Tishk International University
Engineering Faculty
Petroleum and Mining Department

Petroleum Reservoir Engineering I

Lecture 2: Fundamentals of Reservoir Fluid Behavior Part I
Theoretical Session

3rd-Grade- Fall Semester 2022-2023

Instructor: Nabaz Ali
nabaz.ali@tiu.edu.iq

Content

- **Classification of Reservoirs**
- **Pressure-temperature Diagram (Phase Diagram)**
- **Classification of Reservoir Based on Phase Diagram**
- **Oil Reservoirs Classification Based on Initial Reservoir Pressure**
- **Oil Reservoir Classification Based on Physical Properties and Chemical Composition.**

Classification of Reservoirs

- Naturally occurring hydrocarbon system found in petroleum reservoirs are:

✓ Mixture of **organic compound.**

✓ Exhibit **multiphase behavior** over wide range of **pressure** and **temperature**.

✓ Occur in **gaseous** state, the **liquid** state, the **solid** state or in combination of those phases.

Classification of Reservoirs

- Reservoir are broadly classified as:

1. Oil Reservoirs
2. Gas Reservoirs

How can we classify Reservoirs as oil and gas reservoirs?

Phase Diagram

- A diagram expresses the experimental and the mathematical determinations of conditions which various phases exist.
- The phase behavior of a reservoir fluid can be best described with the help of a phase diagram.
- The simplest phase diagram is P-T diagram which is 2-dimensional diagram.
- The P-T diagram is a **pressure** vs. **temperature** diagram.

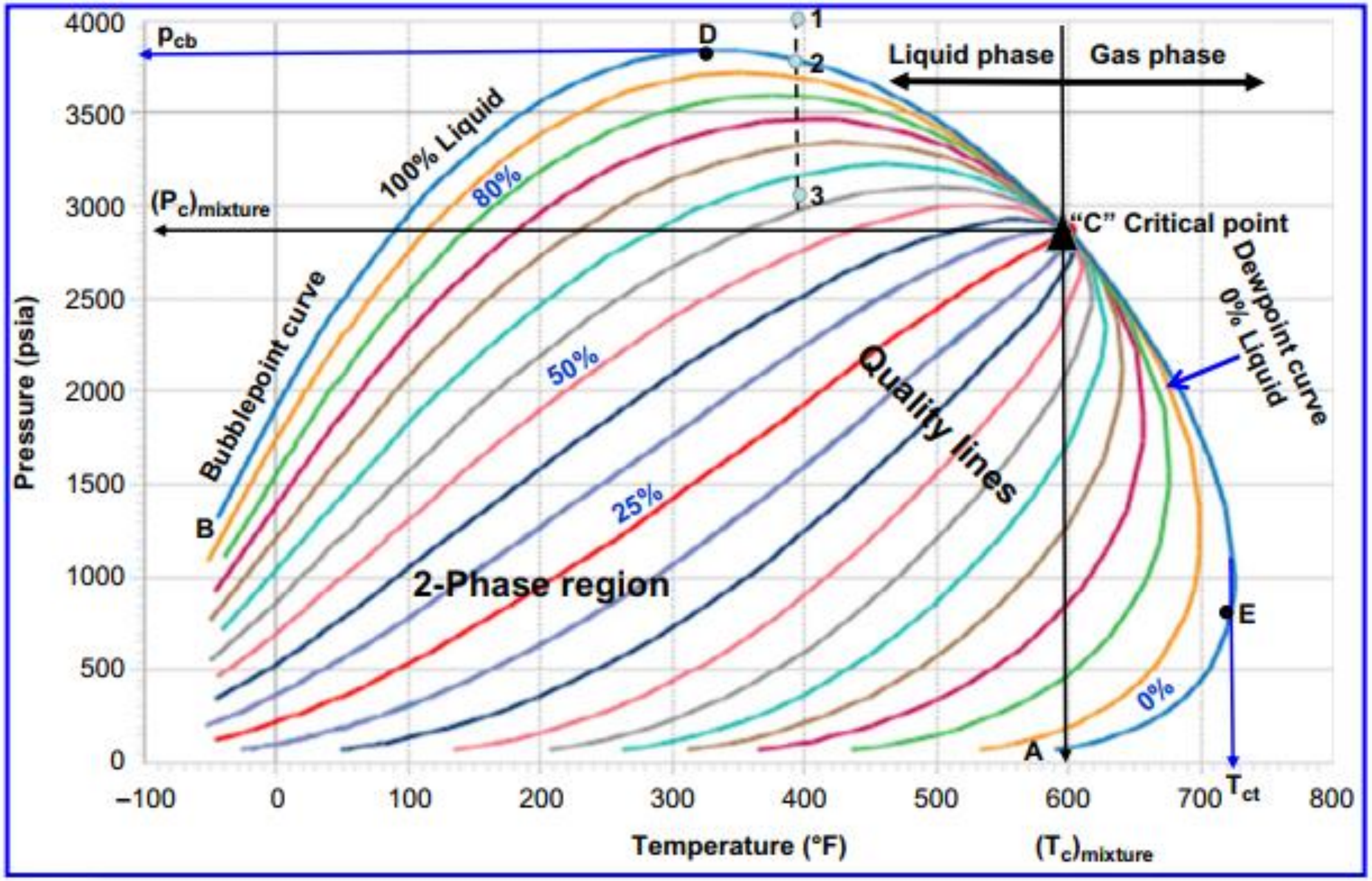
Pressure-Temperature Diagram of Multicomponent

- Although a different hydrocarbon system would have a different phase diagram, the **general configuration is similar**.
- These multicomponent pressure-temperature diagrams are essentially used to:

1. Classify reservoirs.
2. Classify the naturally occurring hydrocarbon systems.
3. Describe the phase behavior of the reservoir fluid.

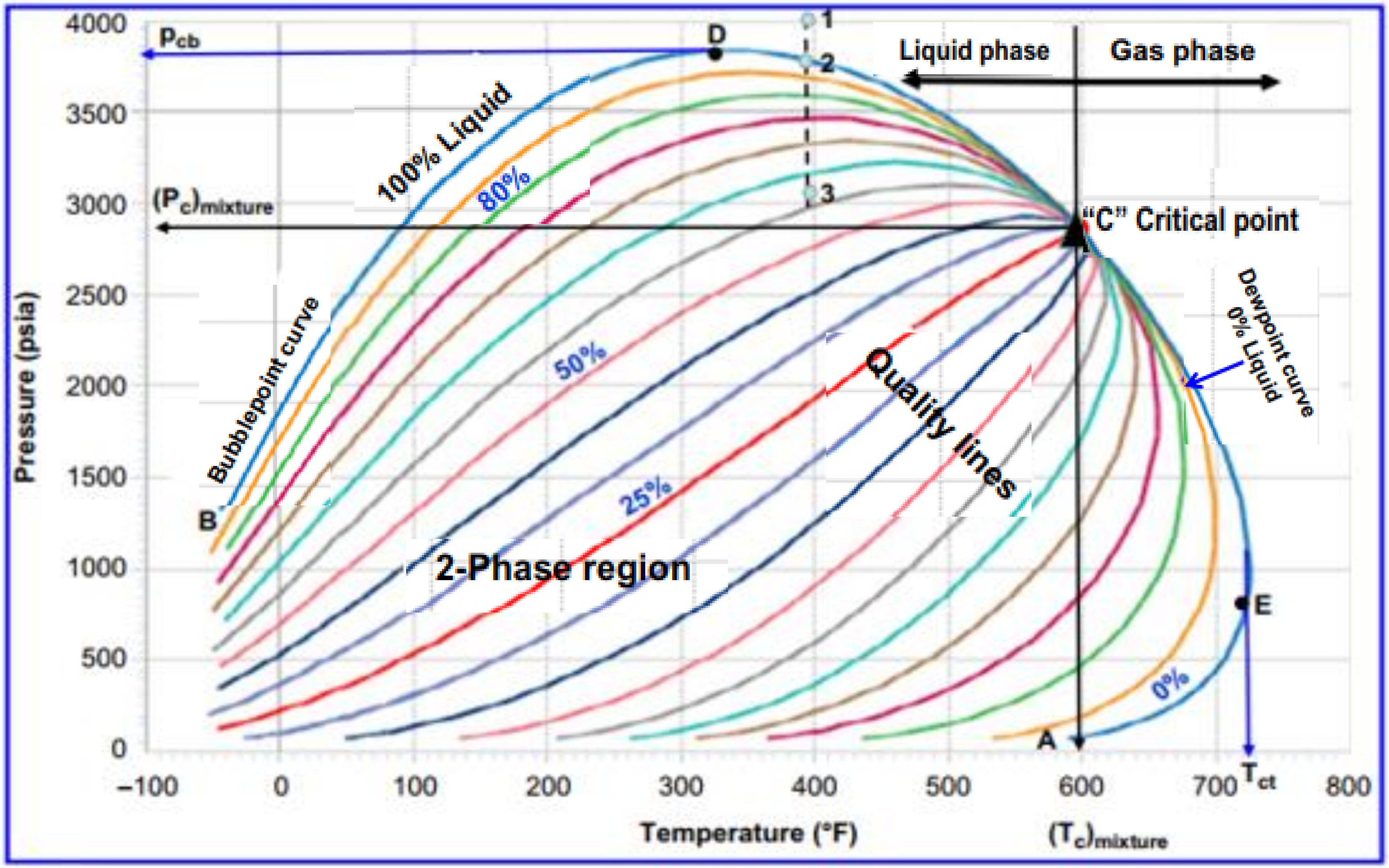
- A Reservoir Rock is saturated at least with two and sometimes three fluids: Water, Oil and Gas.

Pressure-Temperature Diagram



A typical p-T diagram for a multicomponent system.

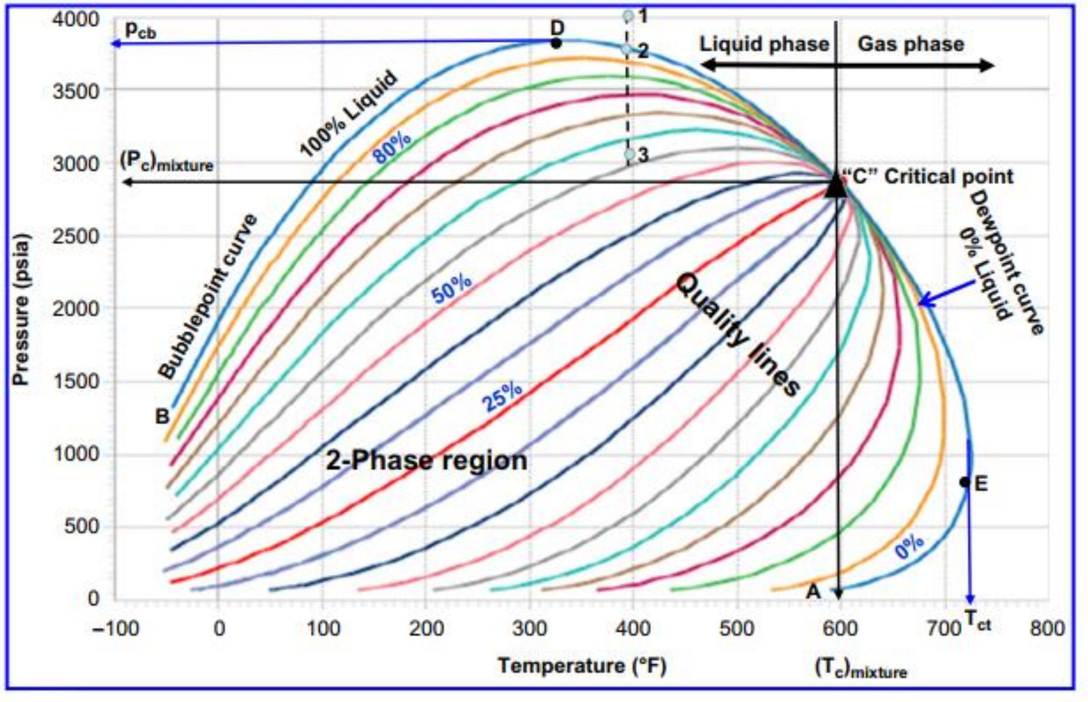
Pressure-Temperature Diagram



A typical p-T diagram for a multicomponent system.

P-T Diagram Terminology

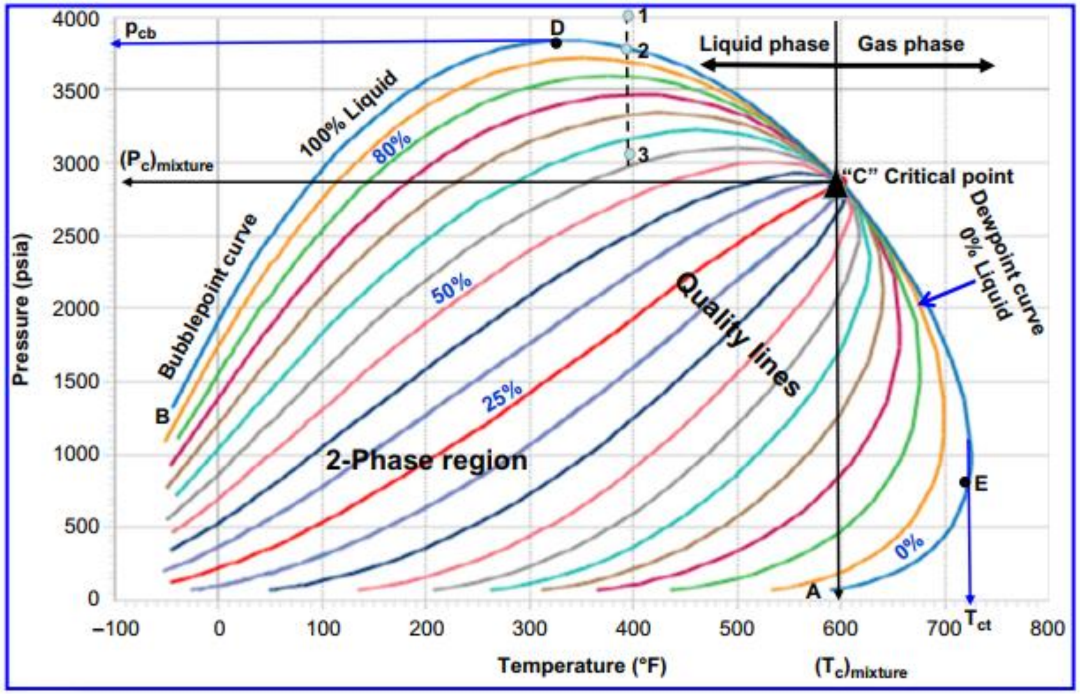
Cricondentherm (Tct)—The Cricondentherm is defined as the maximum temperature above which liquid cannot be formed regardless of pressure (point E). The corresponding pressure is termed the Cricondentherm pressure pct.



A typical p-T diagram for a multicomponent system.

P-T Diagram Terminology

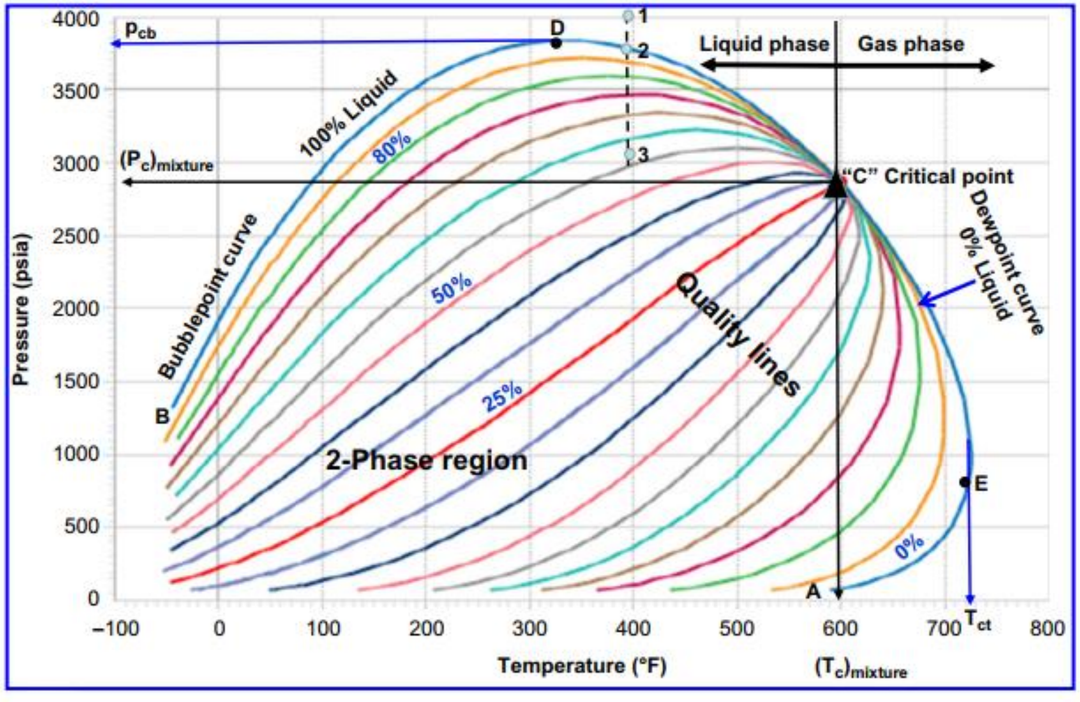
Cricondenbar (pcb)—The Cricondenbar is the maximum pressure above which no gas can be formed regardless of temperature (point D). The corresponding temperature is called the Cricondenbar temperature Tcb.



A typical p-T diagram for a multicomponent system.

P-T Diagram Terminology

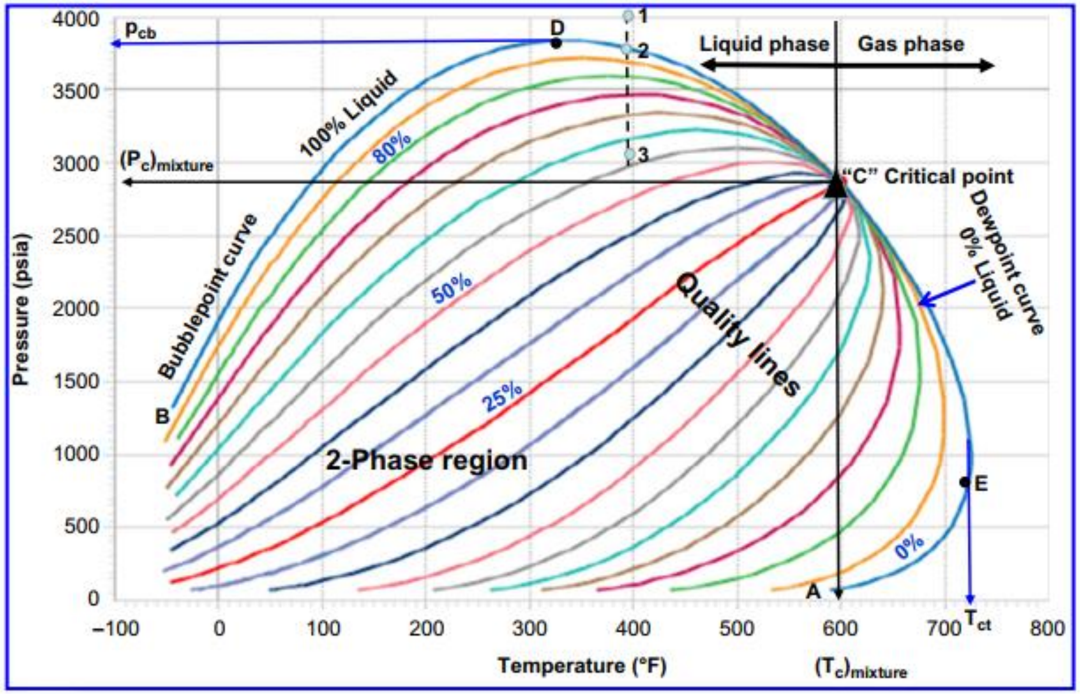
Critical point—The critical point for a multicomponent mixture is referred to as the state of pressure and temperature at which all intensive properties of the gas and liquid phases are equal (point C). At the critical point, the corresponding pressure and temperature are called the critical pressure pc and critical temperature Tc of the mixture.



A typical p-T diagram for a multicomponent system.

P-T Diagram Terminology

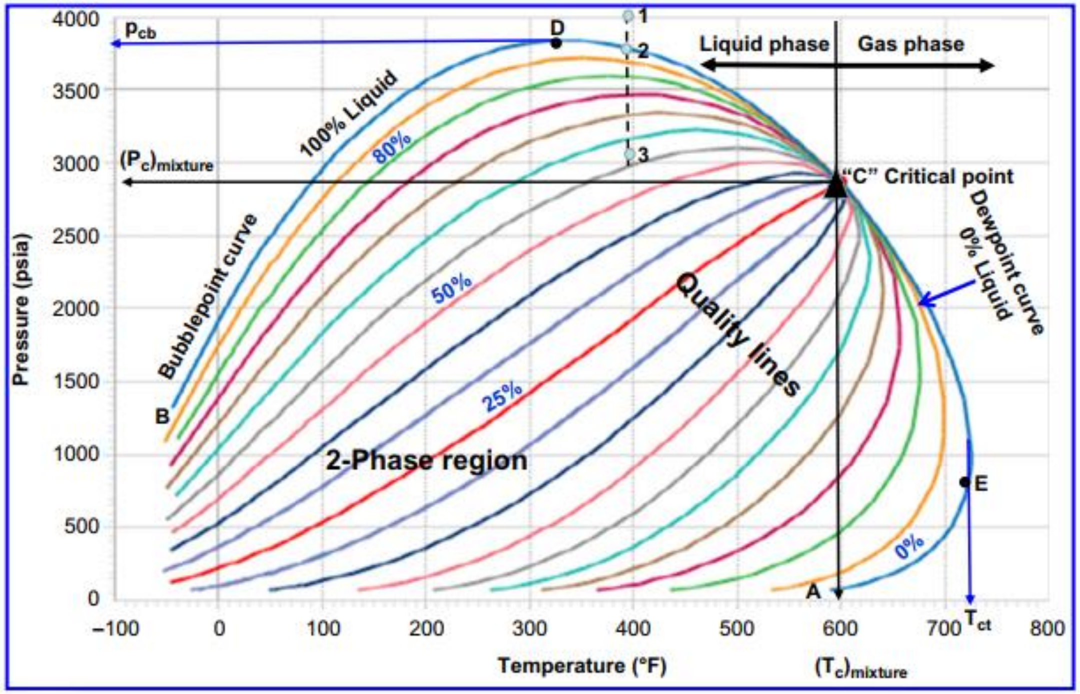
Phase envelope (two-phase region)—The region enclosed by the bubble point curve and the dew-point curve (line BCA), wherein gas and liquid coexist in equilibrium, is identified as the phase envelope of the hydrocarbon system.



A typical p-T diagram for a multicomponent system.

P-T Diagram Terminology

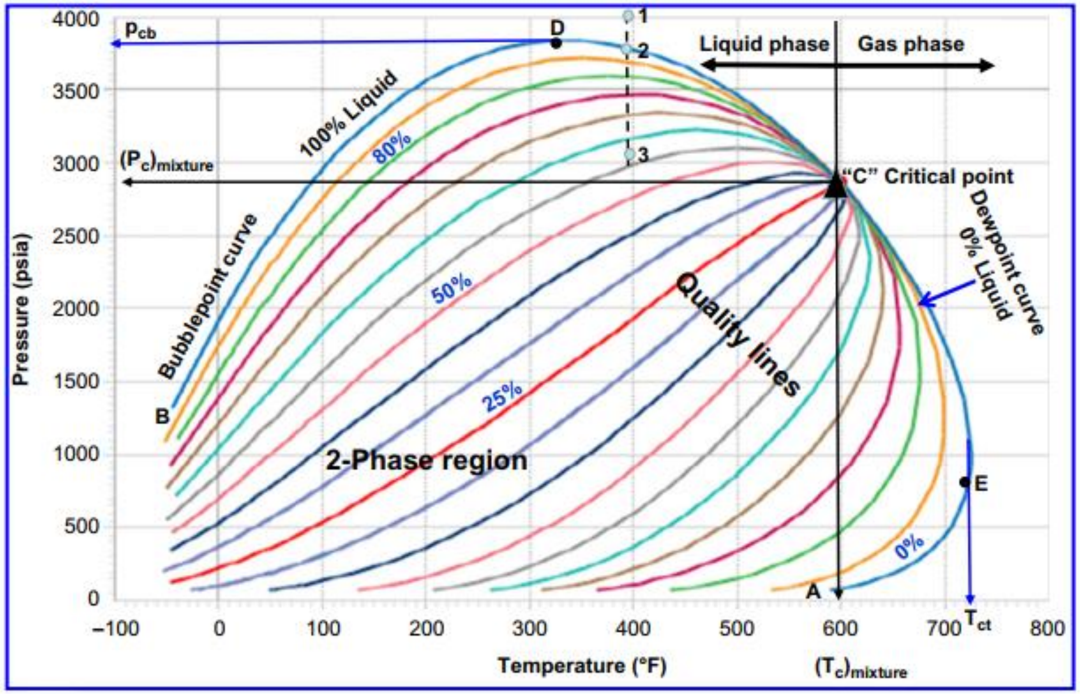
Quality lines—The dashed lines within the phase diagram are called quality lines. They describe the pressure and temperature conditions for equal volumes of liquids. Note that the quality lines converge at the critical point (point C).



A typical p-T diagram for a multicomponent system.

P-T Diagram Terminology

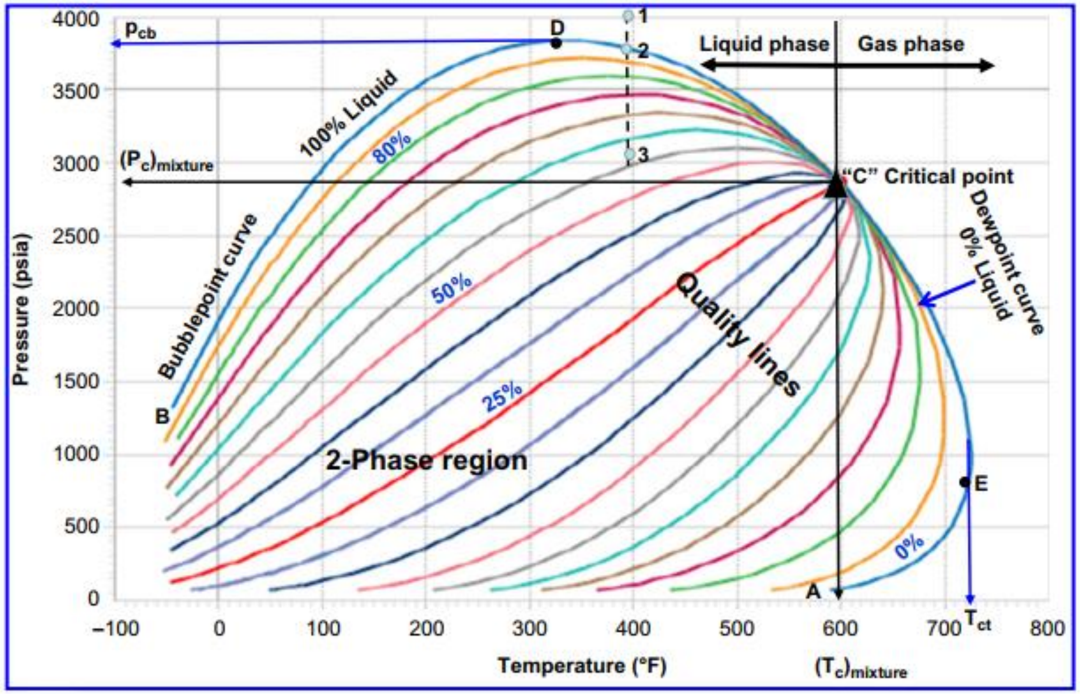
Bubble-point curve—The bubble-point curve (line BC) is defined as the line separating the liquid-phase region from the two-phase region.



A typical p-T diagram for a multicomponent system.

P-T Diagram Terminology

Dew-point curve—The dew-point curve (line AC) is defined as the line separating the vapor-phase region from the two-phase region.



A typical p-T diagram for a multicomponent system.

Classification of Reservoir

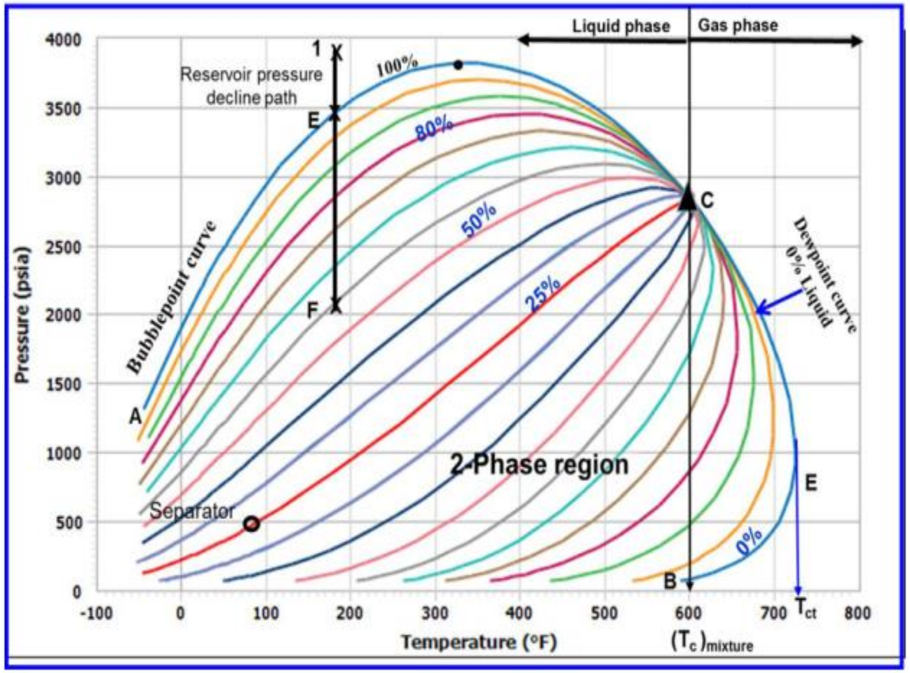
- Reservoirs can be classified into basically two types. These are:

  - **Oil reservoirs—**If the reservoir temperature T is less than the critical temperature Tc of the reservoir fluid, the reservoir is classified as an oil reservoir.
  - **Gas reservoirs—**If the reservoir temperature is greater than the critical temperature of the hydrocarbon fluid, the reservoir is considered a gas reservoir.

Classification of Reservoir

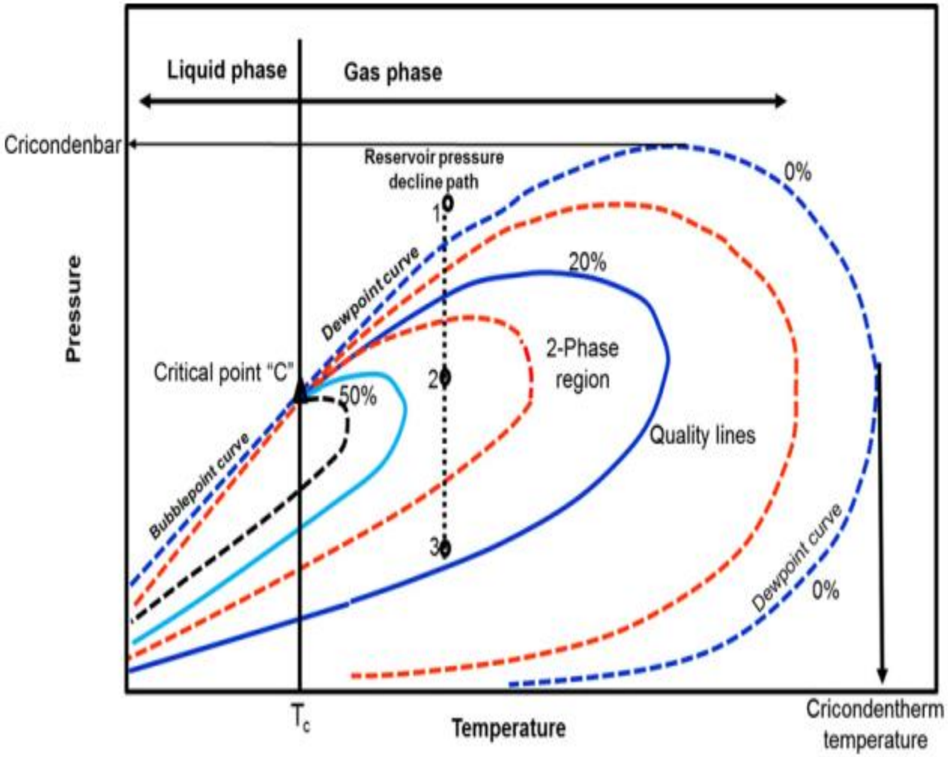
Oil Reservoir

$T_{res} < T_c$



Gas Reservoir

$T_{res} > T_c$



Classification of Oil and Gas Reservoirs

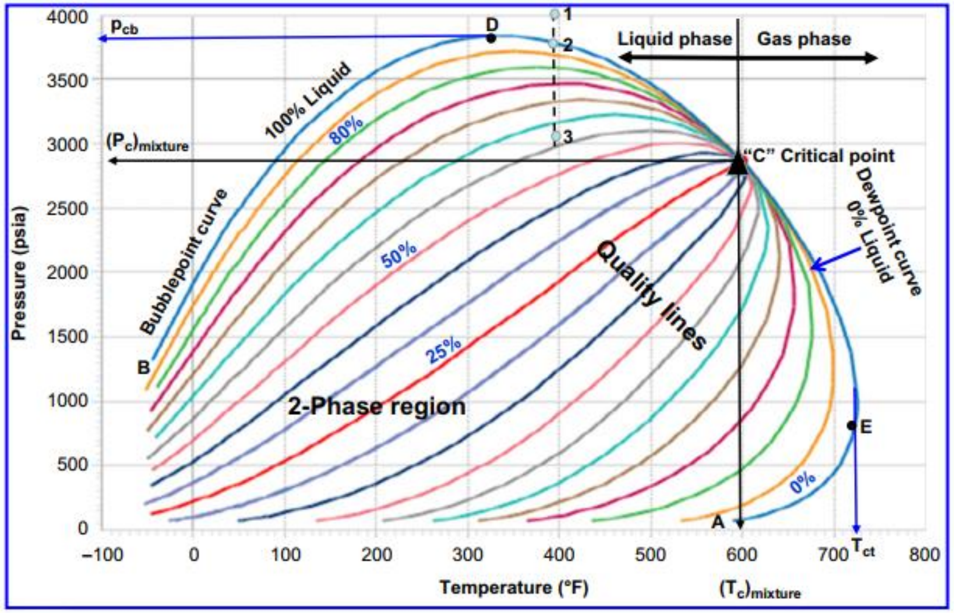
❑ Oil and Gas Reservoirs can be subdivided based on:

- The composition of the reservoir hydrocarbon mixture.
- Initial reservoir pressure and temperature.
- Pressure and temperature of the surface production.

Classification of Oil Reservoir

- Oil reservoirs can be subclassified into the following categories depending upon P_i. As shown on PT diagram

1. **Undersaturated oil reservoir**: If $P_i > P_b$
2. **Saturated oil reservoir:** $P_i = P_b$
3. **Gas-cap reservoir**: $P_i < P_b$



A typical p-T diagram for a multicomponent system.

Oil Reservoir

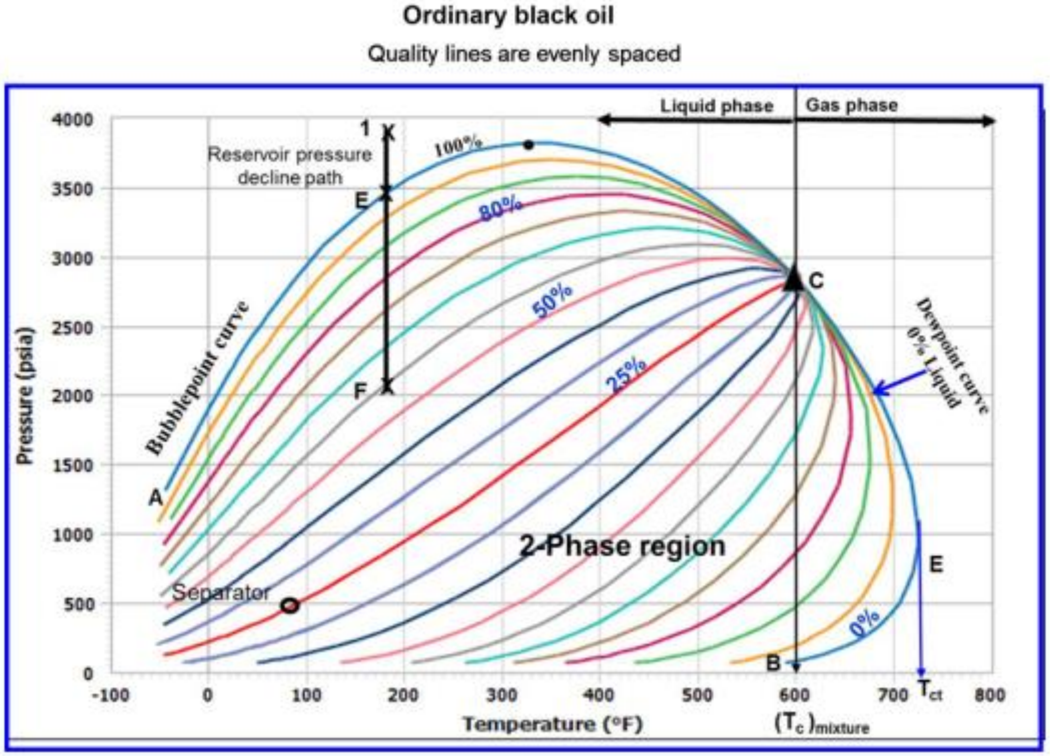
- Crude oil covers a wide range in physical properties and chemical compositions which can be grouped into the following categories:

1. Ordinary black oil
2. Low-shrinkage crude oil
3. High-shrinkage (volatile) crude oil
4. Near-critical crude oil

1.Ordinary Black Oil

❑The characteristics:

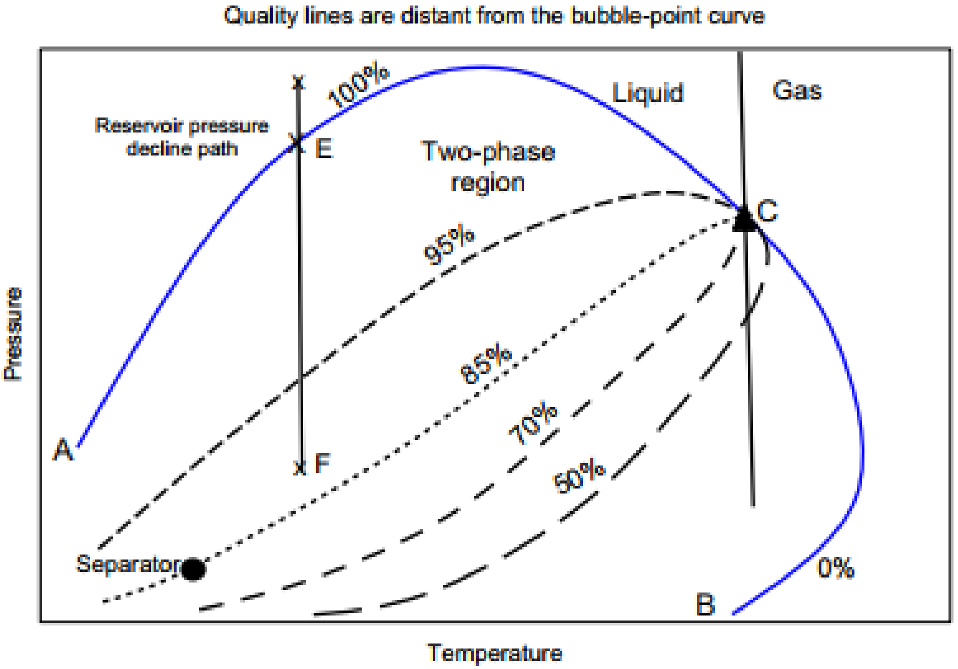
- Quality lines are approximately equally spaced.
- **GOR** between 200-700 scf/STB
- Oil gravities 15-40 ° API
- The stock tank oil is usually brown or dark green in color.



A typical p-T diagram for an ordinary black oil.

2.Low Shrinkage Crude Oil

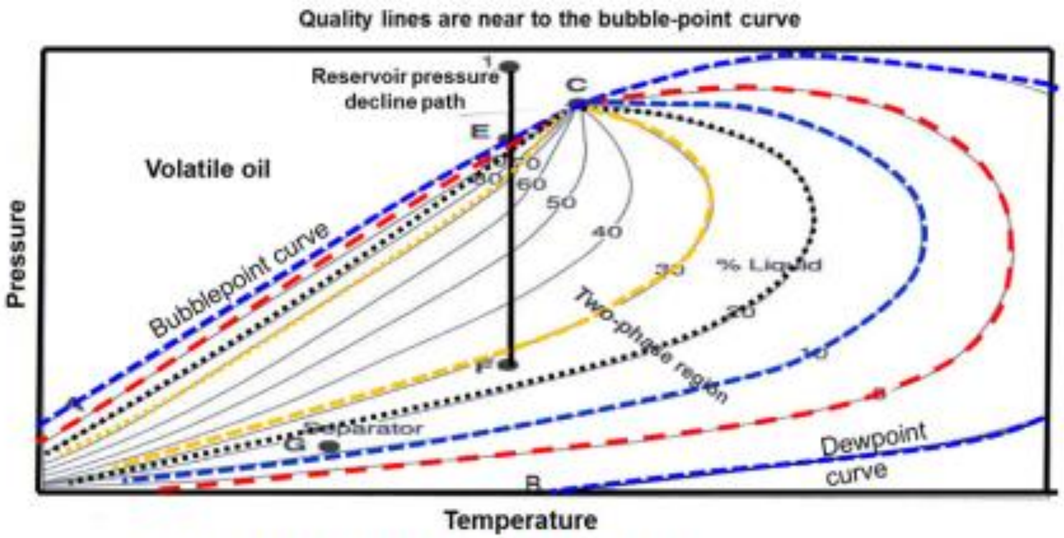
- The quality lines are closely spaced near the dew-point curve.
- $\mathbf{B_o} < 1.2$ bbl/STB
- **GOR** less than 200 scf/STB
- **Oil gravity** $< 35°$ API.
- Black or deeply colored.



A typical phase diagram for a low-shrinkage oil.

3.High-Shrinkage (Volatile) Crude Oil

- The quality lines are close together near the bubble-point and more are more widely spaced at low pressure.
- $\mathbf{B_o} < 2$ bbl/STB
- **GOR** between 2000-3000 scf/STB
- **Oil Gravities** between 45-55° API
- Greenish to Orange in color



A typical p-T diagram for a volatile crude oil.

4.Near-Critical Crude Oil

- T_{res} is near T_C of the hydrocarbon system.
- High **GOR** exceed 3000 scf/STB.
- $\mathbf{B_o}$ of 2 bbl/STB or higher.

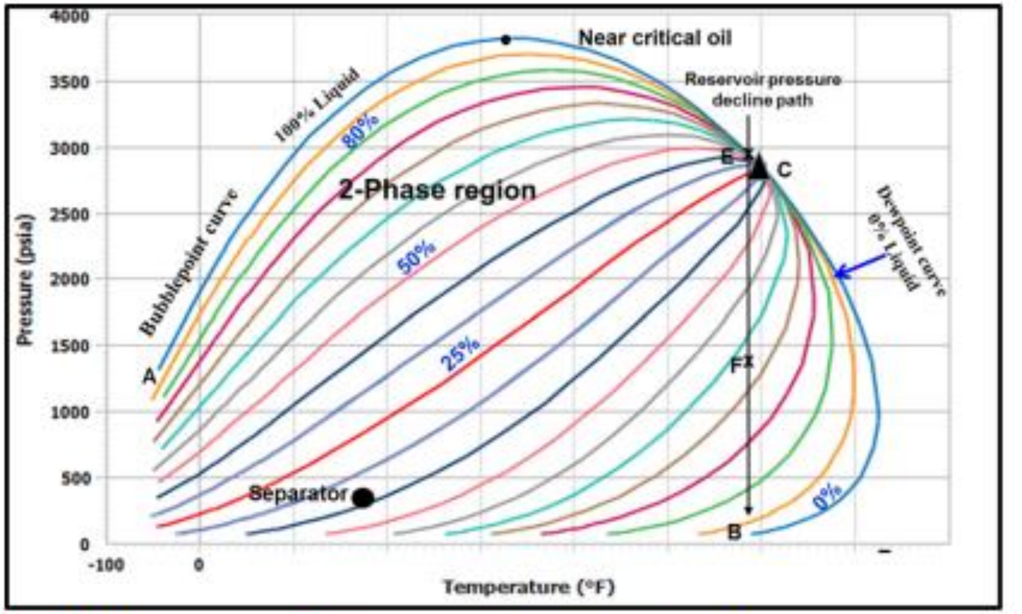


FIGURE 1-8 A schematic phase diagram for the near-critical crude oil.

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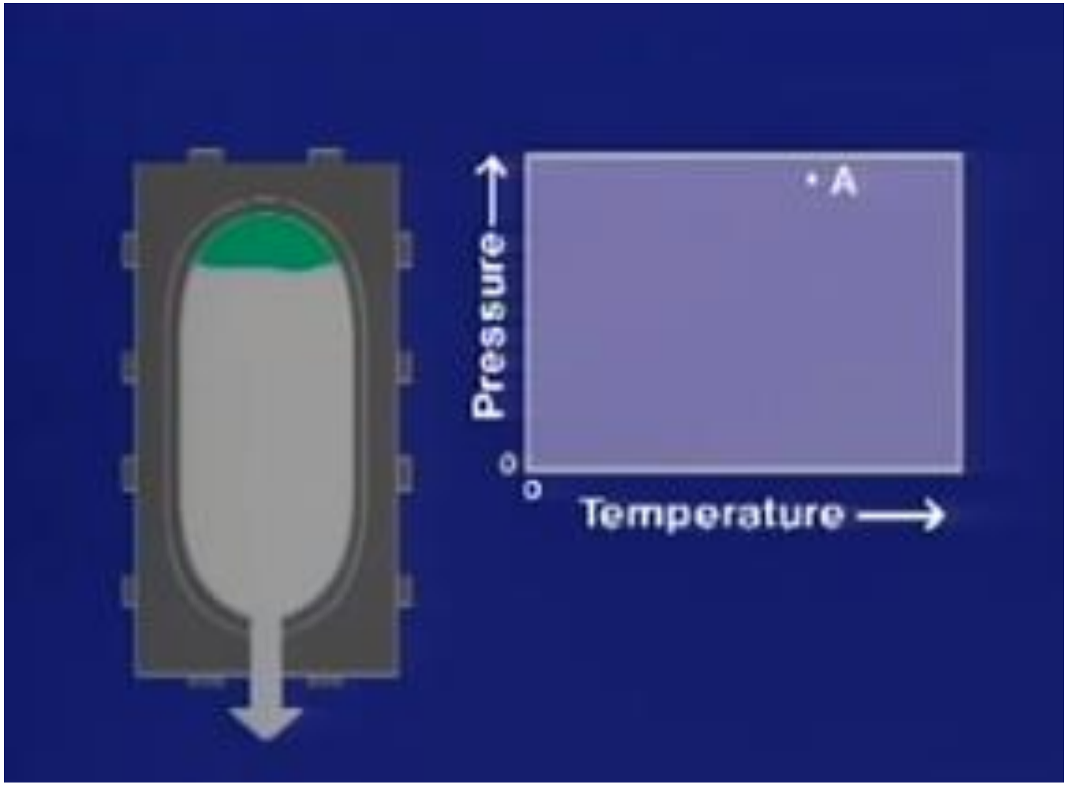
Content

- Development of Phase Diagram
- Assignment

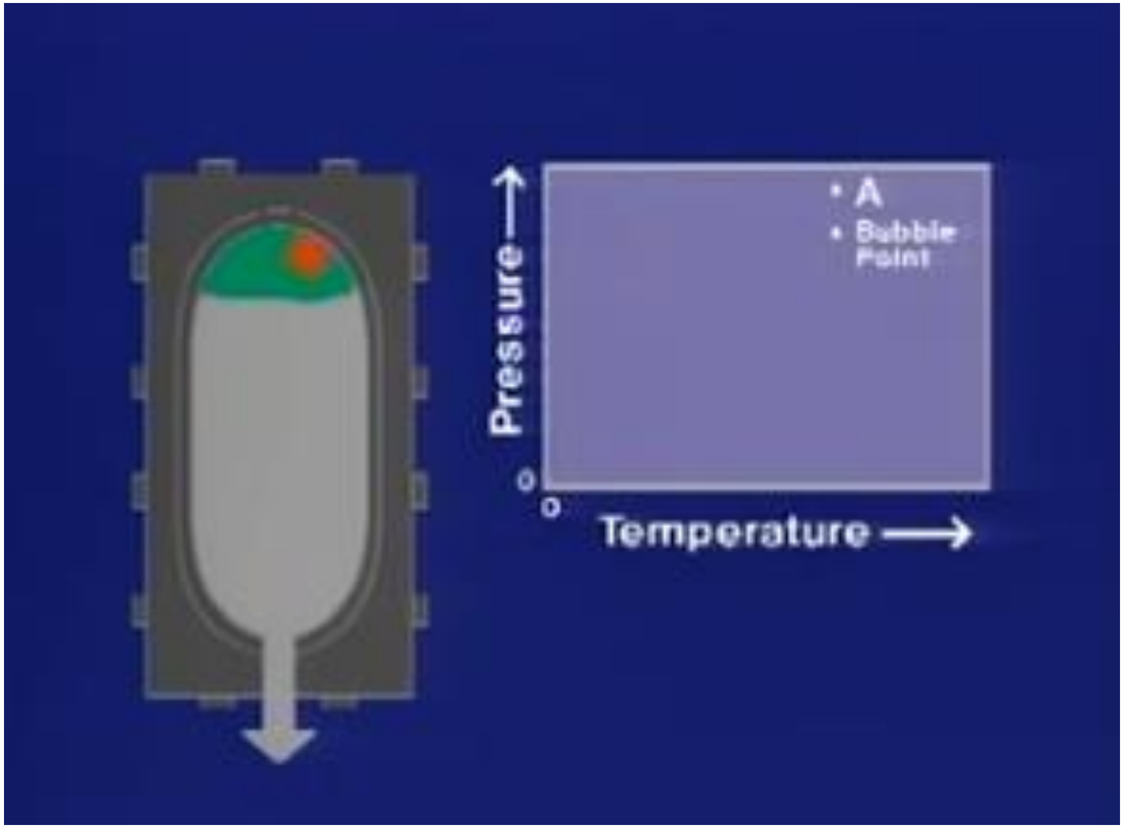
Development of Phase Diagram

- Let's assume that we have a sample of crude oil.
- We take the crude oil sample to the laboratory and place it in a sample chamber and restore it to its original reservoir condition of P and T with mercury pump.
- We look at the cell window and we can see that it is all liquid.
- The conditions of the sample are shown by point A on the P-T diagram.



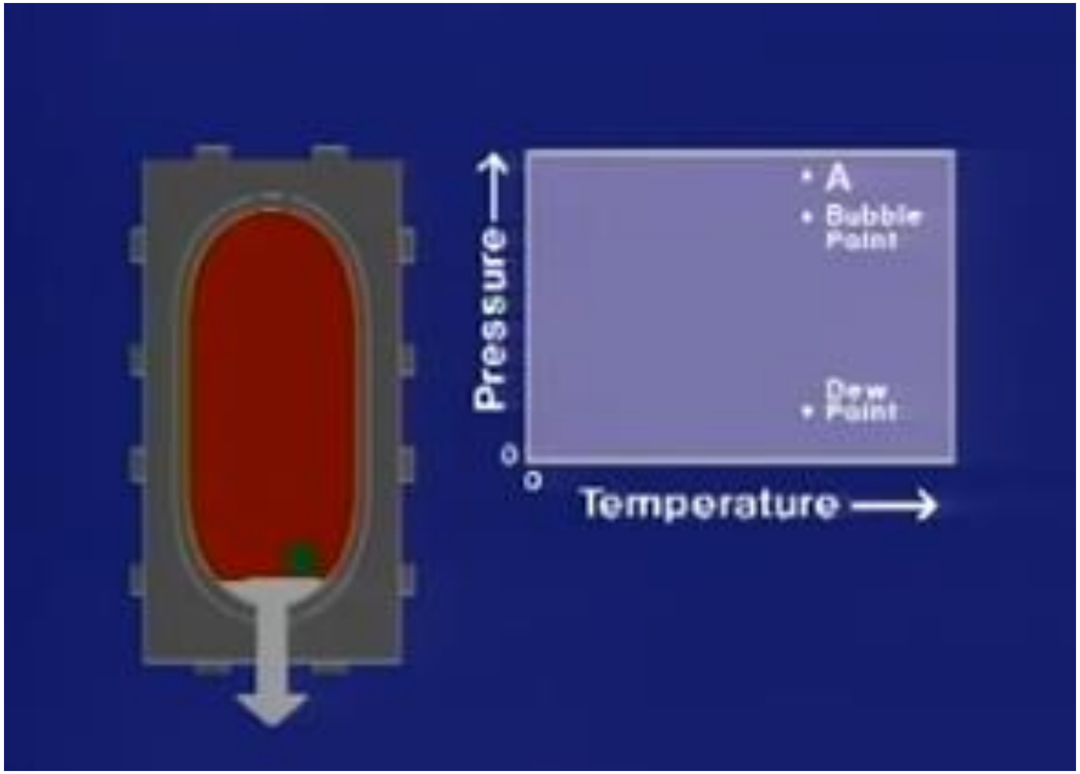
Development of Phase Diagram

- Now we slowly drop the pressure.
- Suddenly a bubble of gas appears in the crude.
- We are at the bubble point.
- That is the point where two phases begin to present.



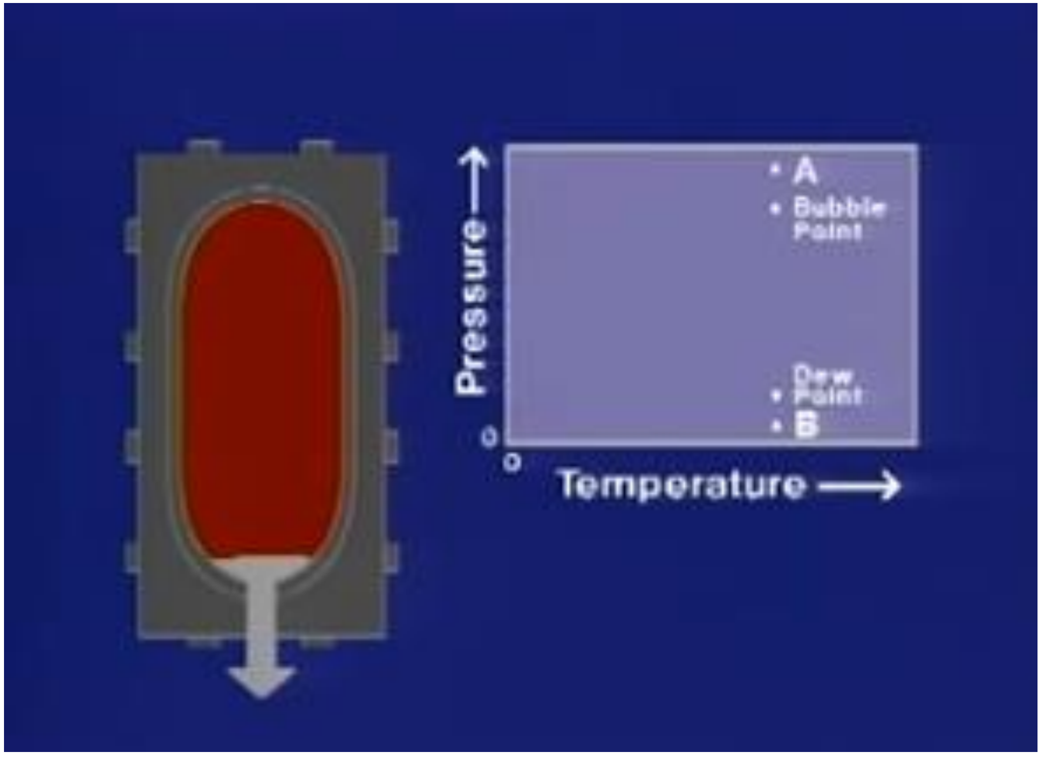
Development of Phase Diagram

- We continue to decrease the pressure.
- The total volume expands and more of the total volume is gas.
- Finally, we reach a pint where a small drop of liquid remains in the chamber.
- This is the dew point.



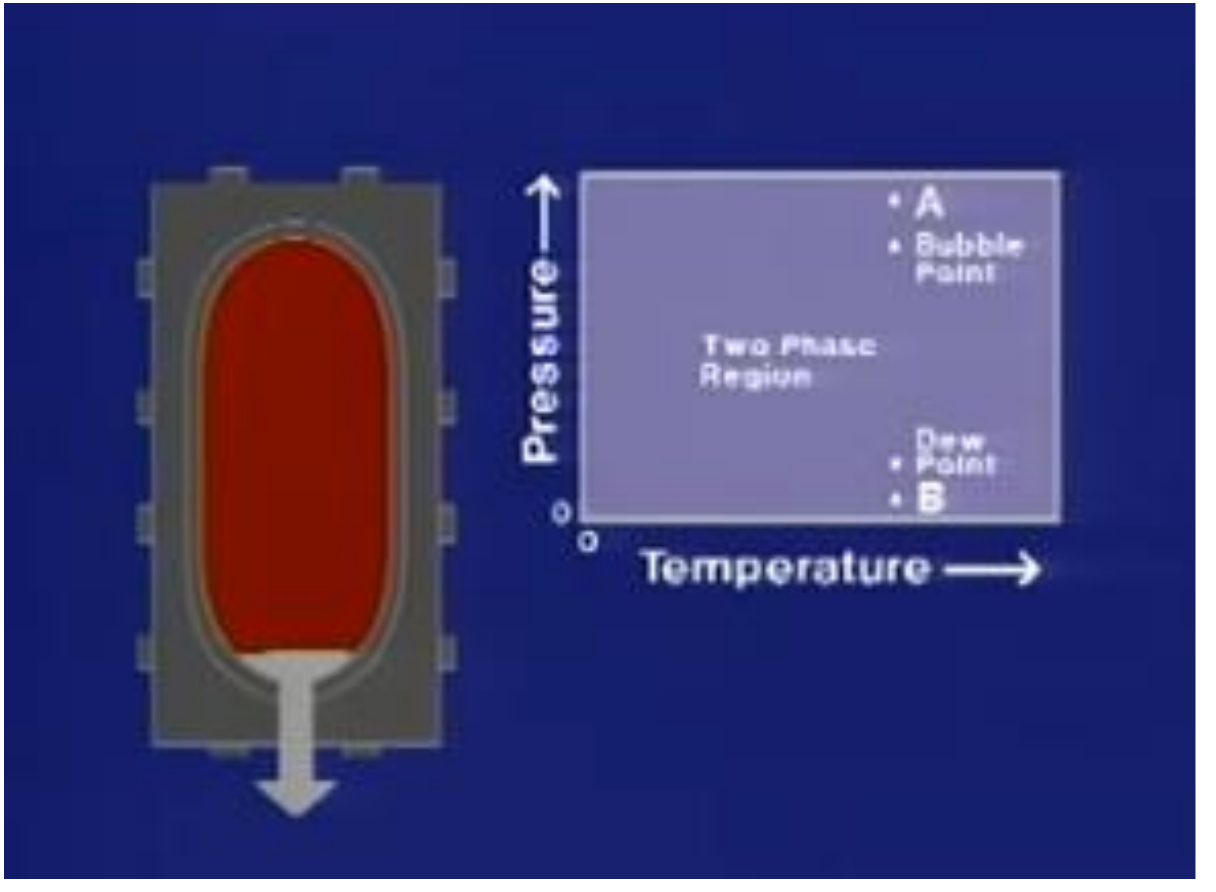
Development of Phase Diagram

- Once we drop pressure to a lower value, the liquid disappears, and everything is in vapor or gas phase.
- This is represented by point B on P-T diagram.



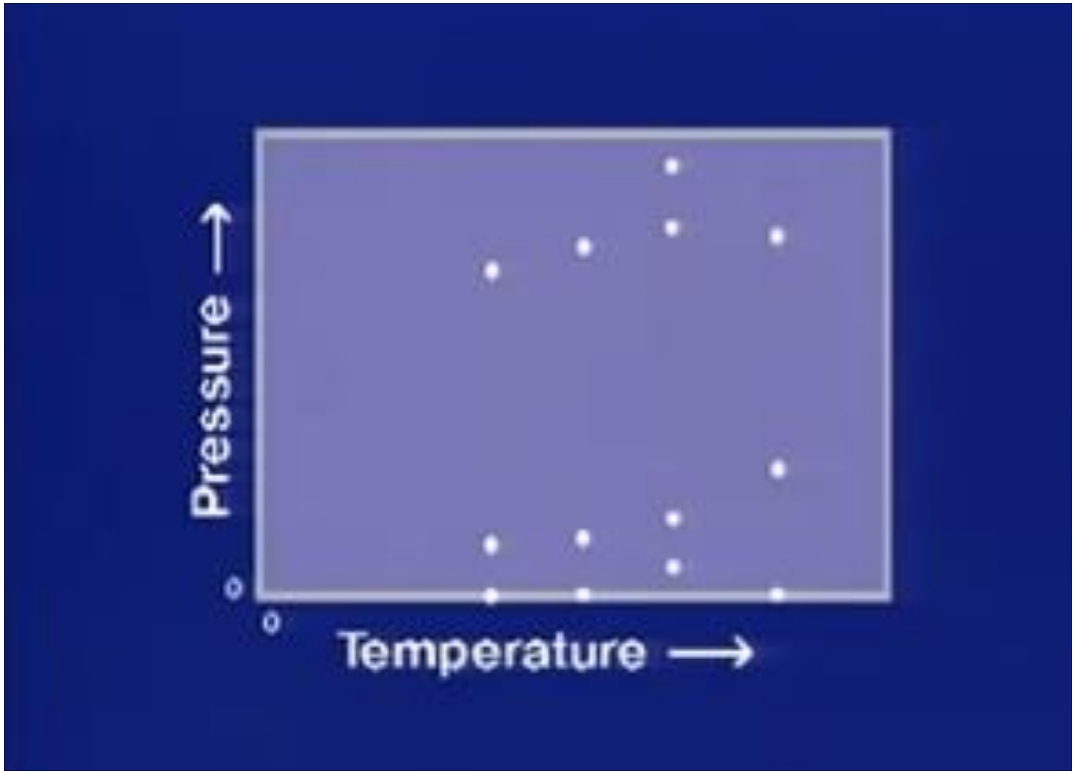
Development of Phase Diagram

- Between the bubble point and dew points, we have two phase present.
- This is known as two phase region.



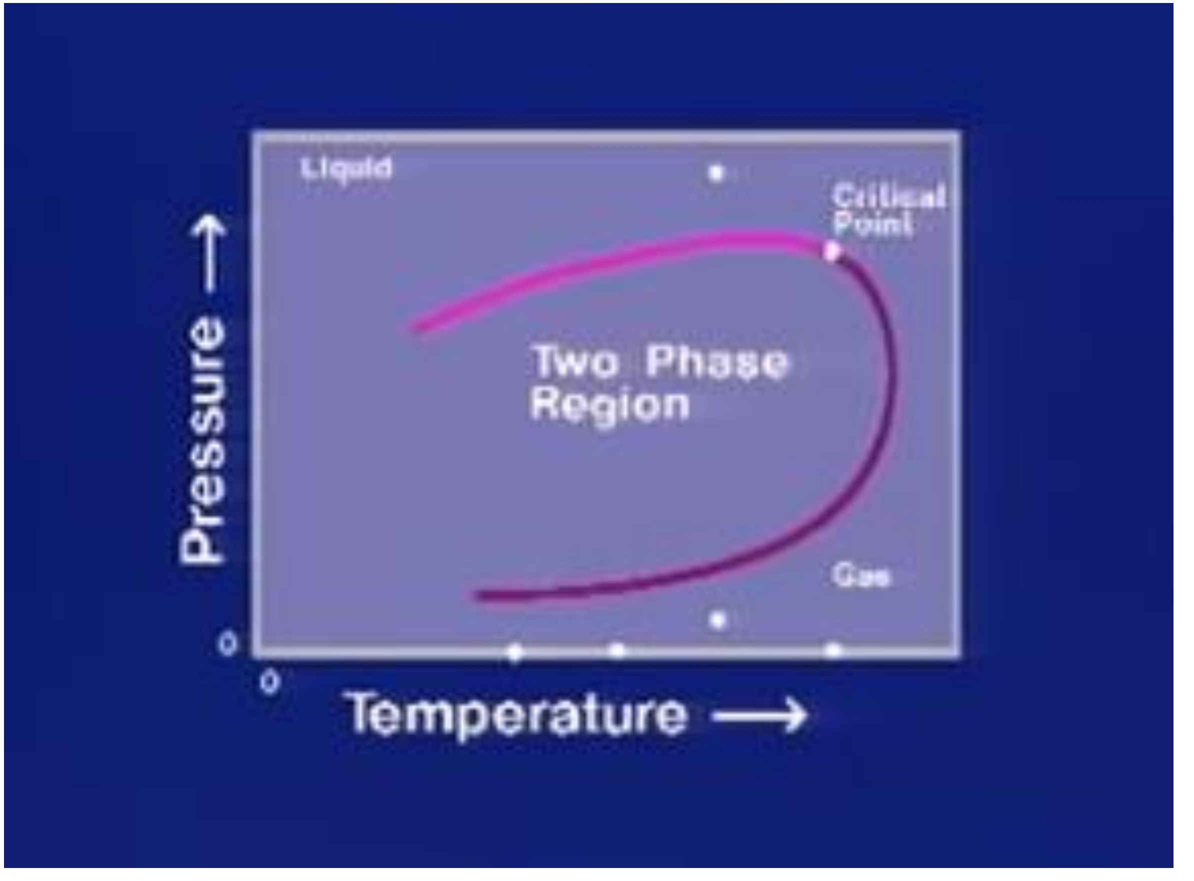
Development of Phase Diagram

- If we repeat this experiment on the crude oil at different number of temperature, we will find new bubble points and dew points at each temperature.



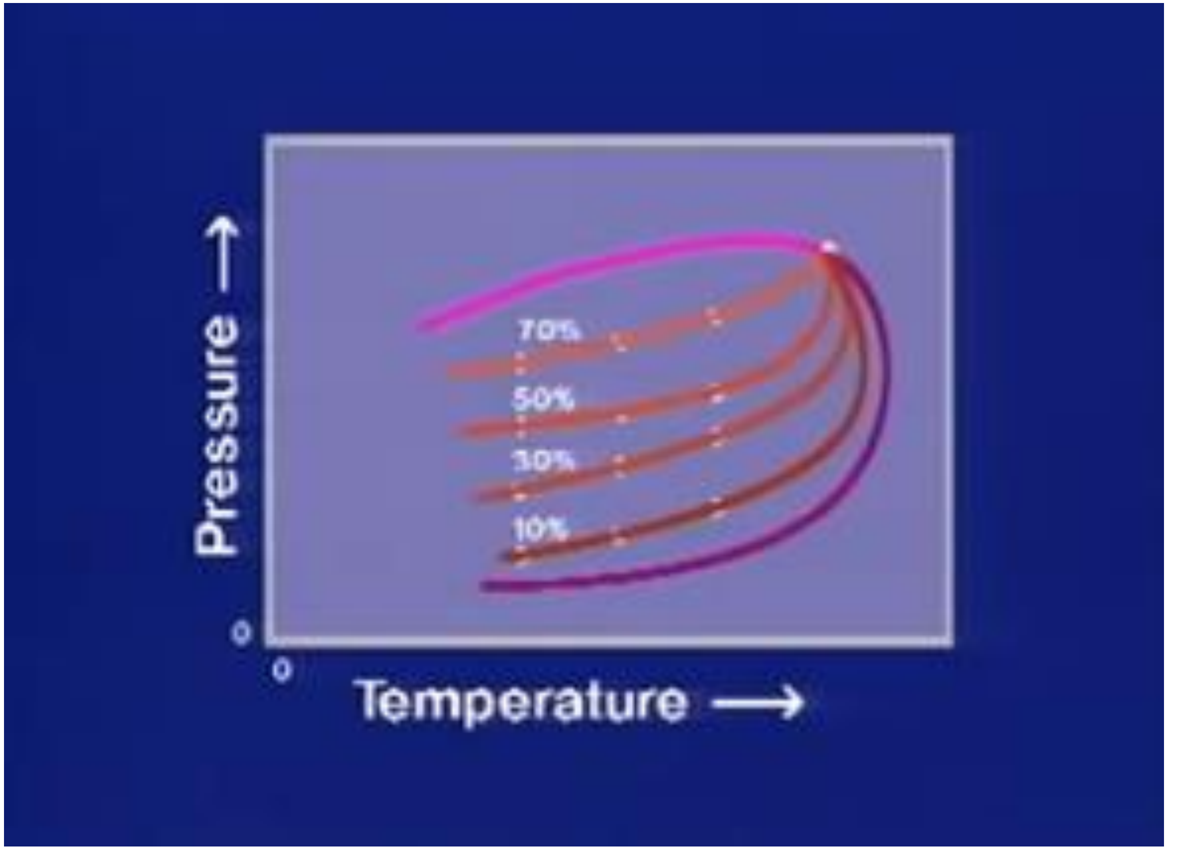
Development of Phase Diagram

- Now we can join these points and we obtain the bubble point and dew point lines.
- The curves join at the critical point.
- Between the two curves, we have the two-phase region.
- Above it only liquid and below it only gas.



Development of Phase Diagram

- Within the two-phase region, we can join points of equal percent of liquid.



Assignment

- Prepare a report about constant composition expansion test to calculate bubble point pressure.
- Introduction
- Experimental apparatus
- Experimental procedure
- Example (preferred)