PETE 310

Lecture # 15

Properties of Black Oils

Definitions

(pages 224-240)
Please adhere strictly to the rules indicated in this test

- Disable your cell phone (no text messages either)
- Use your own calculator pencil, ruler, and eraser.
- You cannot use a laptop
- Write all your work on the test paper and in the space provided for the answer, do no write on the back.
- Grading will be based on approach and answers.
PETROLEUM ENGINEERING 310

Please adhere strictly to the rules indicated in this test

- Do not fold or un-staple this examination booklet.
- This examination is open book, notes, HW, and SPE papers you cannot talk to anybody but me or the TA’s.
- Raise your hand if you have a question and we’ll go to your desk.
- Do not even look into your neighbor’s paper.
- Show all your work!!!! Answers with no evidence of calculations where they are required will not be graded.
- Time allotted for the test is 120 minutes.
Recall.... Black Oil Phase Diagram
A Reservoir Engineer Questions

- How much oil is in the reservoir?
- How can I get it out?
- How fast?
Oil Properties Used in Reservoir Engineering...

- Formation Volume Factor of oil $B_o$
- Total Formation Volume Factor of oil $B_t$
- Solution Gas oil Ratio $R_s$
- Coefficient of Isothermal Compressibility $C_o$
Oil Properties Used in...Production, EOR, Transportation...

- Thermal Expansion Coefficient (EOR – Steam flooding) $\beta_o$
- Interfacial Tension (EOR)
- Oil Viscosity $\mu_o$ (EOR, transportation, production)

**NOTE:** Density is related to $B_o$
Learning Goals

- Understand the behavior of those PVT properties (Bo, Rs, ...) vs P and type of fluid (now)

- Evaluate PVT properties from (later)
  - Field data
  - Laboratory studies
  - Correlations
Definitions

- **Specific gravity of a liquid**
  \[ \gamma_o = \frac{\rho_o(P_1, T_1)}{\rho_w(P_1, T_1)} \]

- **API gravity**
  \[ \circ API = \frac{141.5}{\gamma_o} - 131.5 \]
Definitions

Formation Volume Factor of Oil

Surface P & T

Pressure Decreasing

Reservoir P & T

Gas out of Solution
Definitions

\[ Bo = \frac{\text{Volume of Oil + Dissolved Gas at Reservoir P & T}}{\text{Volume of Oil Entering Stock Tank at Tsc,Psc}} \]

Units \[\text{[= ]}\]

Reservoir barrels (bbl) / Stock tank barrels (STB)
General Features of Bo

At reservoir T (constant)
Solution Gas Oil Ratio (Rs)

- How much gas is dissolved in the oil volume per volume basis
- Rs depends upon pressure, temperature and oil type

Units $= \frac{\text{SCF gas}}{\text{STB oil}}$
General Features of Rs

At reservoir T (constant)
Total Formation Volume Factor Bt

$P_b$

$B_{ob}$

$B_g(R_{sb} - R_s)$

$B_o$
Definition of $B_t$

Also called Two-phase formation volume factor

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

Units:

$bbl/STB + bbl/SCF \times (SCF/STB)$
General Shape of Bt

Reservoir $T = \text{constant}$

Bo, Bt

Reservoir Pressure

$Bt = Bo$
Definition of Oil & Gas PVT Properties

**Standard Conditions**

\[ B_g = \frac{R_v}{R_s} \]

**Reservoir**

- \( P \)
- \( P_1 \)
- \( P_2 \)
- \( P_3 \)

**Decreasing Pressure**

- **Separator gas**
- **STB**
- **Gas**
- **Oil**

**STB**
The Coefficient of Isothermal Compressibility of Oil

Provides instantaneous change of volume with $P$ at constant $T$

$$C_o(P_A, T_A) = -\frac{1}{V} \left[ \frac{\partial V}{\partial P} \right]_{T_A}$$

alternatively using molar volume and specific volume
Coefficient of Thermal Expansion

(Use in Steam Injection Processes)
Oil Viscosity

- Viscosity is a measure of the resistance to flow exerted by a fluid
- This is called dynamic viscosity and has units of
  \[ \text{centipoise} = \frac{\text{g mass}}{100 \text{ sec cm}} \]
- Kinematic viscosity is viscosity / density, units are in
  \[ \text{centistokes} = \frac{\text{centipoise}}{\text{g/cc}} \]
Needs of Crude Oil Viscosity

- Calculation of two-phase flow
- Gas-lift and pipeline design
- Calculate oil recovery either from natural depletion or from recovery techniques such as waterflooding and gas-injection processes
Variation of Oil Viscosity

- **T = constant**
- **Gas Out of Solution**
- **Two Phase Flow**
- **Single Phase Flow**
- **P_b**