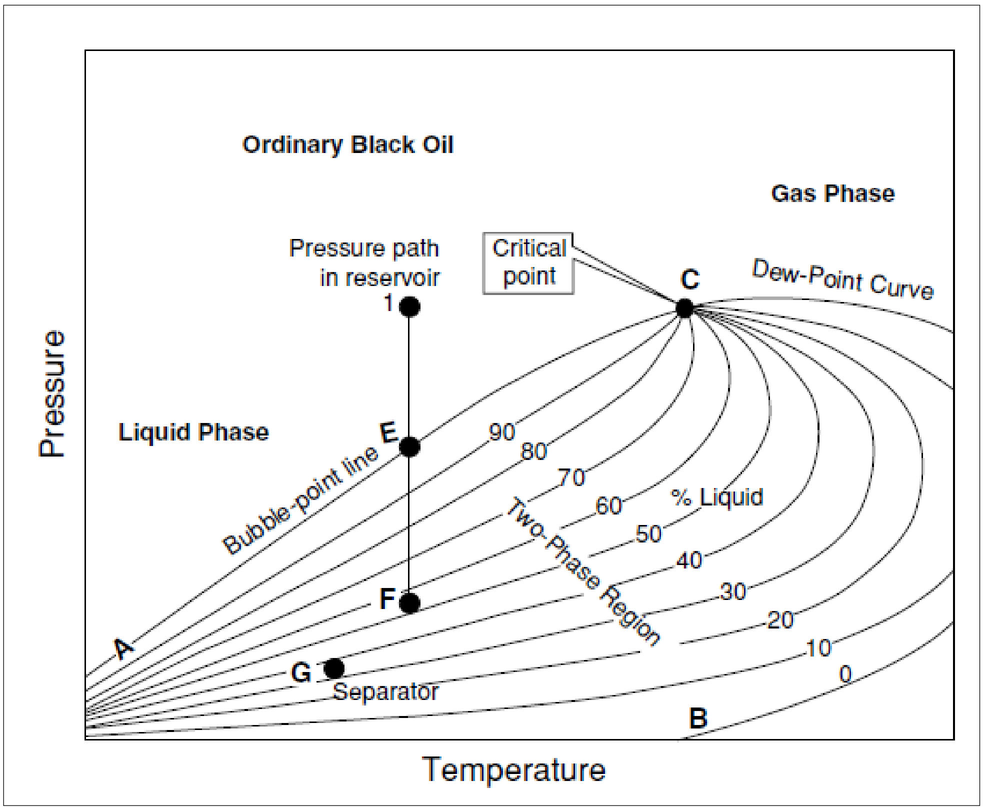

Figure 2: A typical P-T diagram for an ordinary black oil.

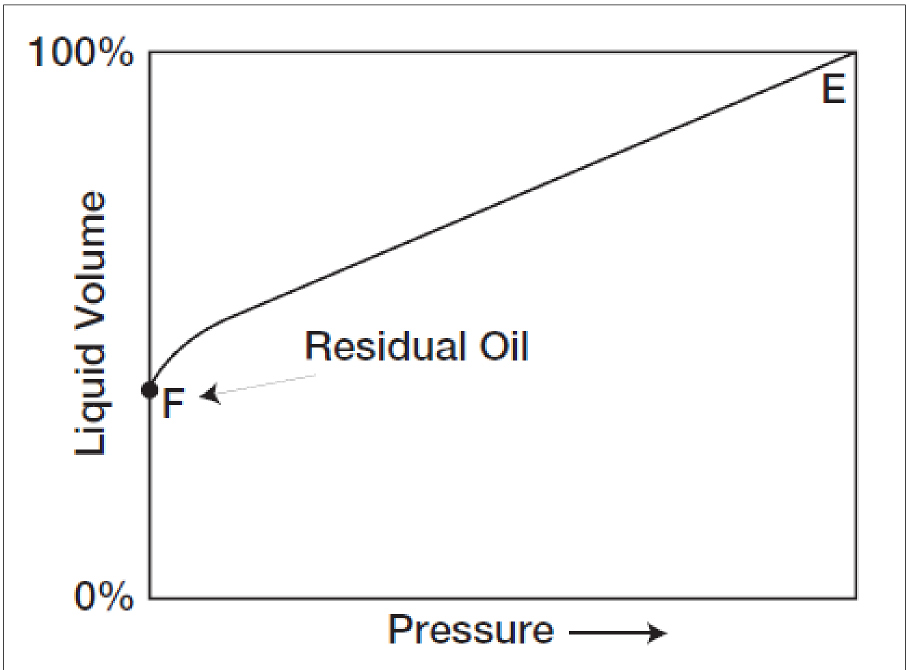

Figure 3: Liquid-shrinkage curve for black oil.

2- Low-shrinkage oil:

The typical pressure-temperature phase diagram for low-shrinkage oil is shown in Figure 4. The diagram is characterized by quality lines that are closely spaced near the dew-point curve. The liquid-shrinkage curve shows the shrinkage characteristics of this category of crude oils (Figure 5).

The other properties of the low-shrinkage oil are:

● Oil formation volume factor less than 1.2 bbl/STB.

● Gas-oil ratio less than 200 scf/STB.

● Oil gravity less than 35° API.

● Black or deeply coloured.

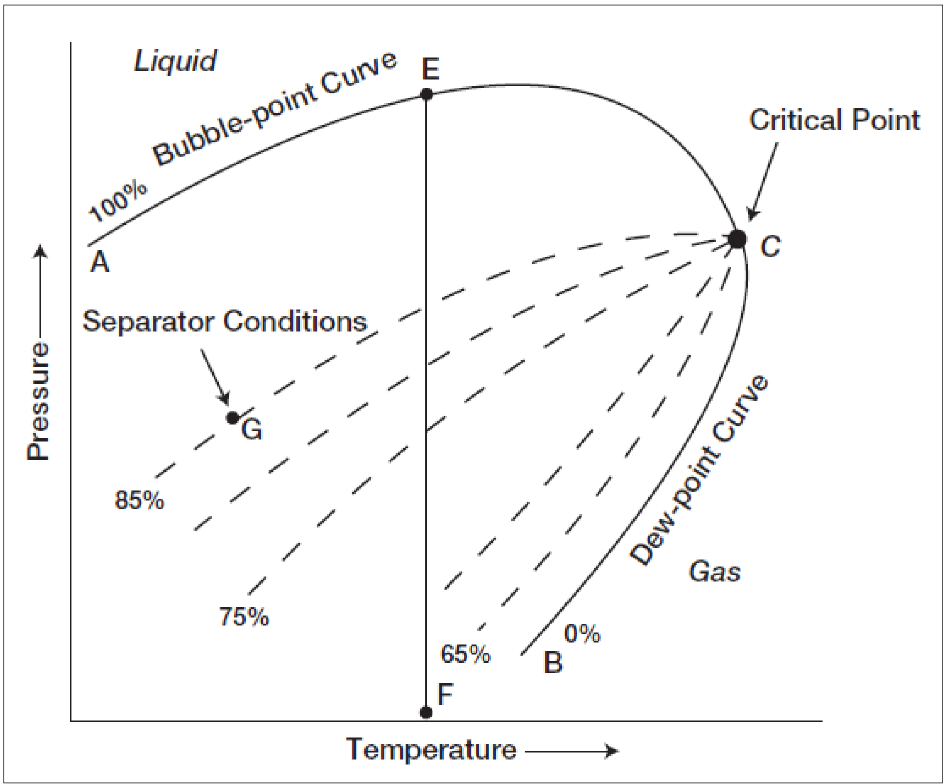

Figure 4: A typical phase diagram for a low-shrinkage oil.

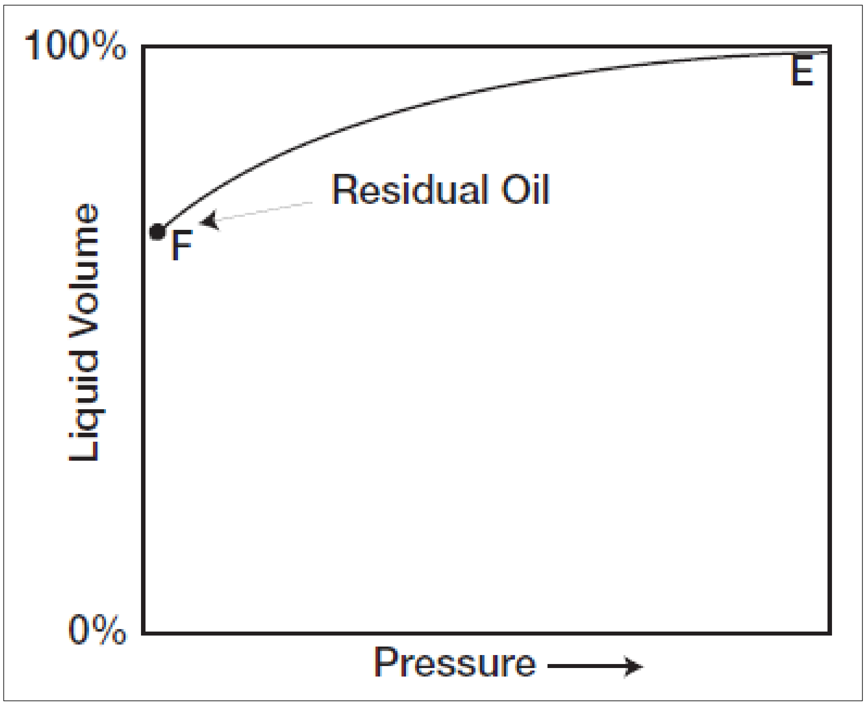

Figure 5: Oil-shrinkage curve for low-shrinkage oil.

3- Volatile crude oil:

The phase diagram for a volatile (high-shrinkage) crude oil is given in Figure 6. The quality lines of the diagram are close together near the bubble-point and more widely spaced at lower pressures. This type of crude oil is commonly characterized by a high liquid shrinkage immediately below the bubble-point as shown in Figure 7.

The other characteristic properties of this type of crude oil include:

● Oil formation volume factor less than 2 bbl/STB.

● Gas-oil ratios between 2,000 and 3,200 scf/STB.

● Oil gravities between 45^o and 55^o API.

● Greenish to orange in colour.

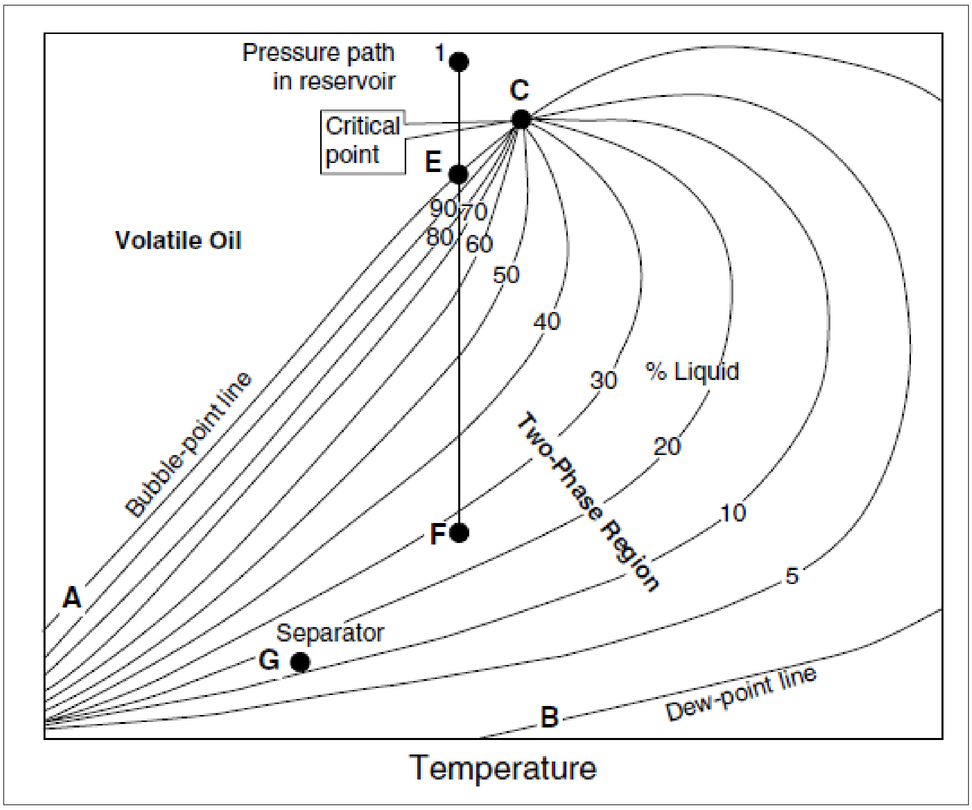

Figure 6: A typical P-T diagram for a volatile crude oil.

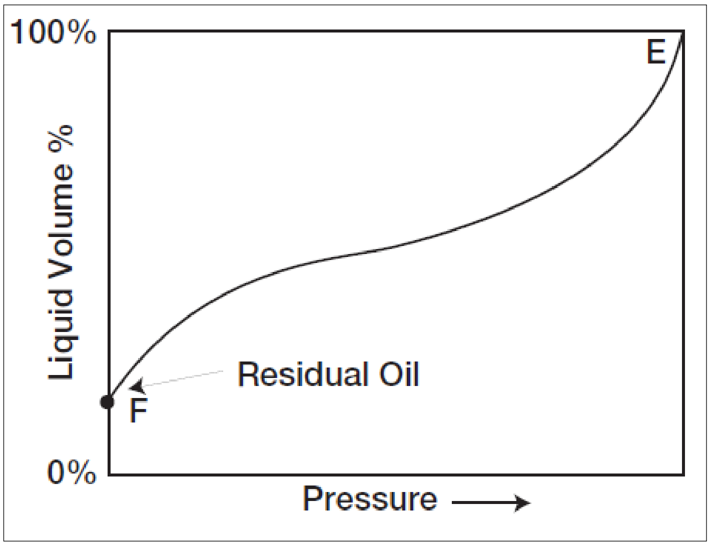

Figure 7: A typical liquid-shrinkage curve for a volatile crude oil.

4- Near-critical crude oil:

If the reservoir temperature T is near the critical temperature T_c of the hydrocarbon system, the hydrocarbon mixture is identified as a near-critical crude oil (Figure 8). Because all the quality lines converge at the critical point, an isothermal pressure drop (as shown by the vertical line EF in Figure 8) may shrink the crude oil from 100% of the hydrocarbon pore volume at the bubble-point to 55% or less at a pressure 10 to 50 psi below the bubble-point. The shrinkage characteristic behaviour of the near-critical crude oil is shown in Figure 9.

The near-critical crude oil is characterized by:

● High gas-oil ratio in excess of 3,000 scf/STB.

● Oil formation volume factor of 2.0 bbl/STB or higher.

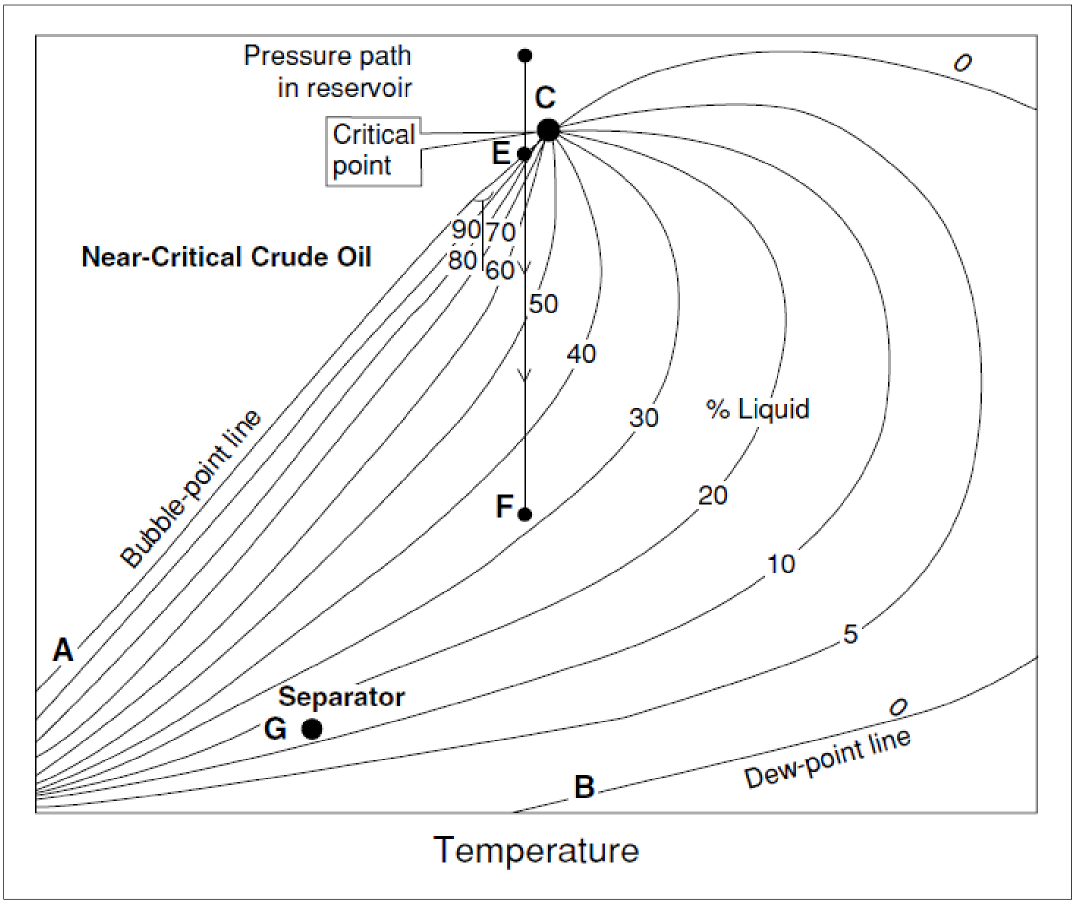

Figure 8: A schematic phase diagram for the near-critical crude oil.

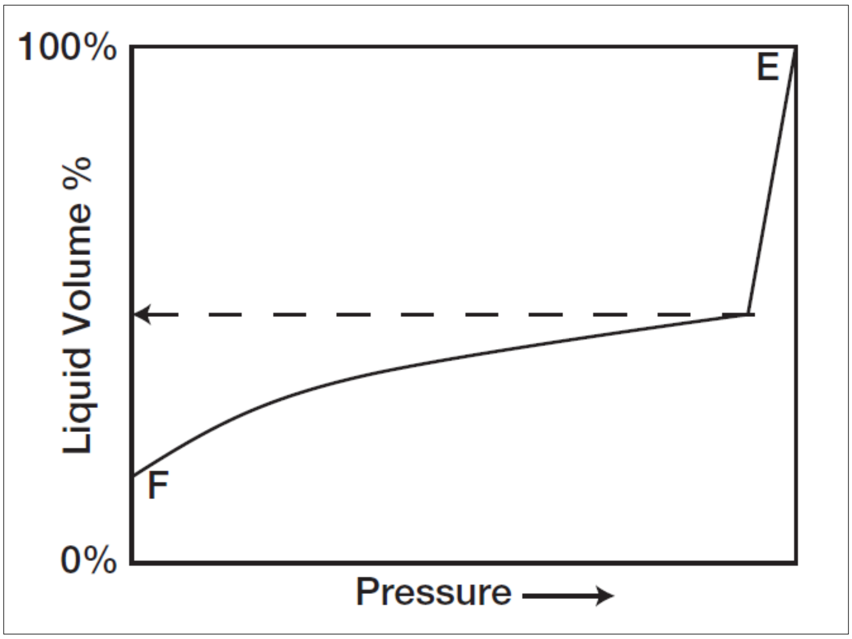

Figure 9: A typical liquid-shrinkage curve for the near-critical crude oil.