CHAPTER-6
PHASE BEHAVIOR OF HYDROCARBON FLUIDS

Hydrocarbon accumulations are invariably associated with formation waters that exist in the hydrocarbon zone as interstitial water, and as aquifers, which lend energy to the production process. Commonly two or three different fluid phases exist together in the reservoir. Any analysis of reservoir behavior depends on the PVT (pressure-volume and temperature) relationships for the co-existing fluids. It is customary to represent the phase behavior of hydrocarbon reservoir fluids on the P-T plane showing the limits over which the fluid exists as a single phase and the proportions of oil and gas in equilibrium over the two-phase P-T range.

6.1 Phase Behavior of Single Component System

Single component hydrocarbons are not found in nature; however it is beneficial to observe the behavior of pure hydrocarbon substance under varying pressure and temperature to gain insight into more complex hydrocarbon systems under similar conditions. As an example of the behavior of a pure hydrocarbon substance PVT cell is charged with ethane at 60 F and 1000 psia. Under these conditions, ethane is in the liquid state. If the cell volume is increased while holding the temperature constant at 60 F throughout, it will be found that the pressure falls rapidly until the first bubble of gas appears. This is called *bubble point*. Further increase of cylinder volume does not reduce the pressure provided, temperature is held at 60 F although heat must be added to the system to maintain a constant temperature. The gas volume increases at this constant pressure until the point is reached where all of the liquid is vaporized. This is called the *dew point*. The ethane gas expands with further increase of cylinder volume at 60 F as pressure decreases hyperbolically.

6.2 Phase Behavior of Multi -Component System

Consider the phase behavior of a 50:50 mixture of two pure hydrocarbon components on the P-T plane. The vapor pressure and bubble point lines do not coincide but form an envelope enclosing a broad range of temperatures and pressures at which two phases (gas and oil) exists in equilibrium. The dew and bubble point curves meet at the critical point, which is defined as that temperature and pressure at which liquid and vapor (gas) phases have identical intensive properties. Fluid above bubble point is in the liquid state and fluid below the dew point line is gas : in the space enveloped between the two lines, liquid and gas are in equilibrium.

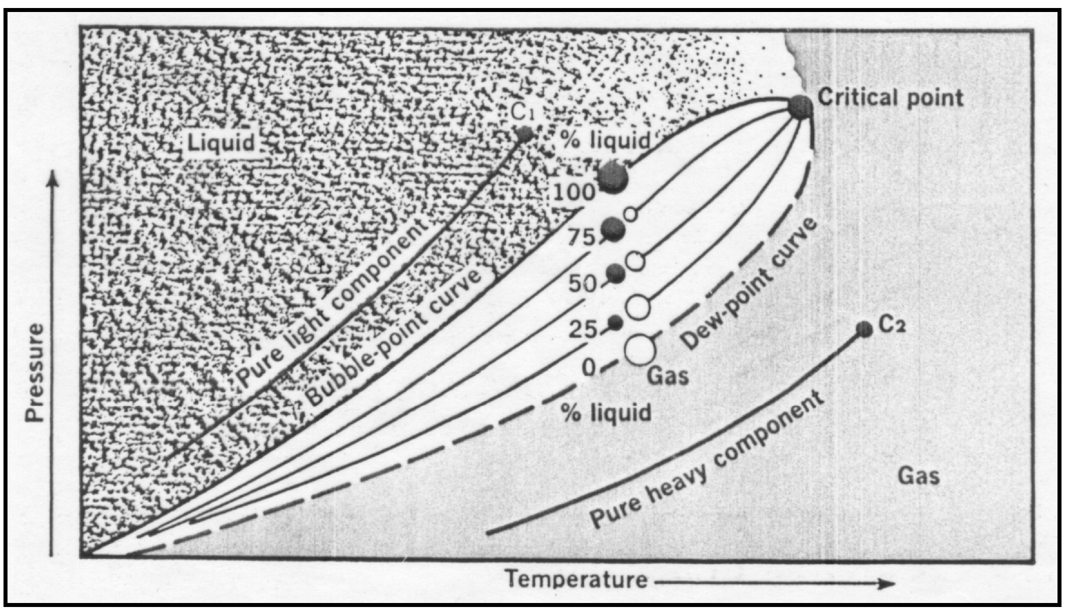

Figure 6-1 Vapor Pressure Curves for Two Pure Components and Phase Diagram for a 50:50 Mixture

6.3 Phase Behavior of Low Shrinkage Reservoir Fluid

The chemical composition and amount of each constituent present determine the shape of two-phase envelope and its position on the P-T diagram. Each reservoir fluid has a unique phase diagram. Figure is a phase diagram typical of a low shrinkage reservoir fluid. Fluid at reservoir temperature and pressure at point A' exists as under-saturated liquid. If a sample of this fluid is expanded in a PVT cell at reservoir temperature T_r, the bubble point pressure will be reached at A. This is approximately the path that fluids follow in moving horizontally through the reservoir to the well bore.

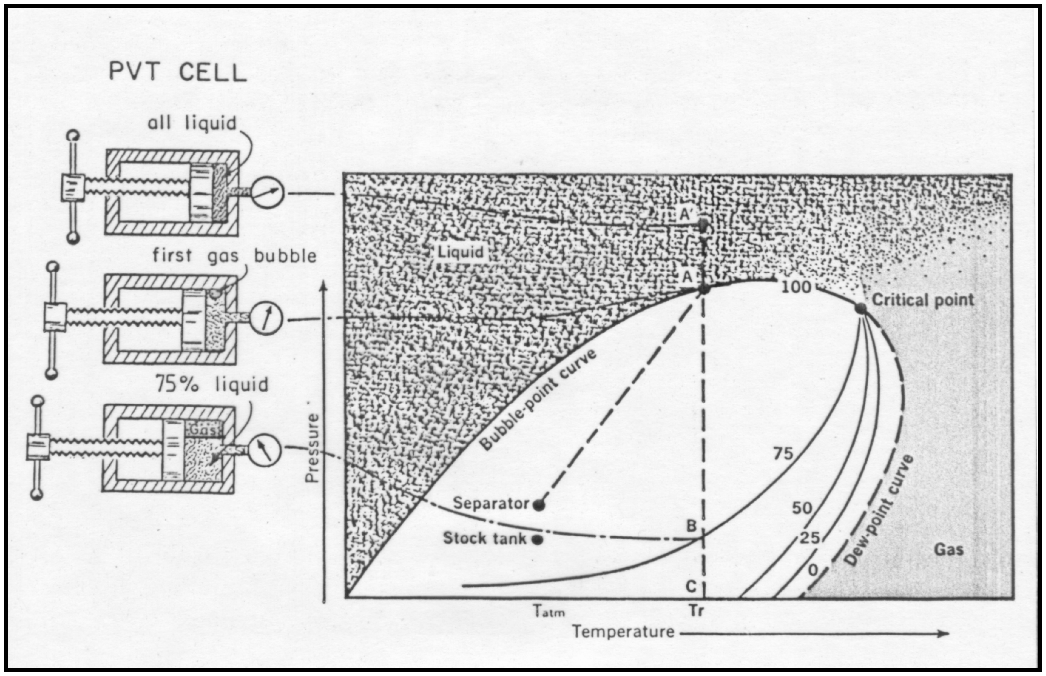

Figure 6-2 Phase Diagram of Low Shrinkage Oil

6.4 Phase Behavior of Retrograde Condensate Reservoir Fluid

The phase diagram typifies the behavior of retrograde reservoir. Fluid at point A' is above critical temperature and is therefore classified as gas. On reduction of pressure at constant temperature from point A', the dew point line is crossed at A and liquid begins to condense from the reservoir gas. If the pressure and temperature are reduced from A along the dashed path to separator condition, the diagram shows that 25 % of liquid is recovered at this point. On further reduction of pressure to atmospheric pressure, only 2 % of liquid remains.

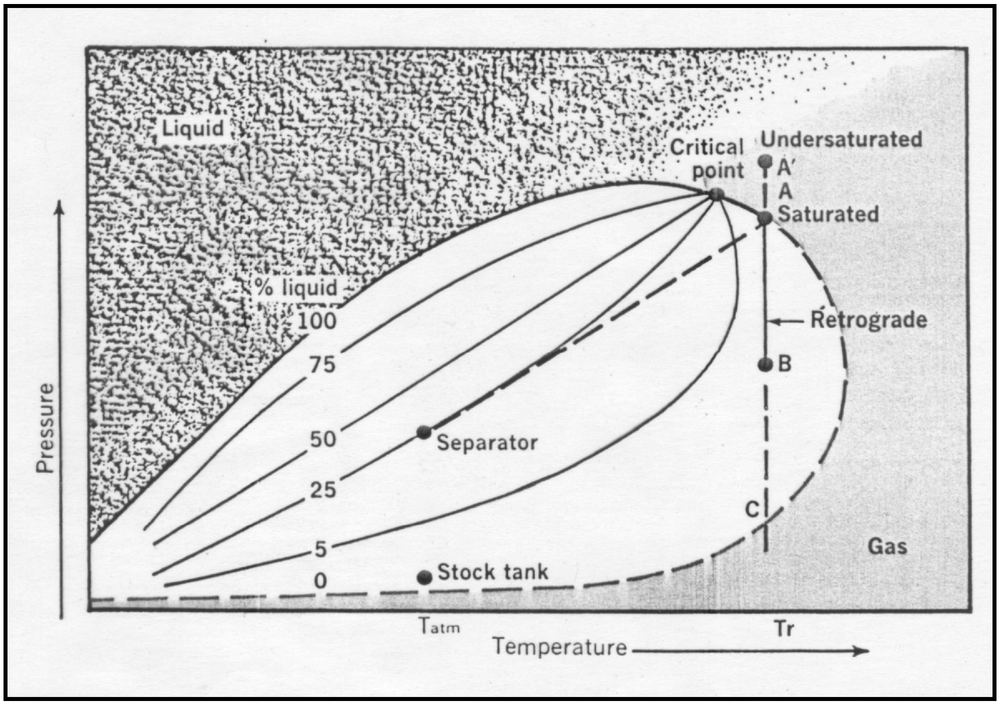

Figure 6-3 Phase Diagram of Retrograde Condensate Gas

6.5 Phase Behavior of Dry Gas Reservoir Fluid

The phase diagram on the pressure-temperature plane, typifies the behavior of a dry gas reservoir. If the pressure and temperature are reduced from the original reservoir conditions at point A to standard stock tank conditions (60 F and 14.7 psia), there is no liquid recovery and the reservoir fluid remain completely in the gaseous phase during the process.

6.6 Phase Behavior of Wet Gas Reservoir Fluid

Fluid that exists above its critical temperature as gas in reservoir conditions, but produces a small quantity of liquid condensate on reduction to separator/stock tank conditions, may be termed wet gas.

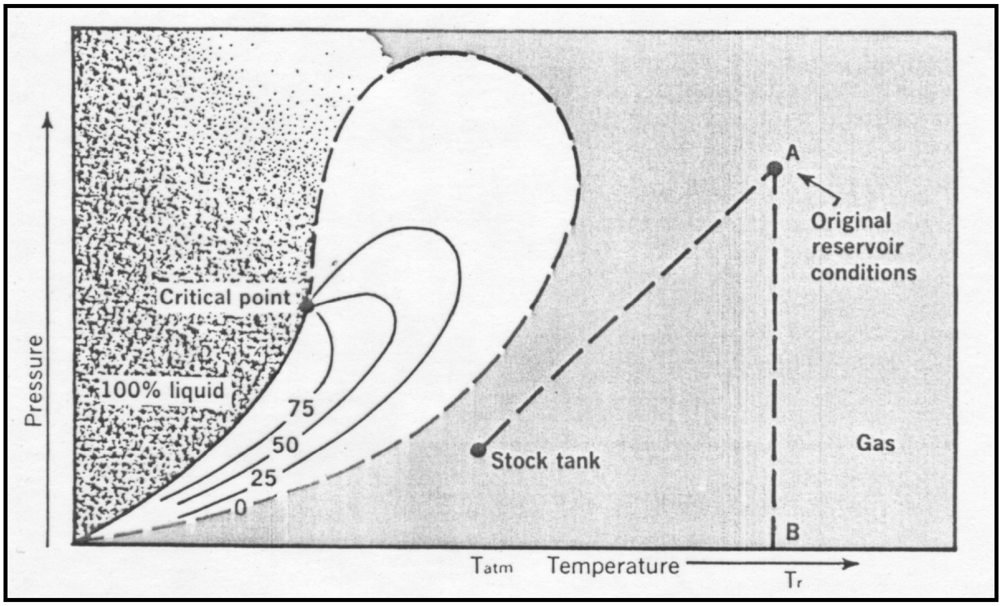

Figure 6-4 Phase Diagram of Dry Gas

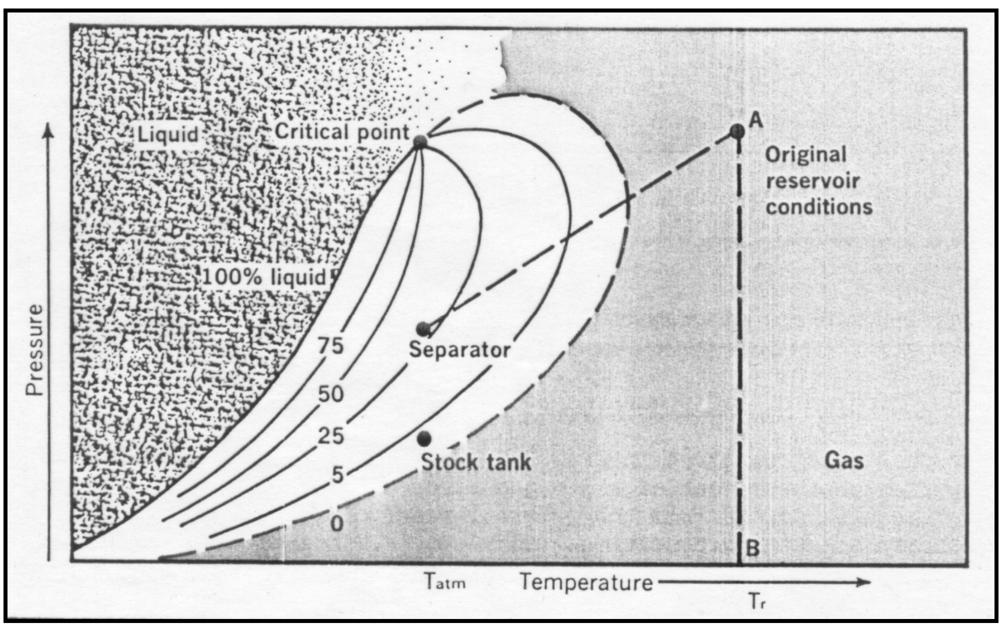

Figure 6-5 Phase Diagram of Wet Gas