PVT – What's Important and Why

Curtis Hays Whitson, Founder and CEO at Whitson AS

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In Memory of My PVT "Influencers"



Marshall B. Standing

(1913-2010)



Keith H. Coats

(1934-2016)



Kenneth E. Starling

(1935-2019)



Michael L. Michelsen

(1944-2020)

“Doing” PVT

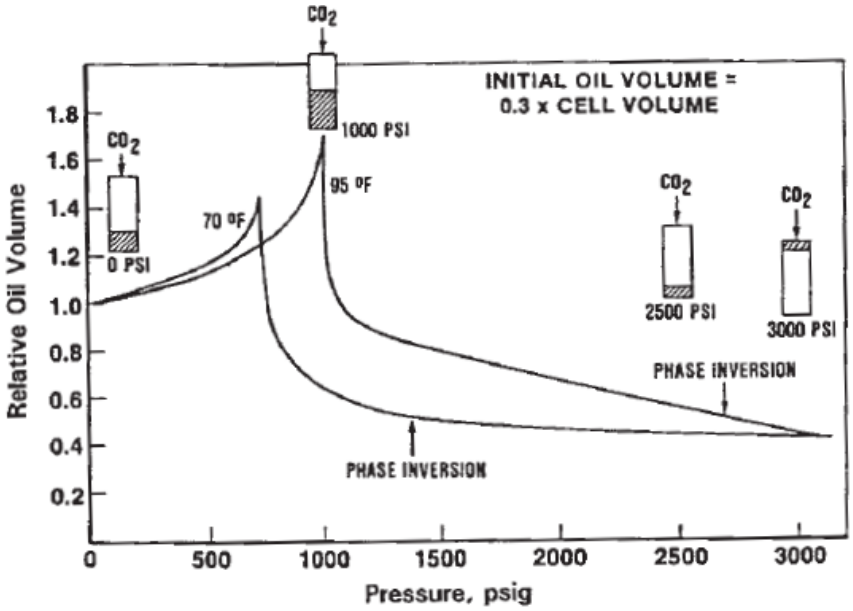
Whitson work motto

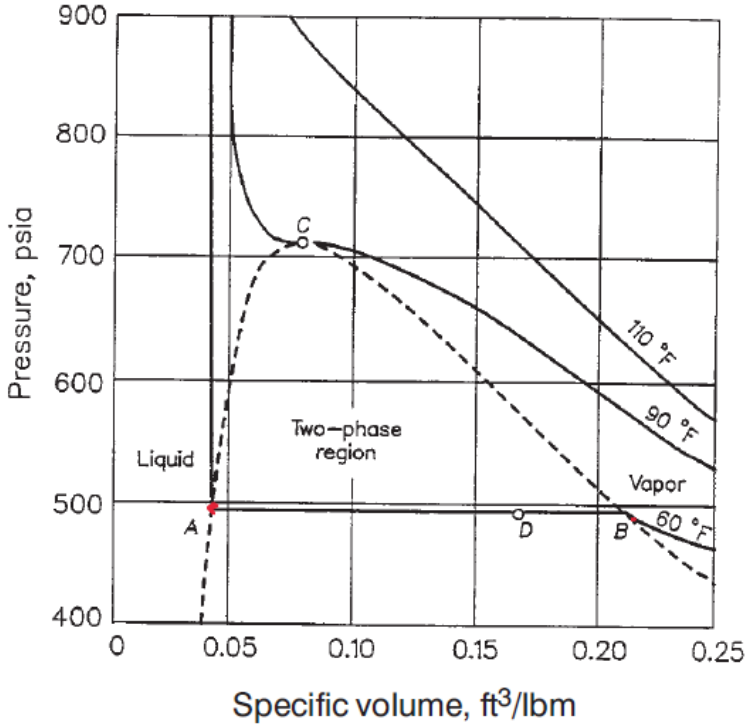


measure & calculate

Pressure | Volume | Temperature

- How does **V**olume change with **P**&**T**?
- Volume of what?





PVT = Fluid Phase Behavior

- **Fluid** = mixture of one or more components

… we must know the ***total*** mixture composition z_i

- Components *i* {N_2,CO_2,H_2S} | {HCs} | {H_2O} | {…}

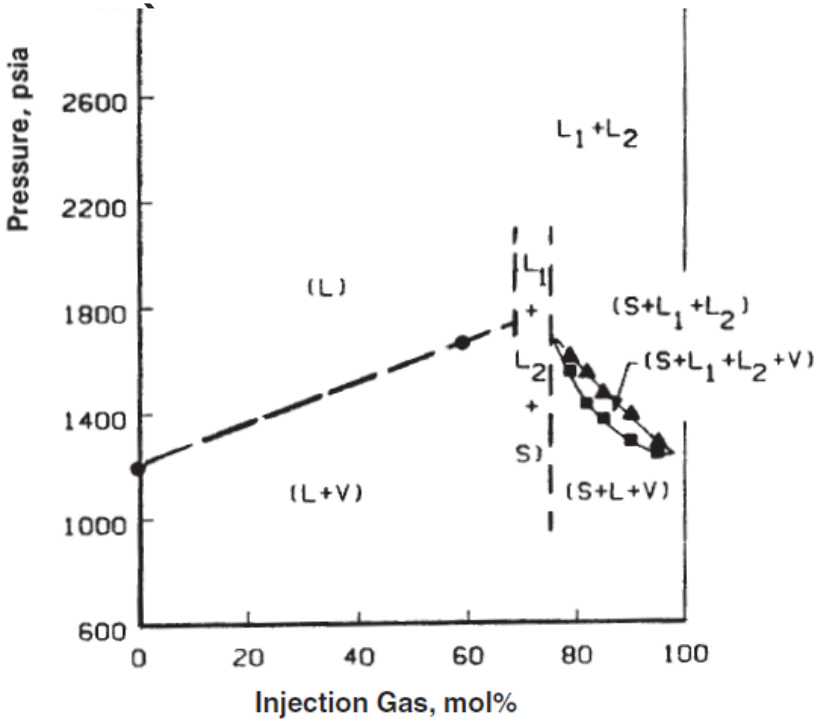
- Amounts of components (n_i, $n=\sum_i n_i$, $z_i=n_i/n$)

PVT = Fluid Phase Behavior

- **Phase** = homogeneous mixture of components
  - General: Vapor | Liquid(s) | Solid(s)
  - Usual: Gas | Oil | Water (aqu
  - Fluids: Lightest | Lighter | He
    - CO_2-EOR: C_1-rich | CO_2-rich |
    - CCS: CO_2-H_2O | H_2O-CO_2 (wh
  - Solids: Salt/Scale | Wax |

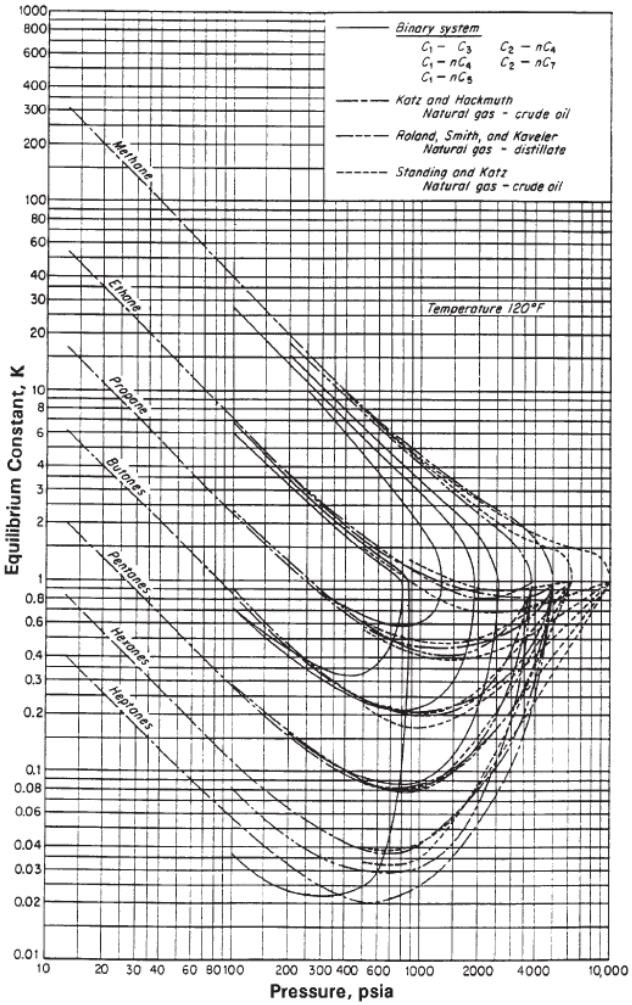


Asphaltenes | Hydrates



PVT = Fluid Phase Behavior

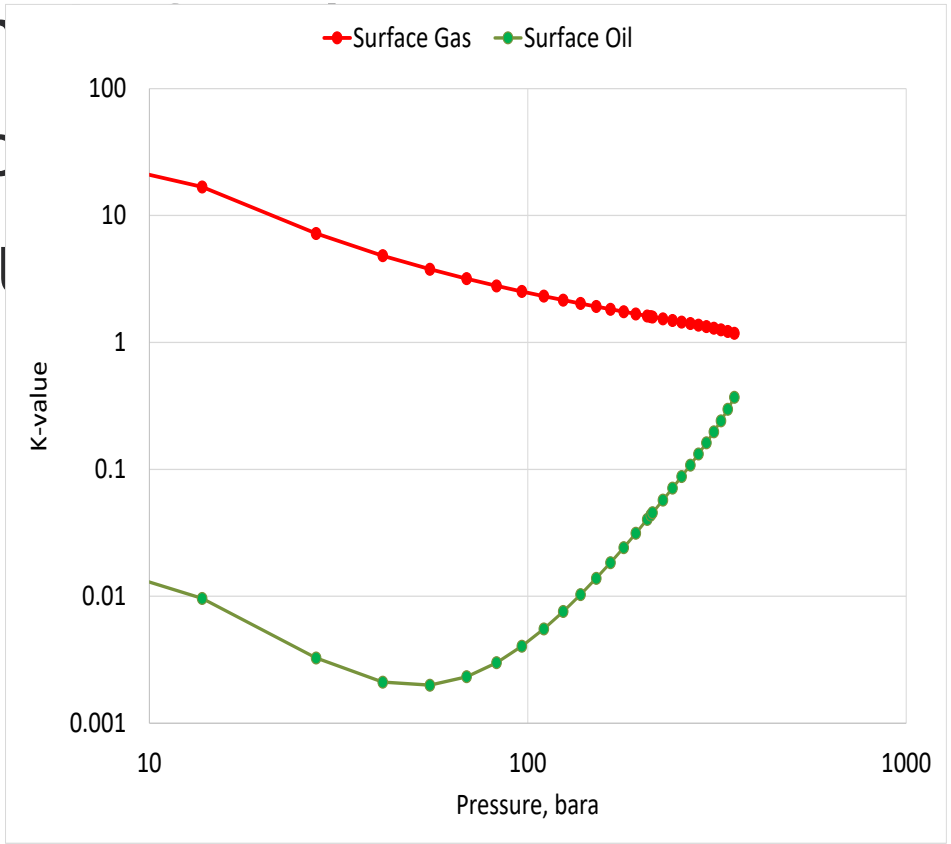
- **Behavior** =
  - u_i = phase component mole fra
    - y_i (gas) & x_i (oil)
  - K_i = component equilibrium rat
    - $K_{i(g\text{-}o)} = y_i/x_i$
    - Every phase-pair (gas-oil | gas-
  - ρ = phase mass density
  - μ = phase viscosity



"PVT" (Black-Oil)

PVT = Fluid Phase Behavior

- **Behavior** = {R} {R_s, B_o, μ_o} {r_s, B_g, μ_g} {R_{sw}, B_w, μ_w}
  - u_i = phase component m
    - i = {surface gas} | {surfac
  - K_i = component equilibri
    - $K_{i(g-o)}$ | $K_{i(g-w)}$
  - ρ = phase mass density
  - μ = phase viscosity



PVT = Fluid Phase Behavior

- **Behavior** = $\{z_i\}$ {EOS-LBC} $\{R_{sw}, B_w, \mu_w\}$
  - u_i = phase component mole fractions
    - i = $\{N_2, CO_2, H_2S\}$ | $\{C_1, C_2, C_3 \ldots C_6 \ldots C_{N+}\}$ | $\{H_2O\}$
  - K_i = component equilibrium ratios (K-values)
    - $K_{i(g\text{-}o)}$ | $K_{i(g\text{-}w)}$
  - ρ = phase mass density
  - μ = phase viscosity

PVT = Fluid Phase Behavior

- **Behavior** = $\{z_i\}$ {EOS-LBC} ⇒ $\{K_i(p), \rho_v(p), \rho_w(p)\}$
  - u_i = component mole fractions
    - i = {CO_2,H_2O} | {minerals NaCl…}
  - K_i = component equilibrium ratios (K-values)
  - Phases: CO_2-rich | H_2O-rich | solids
  - ρ_m = phase mass density
  - μ = phase viscosity

What = Quantifying PVT Properties

Given "P" & "T" of the total mixture z_i, quantify:

- N_p = number of phases (≥1)
- β_p = molar amounts of each phase
- u_{pi} = component mole fractions of each phase
- M_p = molar mass of each phase
- ρ_p = mass density of each phase
- μ_p = viscosity of each phase

If volume "V" is known, determine the total moles (n); else, if total moles n is known, determine the volume V occupied by all phases in the total mixture. *Adjust (P,T) to satisfy mole/volume constraints.*

"What"

What = Quantifying PVT Properties

- Experimentally in the laboratory
  - Published data (1930s-1960s)
  - *Fluid-specific data (1950s-present)*
- Computationally with models
  - Published "generalized" correlations (1940s-1960s)
    - Empirical correlations (1940s-1960s)
    - Equations of State (EOS) (1949-1970s)
    - Compositional viscosity correlations (1960s-2000)
    - *Fluid-specific EOS-LBC models (1970s-present)*

"Important"

- **Costs**
  - … (next slides)
- **Revenues**
  - EOR (ρ,μ,σ,K_i), surface processing ($K_i,y_i,x_i,\ldots$)
- **Environmental Impact**
  - e.g. C_1 loss from storage tanks (oil and water)
- **Health & Safety**
  - e.g. H_2S in field operations & drilling

Major Costs & Revenues

- **# Platforms**
  - (k/μ) , (ρ,c,μ) , Recovery mechanisms
- **# Wells**
  - (k/μ) , (ρ,μ) , Recovery mechanisms
- **Pipe dimensions & quality**
  - (ρ,μ,σ) , Injection fluids
- **Compressors & Pumps**
  - (ρ,μ) , Injection fluids
- **Surface Processing Equipment**
  - (K_i) Well/Field produced compositions

Gravity & Friction (pressure losses) ⇒ Costs

Gravity & Friction (displacement efficiency) ⇒ Revenues

Costs Moving Fluids from Reservoir to Market

- **A–B:** Reservoir to Wellbore — *Reservoir Engineers*
  - Stimulation, Injection (EOR)
- **B–C:** Wellbore to Wellhead — *Production Engineers*
  - Artificial Lift (compressors, pumps)
- **C–D:** Wellhead to Products — *Process Engineers*
  - Process Units (P,T), Compressors
- **D–E:** Product Transportation — *Flow Assurance Engineers*
  - Gathering & Pipelines, Compressors
- **E–F:** Final Product Processing — *Chemical Engineers*
  - Process Units & Refining

"Why"

PVT has impact on Costs & Revenues

- "PVT" (fluid phase behavior)
  1. will have a variable impact along the value chain A-B-C-D-E-F, and
  2. will change in importance with time, and for different field development strategies.
- Figuring out where and when PVT is important is not intuitive and requires systematic analysis.

PVT – What's Important & Why

- **PVT** = fluid phase behavior
- **What** = Phase PVT properties $(u_i , K_i , \rho , \mu)_p$
- **Important** = Costs , Revenues, HSE
- **Why** = PVT impacts important issues

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We help our clients find best possible answers to complex questions and assist them in the successful decision-making on technical challenges. We do this through a continuous, transparent dialog with our clients - before, during and after our engagement.

The company was founded by Dr. Curtis Hays Whitson in 1988 and is a Norwegian corporation located in Trondheim, Norway, with local presence in USA, Middle East, India and Indonesia.

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