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الملك سعود  
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King Saud University  
College Of Engineering



Properties of Reservoir Fluids (PGE 362)

# Reservoir Fluids Characteristics

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# Black Oil Properties

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Specific Gravity ( $\gamma_o$ ):

$$\gamma_o = \frac{\rho_o}{\rho_w}$$

$$^{\circ}API = \frac{141.5}{\gamma_o} - 131.5$$

$$\gamma_o = \frac{141.5}{131.5 + API}$$

# Black Oil Properties

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## Specific Gravity ( $\gamma_o$ ):

Example 8-1 (McCain book, page 225):

*The density of a stock-tank oil at 60°F is 51.25 lb/cu ft.  
Calculate the specific gravity and gravity in °API.*

Solution:

First, calculate the specific gravity

$$\gamma_o = \frac{\rho_o}{\rho_w}$$

$$\gamma_o = \frac{51.25 \text{ lb/cu ft}}{62.37 \text{ lb/cu ft}} = 0.8217$$

Second, calculate gravity in °API

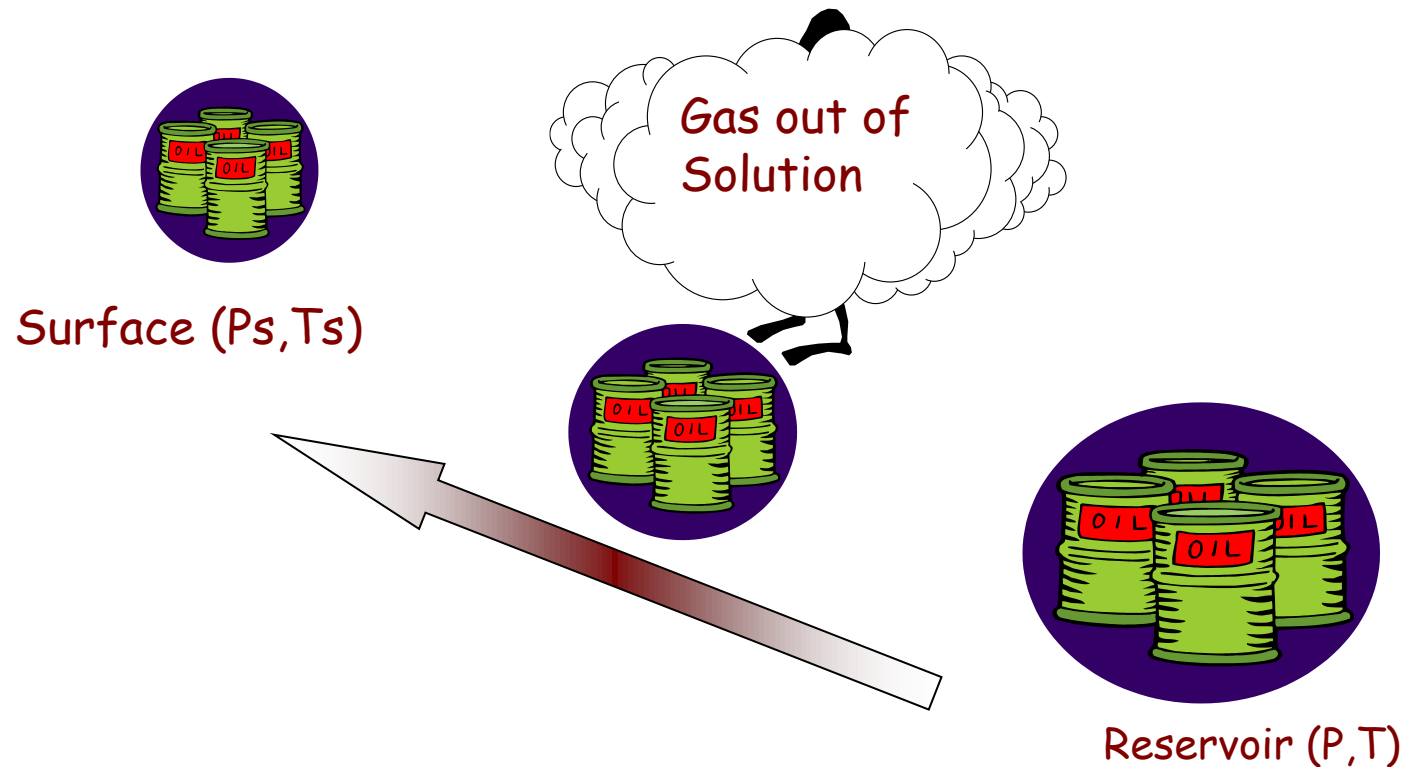
$$^\circ\text{API} = \frac{141.5}{\gamma_o} - 131.5$$

$$^\circ\text{API} = \frac{141.5}{0.8217} - 131.5 = 40.7^\circ\text{API}$$

# Black Oil Properties

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Oil Formation Volume Factor ( $B_o$ ):



# Black Oil Properties

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## Oil Formation Volume Factor ( $B_o$ ):

The volume of reservoir oil required to produce one barrel of oil in the stock tank.

$$B_o = \frac{\text{volume of oil + dissolved gas leaving reservoir at reservoir conditions}}{\text{volume of oil entering stock tank at standard conditions}}$$

Units: res bbl/STB

Factors affecting oil volume change:

1. Gas evolution
2. Pressure reduction
3. Temperature reduction

# Black Oil Properties

Oil Formation Volume Factor (**Bo**):

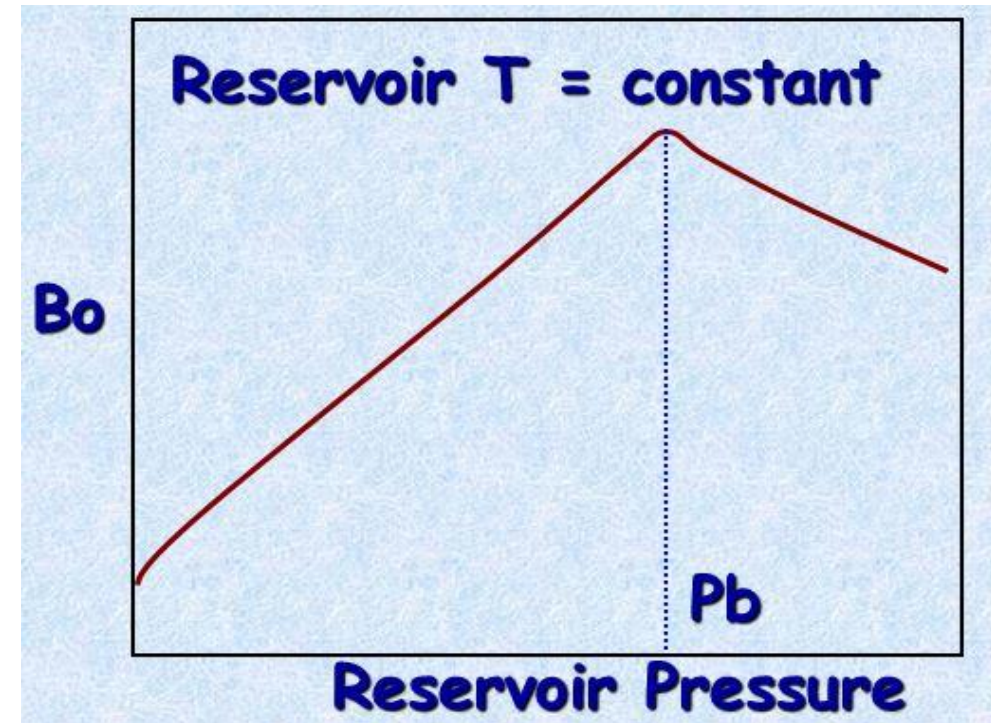
Typical shape (Bo vs. Pressure):

When the value of  $B_o = 1.0$  res bbl/STB?

$$b_o = \frac{1}{B_o} ?$$

Search for:

The temperature effect on **Bo** ! (to be discussed next class)



# Black Oil Properties

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## Oil Formation Volume Factor ( $B_o$ ):

Example 8-2 (McCain book, page 226):

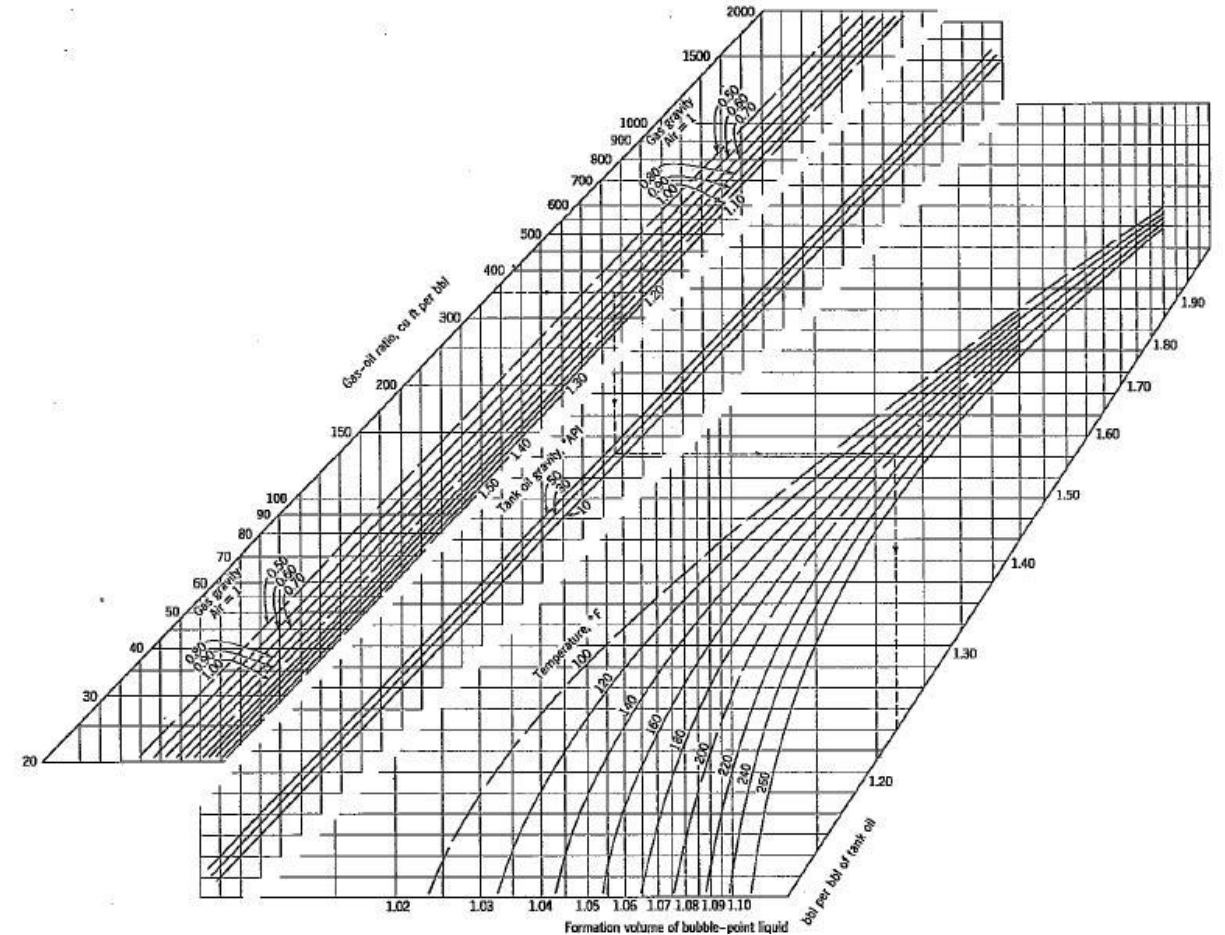
*A sample of reservoir liquid with volume of 400 cc under reservoir conditions was passed through a separator and into a stock tank at atmospheric pressure and 60°F. The liquid volume in the stock tank was 274 cc. A total of 1.21 scf of gas was released. Calculate the oil formation volume factor.*

Solution:

$$B_o = \frac{400 \text{ res cc}}{274 \text{ ST cc}} = 1.46 \frac{\text{res bbl}}{\text{STB}}$$

# Black Oil Properties

Oil Formation Volume Factor ( $B_o$ ):  
Correlation:



# Black Oil Properties

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## Solution Gas Oil Ratio ( $R_s$ ):

The quantity of gas dissolved in oil at reservoir conditions. It is the amount of gas that evolves from the oil as the oil is transported from the reservoir to the surface conditions.

$$R_s = \frac{\text{volume of gas produces at the surface at standard conditions} \left( \frac{\text{scf}}{\text{STB}} \right)}{\text{volume of oil entering stock tank at standard conditions}}$$

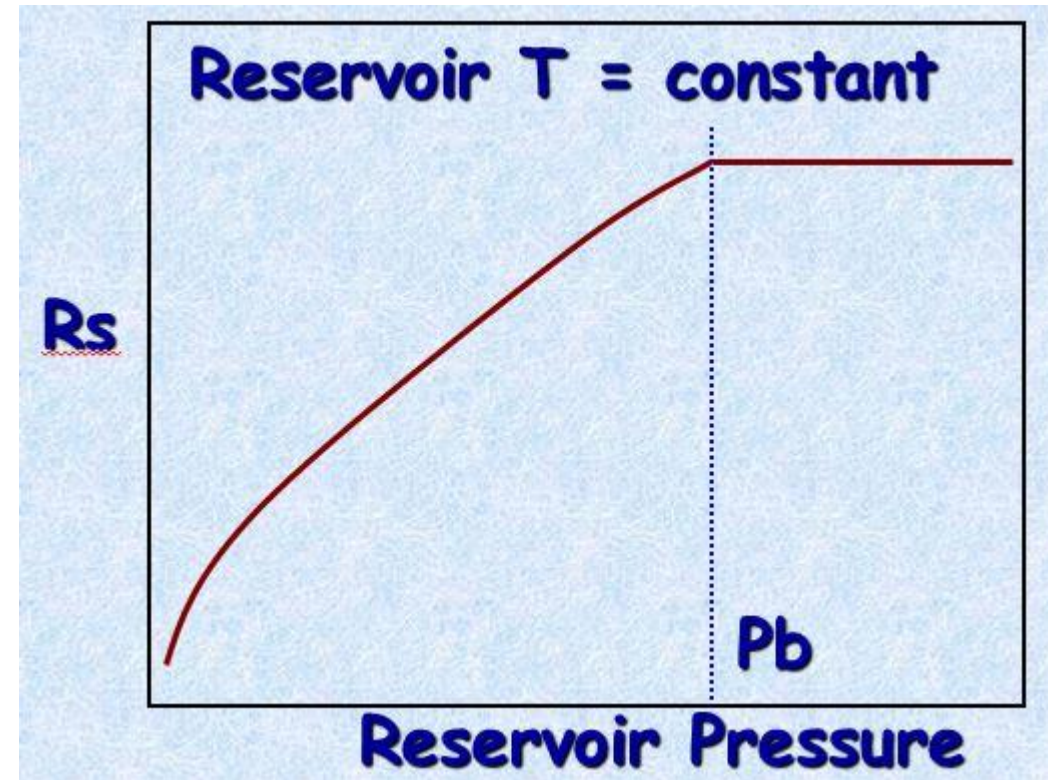
# Black Oil Properties

Solution Gas Oil Ratio ( $R_s$ ):

Typical shape ( $R_s$  vs. Pressure):

Search for:

The temperature effect on  $R_s$  ! (to be discussed next class)



# Black Oil Properties

Solution Gas Oil Ratio ( $R_s$ ):  
Correlation:

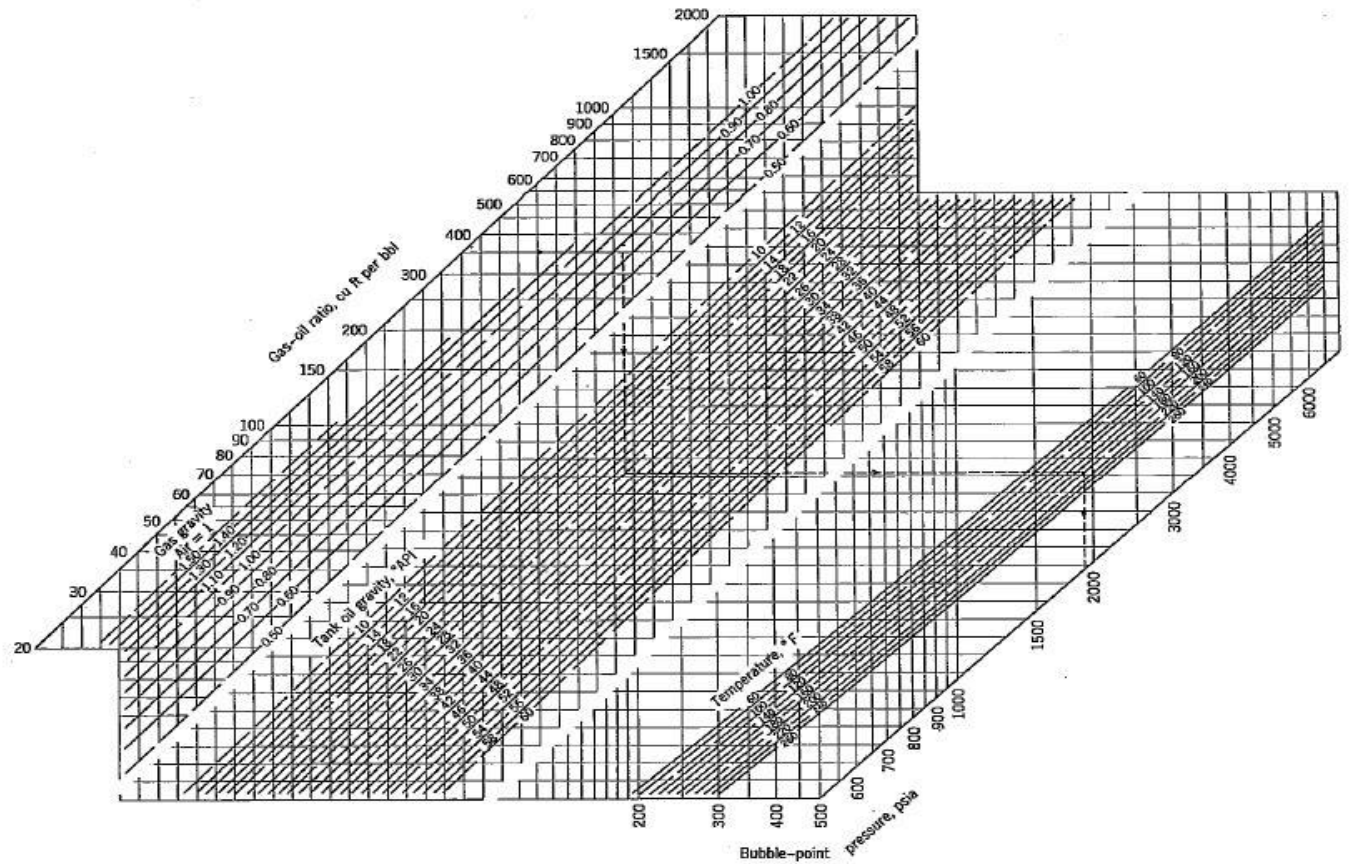


Fig. 58. Gas solubility as a function of pressure, temperature, gas gravity, and oil gravity. (Copyright 1947, California Research Corporation, reprinted by permission.)

# Black Oil Properties

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**Solution Gas Oil Ratio ( $R_s$ ):**

**Example 8-3** (McCain book, page 229):

Calculate the solution gas oil ratio of the reservoir liquid of the previous example (**Example 8-2**).

**Solution:**

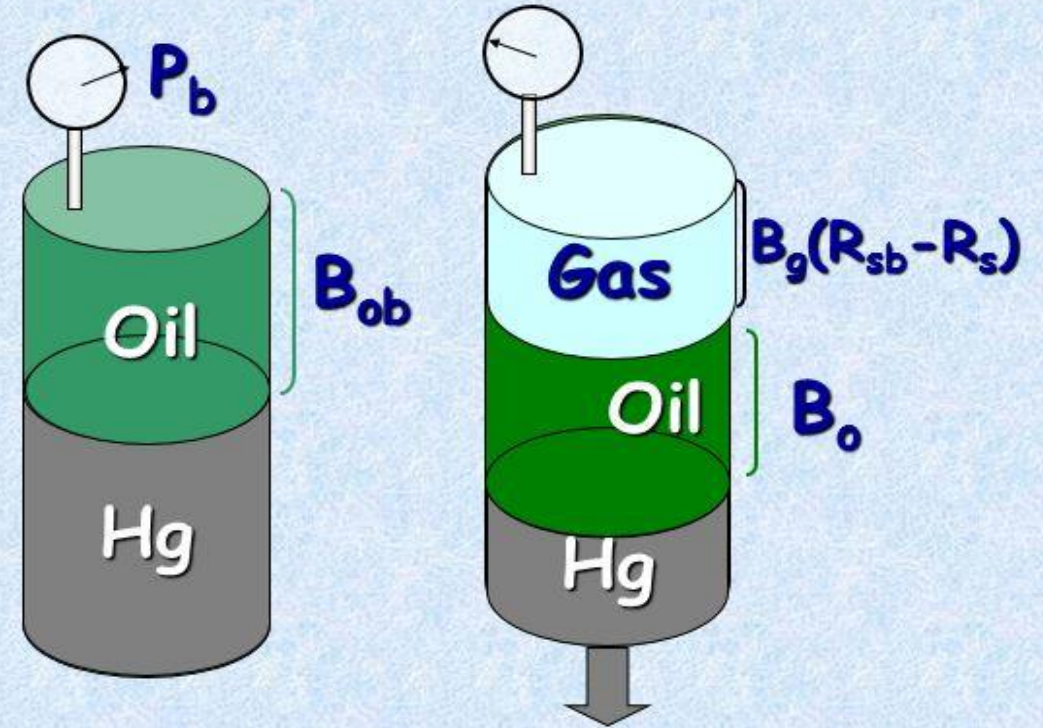
$$R_s = \frac{\text{volume of gas produces at the surface at standard conditions} \left( \frac{\text{scf}}{\text{STB}} \right)}{\text{volume of oil entering stock tank at standard conditions}}$$

$$R_s = \frac{1.21 \text{ scf}}{(274 \text{ ST cc})(6.2898 \times 10^{-6} \text{ bbl/cc})} = 702 \frac{\text{scf}}{\text{STB}}$$

# Black Oil Properties

Total Formation Volume Factor ( $B_t$ ):

Total Formation Volume Factor  $B_t$



# Black Oil Properties

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Total Formation Volume Factor ( $B_t$ ):

Also two-phase formation volume factor.

$$B_t = B_o + B_g (R_{sb} - R_s)$$

Units: bbl/STB + bbl/scf (scf/STB) = bbl/STB

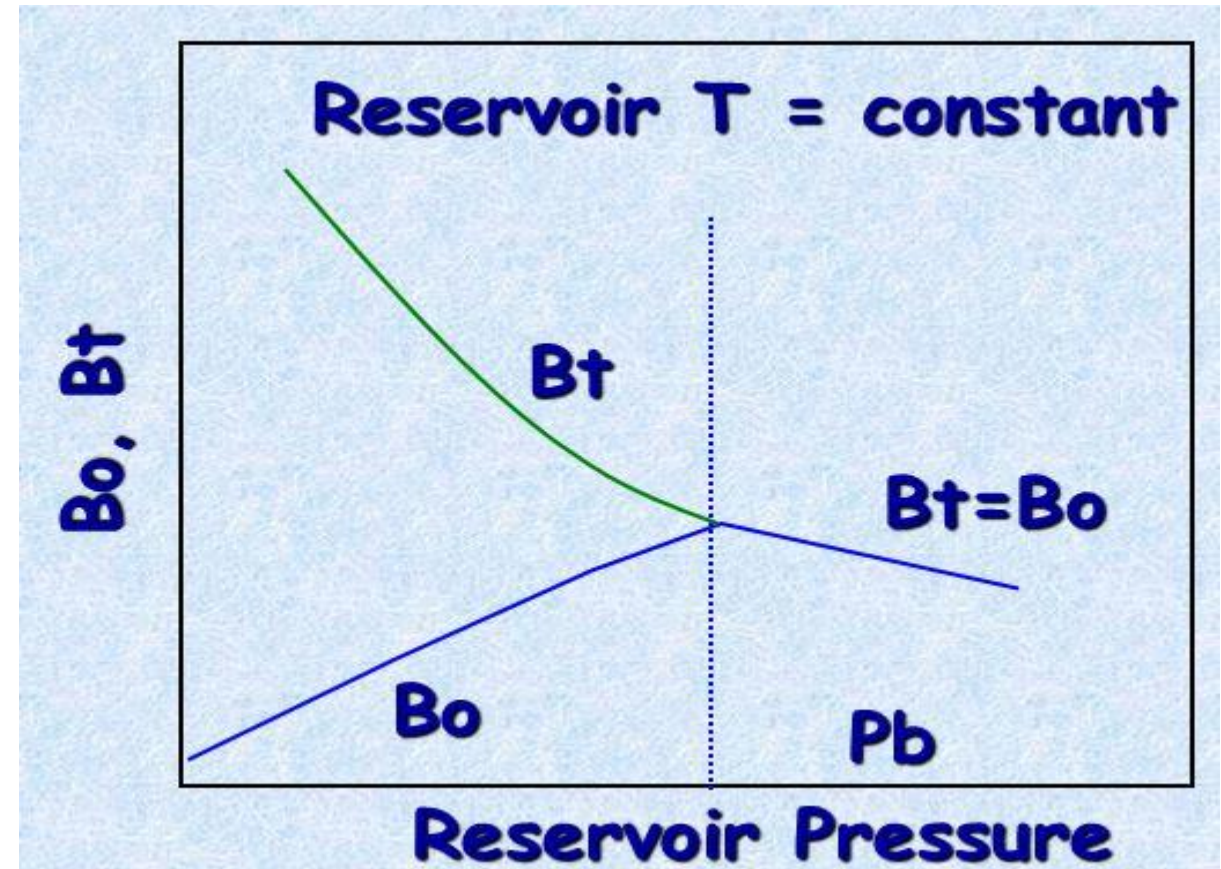
# Black Oil Properties

Total Formation Volume Factor ( $B_t$ ):

Typical shape ( $B_t$  vs. Pressure):

Search for:

The temperature effect on  $B_t$  ! (to be discussed next class)



# Black Oil Properties

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Total Formation Volume Factor ( $B_t$ ):

Example 8-4 (McCain book, page 230):

*Exactly one stock-tank barrel was placed in a laboratory cell. 768 scf of gas was added. Cell temperature was raised to 220°F, the cell was agitated to attain equilibrium between gas and liquid, and pressure was raised until the final bubble of gas disappeared. At that point cell volume was 1.474 barrels and pressure was 2620 psig. Pressure in the cell was reduced to 2253 psig by increasing total cell volume to 1.569 barrels. At that point the oil volume in the cell was 1.418 barrels and the gas volume in the cell was 0.151 barrels. Calculate the total formation volume factor at 2253 psig.*

Solution:

$B_t = ???$

# Black Oil Properties

## The Coefficient of Isothermal Compressibility of Oil ( $C_o$ ):

The instantaneous change of volume with pressure at constant temperature.

Also called Oil Compressibility.

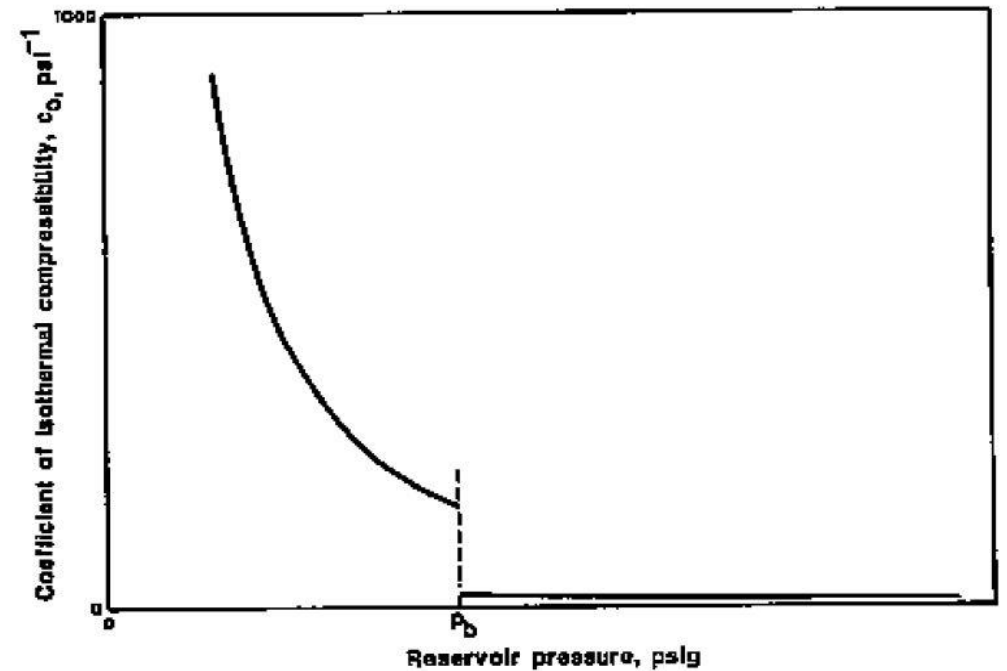
$$C_o = -\frac{1}{V} \left( \frac{\partial V}{\partial P} \right)_T$$

With molar volume:

$$C_o = -\frac{1}{V_M} \left( \frac{\partial V_M}{\partial P} \right)_T$$

Or;

$$C_o = -\frac{1}{B_o} \left( \frac{\partial B_o}{\partial P} \right)_T$$



# Black Oil Properties

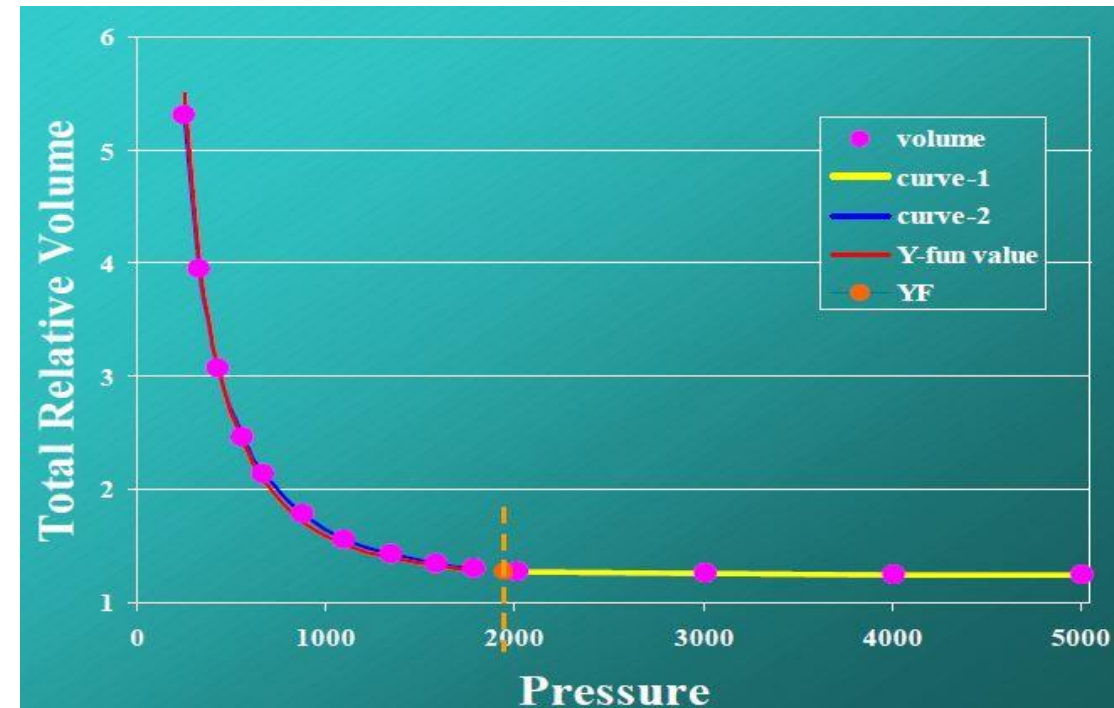
The Coefficient of Isothermal Compressibility of Oil ( $C_o$ ):

Above bubble point pressure:

$$C_o = -\frac{1}{V} \left( \frac{\partial V}{\partial P} \right)_T$$

$$C_o(P_2 - P_1) = -\ln \frac{V_2}{V_1}$$

$$V_2 = V_1 e^{[C_o (P_1 - P_2)]}$$



# Black Oil Properties

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## The Coefficient of Isothermal Compressibility of Oil ( $C_o$ ):

Above bubble point pressure

Example 8-4 (McCain book, page 233):

*A sample of reservoir oil was placed in a laboratory cell at 5000 psig and 220°F. The volume was 59.55 cc. Pressure was reduced to 4000 psig by increasing the oil volume to 60.37 cc. Calculate the coefficient of isothermal compressibility for this oil at cell conditions.*

Solution:

$$C_o(P_2 - P_1) = -\ln \frac{V_2}{V_1}, \quad C_o = -\frac{\ln \frac{V_2}{V_1}}{(P_2 - P_1)}$$

$$C_o = -\frac{\ln \left( \frac{60.37}{59.55} \right)}{(4014.7 - 5014.7)} = 13.68 \times 10^{-6} \text{ psi}^{-1}$$

# Black Oil Properties

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The Coefficient of Isothermal Compressibility of Oil ( $C_o$ ):

Below bubble point pressure:

$$C_o = -\frac{1}{B_o} \left( \frac{\partial B_o}{\partial P} \right)_T + \frac{B_g}{B_o} \left( \frac{\partial R_s}{\partial P} \right)_T$$

# Black Oil Properties

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## Oil Viscosity ( $\mu_o$ ):

The measure of the resistance to flow exerted by a fluid.

Dynamic viscosity:

Units: (centipoise = g mass / 100 sec cm)

Kinematic viscosity: viscosity / density

Units: centistokes = centipoise / g/cc

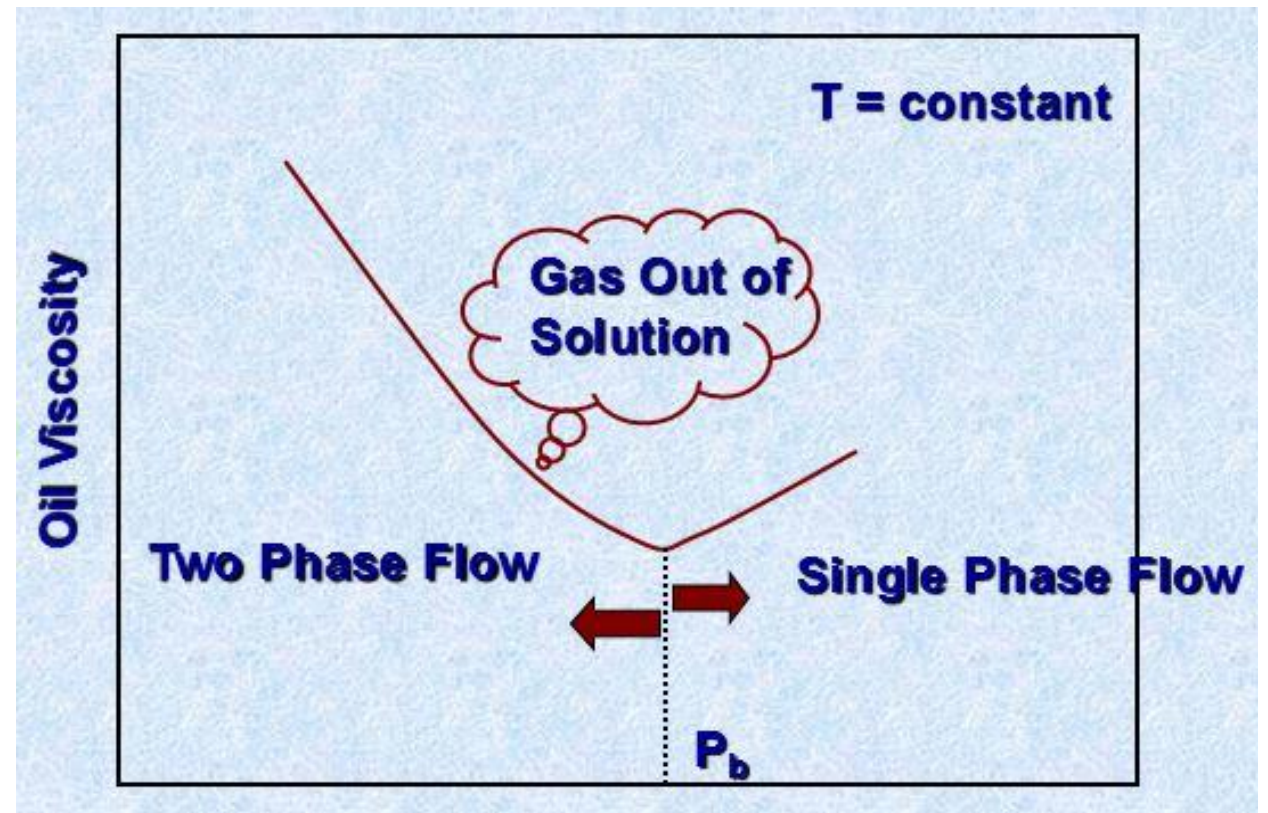
# Black Oil Properties

Oil Viscosity ( $\mu_o$ ):

Typical shape ( $\mu_o$  vs. Pressure):

Search for:

The temperature effect on  $B_t$  ! (to be discussed next class)



# Black Oil Properties

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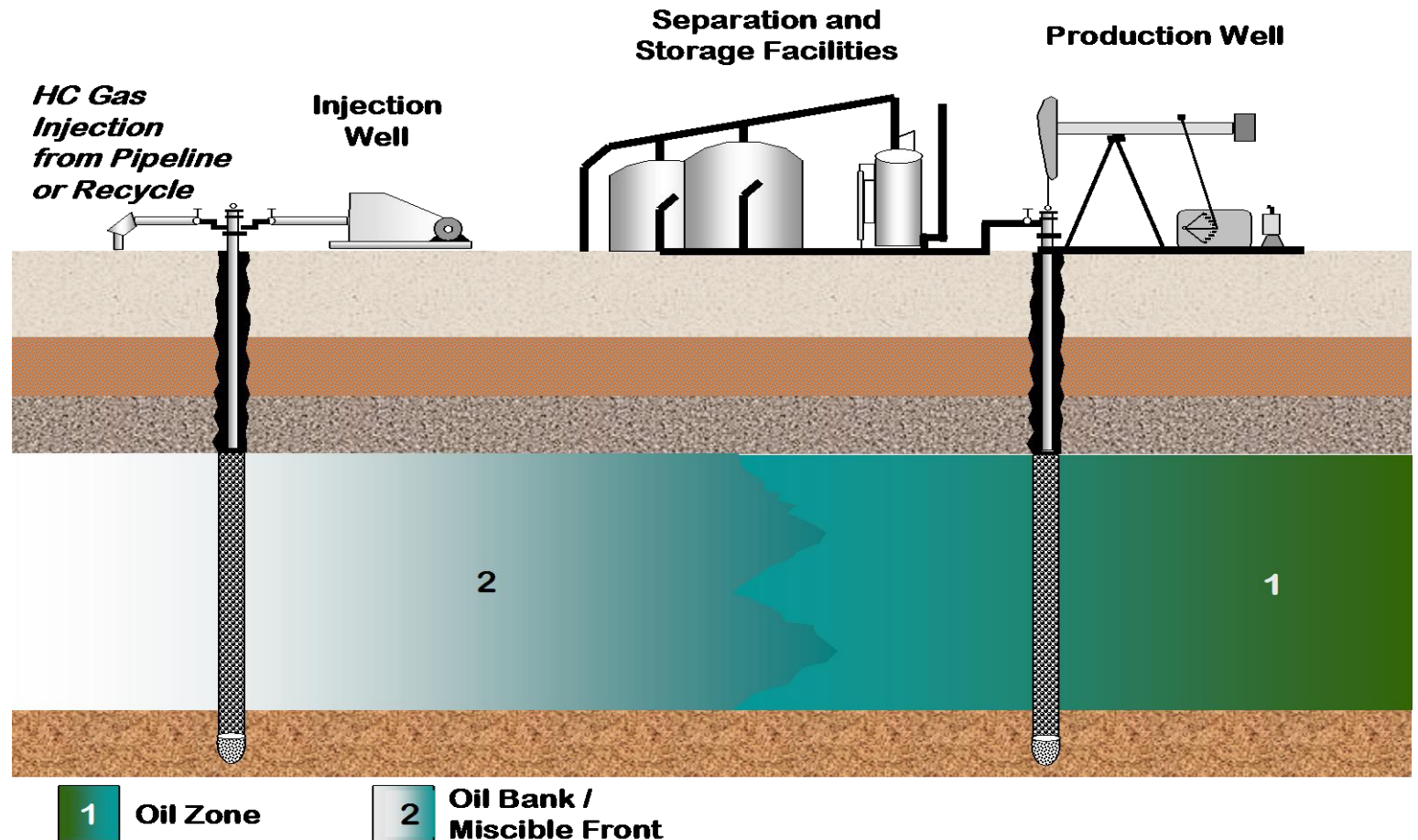
Oil Viscosity ( $\mu_o$ ):

Importance:

- Calculation of two-phase flow
- Gas-lift and pipeline design
- Calculation of oil recovery either from natural depletion or from recovery techniques such as water flooding and gas-injection processes

# Black Oil Properties

Oil Viscosity ( $\mu_o$ ):  
Importance:



# Black Oil Properties

Oil Viscosity ( $\mu_o$ ):  
Importance:

