Note Title 5/9/2016

COMPOSITIONS

* Components $\{N_2\ CO_2\ H_2S\ H_2O\ Hg \cdots\}$ non-HC

$C_1\ C_2\ C_3\ i\text{-}C_4\ n\text{-}C_4\ i\text{-}C_5\ n\text{-}C_5$

$C_6\ C_7\ C_8\ C_9\ C_{10}\ C_{11} \cdots C_{N-1}\ \boxed{C_{N+}}$

Many Isomers (PNA) reported by normal (1 atm) boiling points

SCN

Heavy Plus (Residue)

* Amounts $(m_i,\ n_i)$

$n\text{-}C_6$ ← (last isomer in SCN "C_7")

SCN C_7 { Benzene : C_6 Aromatic

$n\text{-}C_7$ (highest NBP in "C_7")

SCN C_8 { $n\text{-}C_8$

Field A B C

C_{18} GC / TBP

SCN overlap : $\boxed{C_n}$ Distillation

C_{n-2}	C_{n-1}	C_n	C_{n+1}	C_{n+2}
< 5%	< 15%	> 60%	< 15%	< 5%

C_{N+}				
< 1980	C_{7+}			
1980s	C_{10+}	C_{12+}	C_{15+}	
1990s	C_{20+}			
> 2000	C_{26+}	C_{31+}	C_{35+}	

w/ $C_6\ C_7\ C_8\ C_9$ isomers

Gamma Molar Distribution Model

Example

Component Slates

JK1 sample

Component
Hydrogen Sulfide
Nitrogen
Carbon Dioxide
Methane
Ethane
Propane
Iso-butane
N-butane
2-2 Dimethylpropane
Iso-pentane
N-pentane
2-2 Dimethylbutane
Cyclopentane
2-3 Dimethylbutane
2 Methylpentane
3 Methylpentane
Other Hexanes
n-Hexane
Heptanes Plus
TOTAL

C6

Component
Hydrogen Sulfide
Nitrogen
Carbon Dioxide
Methane
Ethane
Propane
Iso-butane
N-butane
2-2 Dimethylpropane
Iso-pentane
N-pentane
2-2 Dimethylbutane
Cyclopentane
2-3 Dimethylbutane
2 Methylpentane
3 Methylpentane
Other Hexanes
n-Hexane
Methylcyclopentane
Benzene
Cyclohexane
2-Methylhexane
3-Methylhexane
2,2,4 Trimethylpentane
Other Heptanes
n-Heptane
Methylcyclohexane
Toluene
Other C-8's
n-Octane
Ethylbenzene
M&P-Xylene
O-Xylene
Other C-9's
n-Nonane
Other C10's
n-Decane
Undecanes Plus
TOTAL

C7

C8

C9

C10

Component
Hydrogen Sulfide
Nitrogen
Carbon Dioxide
Methane
Ethane
Propane
Iso-butane
N-butane
2-2 Dimethylpropane
Iso-pentane
N-pentane
2-2 Dimethylbutane
Cyclopentane
2-3 Dimethylbutane
2 Methylpentane
3 Methylpentane
Other Hexanes
n-Hexane
Methylcyclopentane
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2,2,4 Trimethylpentane
Other Heptanes
n-Heptane
Methylcyclohexane
Toluene
Other C-8's
n-Octane
Ethylbenzene
M&P-Xylene
O-Xylene
Other C-9's
n-Nonane
Other C10's
n-Decane
Undecanes
Dodecanes
Tridecanes

C10

C11

C12

Component
Tetradecanes
Pentadecanes
Hexadecanes
Heptadecanes
Octadecanes
Nonadecanes
Eicosanes
Heneicosanes
Docosanes
Tricosanes
Tetracosanes
Pentacosanes
Hexacosanes
Heptacosanes
Octacosanes
Nonacosanes
Triacontanes
Hentriacontanes Plus

C30

C31+

* Amounts

Lab Measures ⇒ Mass m_i $\quad w_i = \frac{m_i}{m_t}$ $\quad m_t = \sum_j m_j$

Moles n_i $\quad \left.\begin{matrix} z_i \\ y_i \\ x_i \end{matrix}\right\} = \frac{n_i}{n_t}$ $\quad n_t = \sum_j n_j$

$m_i \leftrightarrow n_i$ $\quad M_i \equiv \frac{m_i}{n_i}$ uncertain number for C_6...

Molar Mass

Molecular Weight

PNA

$M_i = 14i + h$

$h = +2$ alkanes (paraffins) "P"

$h = 0$ naphthene

$h = -6$ aromatic

Backed for h for C_7 -20

e.g. Benzene C_6H_6 : $M_B = 6 \cdot 14 - 6 = \underline{78}$

part of "C_7" SCN

M_7

$n\text{-}C_7$: $M = 14 \cdot 7 + 2 = \underline{100}$ $+2$

KF (Table 5.2) = 96 "World Average"

$\frac{2}{0}$

* Measure Composition Amounts ?

Gas Chromatography (GC)

(1) For sep. gases & flashed gas
(2) For flashed (STO) oils
} ⇒ GC → w_{gi} y_i ; w_{oi}

flashed at 1 atm

$\bar{g}$: flash(atm) gas

$\bar{o}$: flash(atm) oil
e.g. STO

General Method to Measure Pressurized Sample Compositions

- BHS
- MDT | RCI |
- Sep. Oil

① Bring to 1 atm @ $T_{ambient}$

$m_{\bar{g}}$ [$V_{\bar{g}}$] $n_{\bar{g}}$ ±5%

→ Flashed Gas ($\bar{g}$) ⇒ GC → $y_{\bar{g}i}$; w_{gi}

→ Flashed Oil ($\bar{o}$) ⇒ GC → w_{oi}

$m_{\bar{o}}$ { $\rho_{\bar{o}}$ $M_{\bar{o}}$ } measured ⇒ $V_{\bar{o}}$ $n_{\bar{o}}$

(±)

$$GOR_{recomb} = \frac{V_{\bar{g}}}{V_{\bar{o}}}$$

1 atm = p, T(t)...

Recombine mathematically

Original Sample

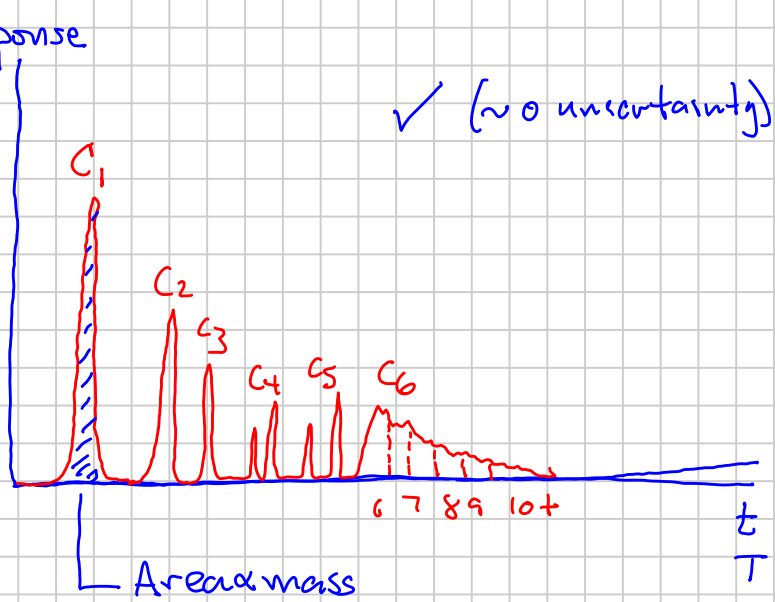
$$m_i = \left(m_{\bar{g}}^{\pm}\ w_{\bar{g}i}^{\checkmark} + m_{\bar{o}}^{\pm}\ w_{\bar{o}i}^{\pm}\right)$$

$$w_i = \frac{m_i}{m_t}$$

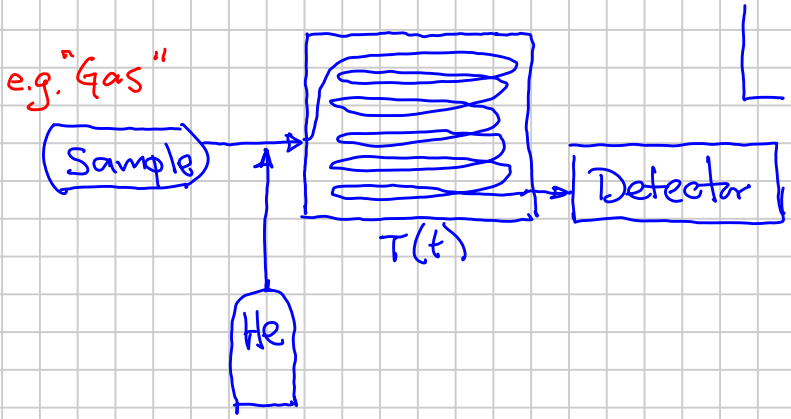
FLASH-GC-RECOMBINE (Alt. Cryogenic Flash-GC-Rec)

Gas Chromatography

- Small Sample
- Helium carrier gas
- Packed Column
- Heater T(t)
- Detector



✓ (w/ uncertainty)



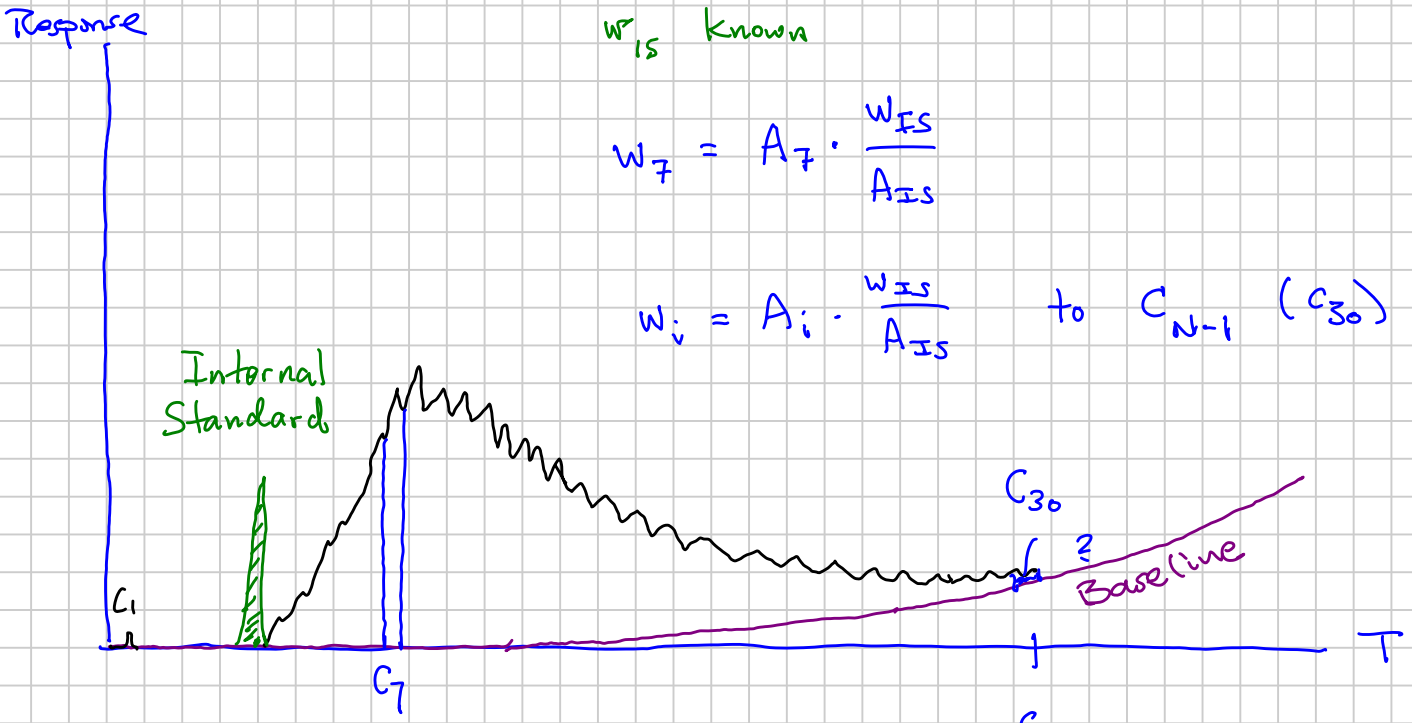
$$w_i = \frac{A_i}{A_t}$$

M_i ✓ pure compounds

$$y_{gi} = \frac{w_i / M_i}{\sum_j w_j / M_j}$$

- He only

Flashed Oil Sample + I.S.



w_{IS} known

$$w_7 = A_7 \cdot \frac{w_{IS}}{A_{IS}}$$

$$w_i = A_i \cdot \frac{w_{IS}}{A_{IS}} \quad \text{to} \quad C_{N-1} \ (C_{30})$$

C_{31+}

$$w_{31+} = 1 - \sum_{i=1}^{30} w_i$$

mass fractions only

- w_i: increasing uncertainty at higher SCNs
- w_{N+}: max uncertainty as N becomes big

⇓

Mole Fractions

$$\pm z_i = (w_i/M_i) \Big/ \sum_{j>7} (w_j/M_j)$$

$\pm z_i$: reported; $\pm$ on w_i/M_i and $\pm$ on the sum

Sample-specific uncertainty needs to be considered in EOS tuning process.

If z_i & w_i given then you can calc. M_i used by the lab

$$M_i = \bar{M} \cdot \frac{w_i}{z_i} \quad \Rightarrow \quad \bar{M} = M_{c_1} \cdot \frac{z_{c_1}}{w_{c_1}}$$

(with $=$ pointing up to $\bar{M}$)

e.g. get $\bar{M}$ knowing M_i, w_i, z_i for a pure compound

$M_{c_1} = 16.04$

Use $(M_i)_{Lab}$ to convert reported mole fractions to Lab "weight fractions" (measured), try to honor w_i

① $\bar{M} = (16.04)(36.47/6.24) = 93.5$

② Find lab $M_{C_6} = (93.5)(3.97/4.33) = 85.7 < M_{n\text{-}C_6}$

Calc. $\bar{M}_{7+} = (\sum z_i M_i) / (\sum z_i)$ = Cell M3

mass / moles

SCN Table

Summarize Composition Uncertainties (in EOS modeling)

① Flash GOR used in recombination ±5%

② w_i $i > C_{15}$ because of baseline shift

③ w_{N+} because of differencing like numbers

$1 - \sum_{i=1}^{N-1} w_i$ ± → 1 as N grows

④ M_i convert $w_i \rightarrow z_i$

} Gamma Molar Dist. Model

Exception of PhazeComp you can't quantify effect ①-④ ± on EOS tuning.

* ①-④ ± ⇒ mol% ±2 for C_7 & C_{7+} Limit on z_i change

* Change in reported z_i should improve EOS predictions for ~ all PVT data (P_b, ρ, V_{ro}, ...)

PVTsim (others) to match p_s (p_d & p_b)

allow one molar composition regression variable:

M_{n+} (last input component)

Internally calculates lab w_i: all components (also C_{N+}) always honored

Recalculates z_i from $(w_i)_{lab}$ and new M_{n+}

$$z_i = \frac{w_i / M_i}{\left(\sum_{j=1}^{n-1} \frac{w_j}{M_j}\right) + \frac{w_{n+}}{M_{n+}}}$$

Every i changed

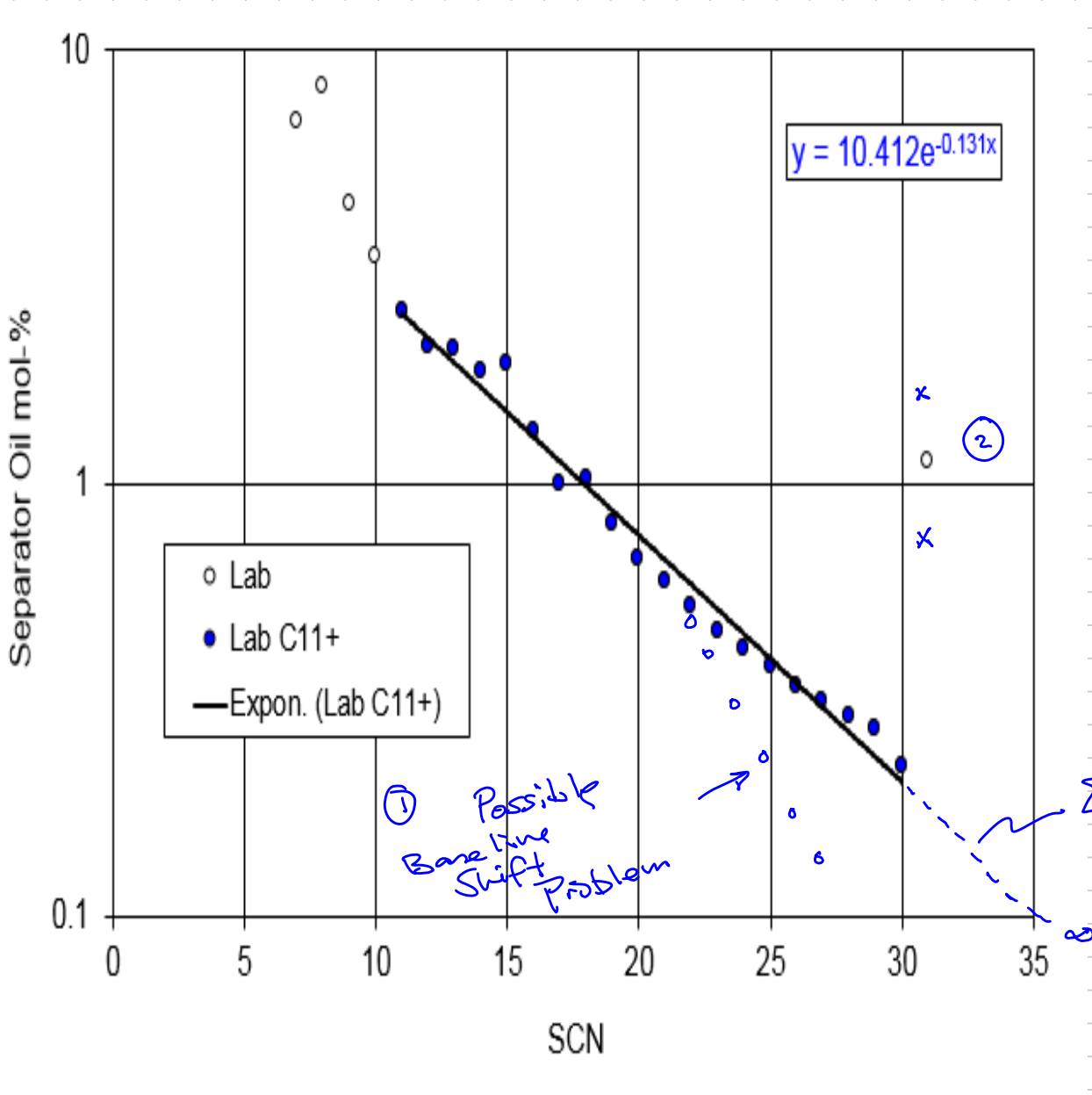
Identify C_{7+} Data Errors / Uncertainty

- Molar distribution model : Exponential

C_{n+} $z_i = z_n \cdot \exp\left[A(i-n)\right]$

PVTsim

M:
i

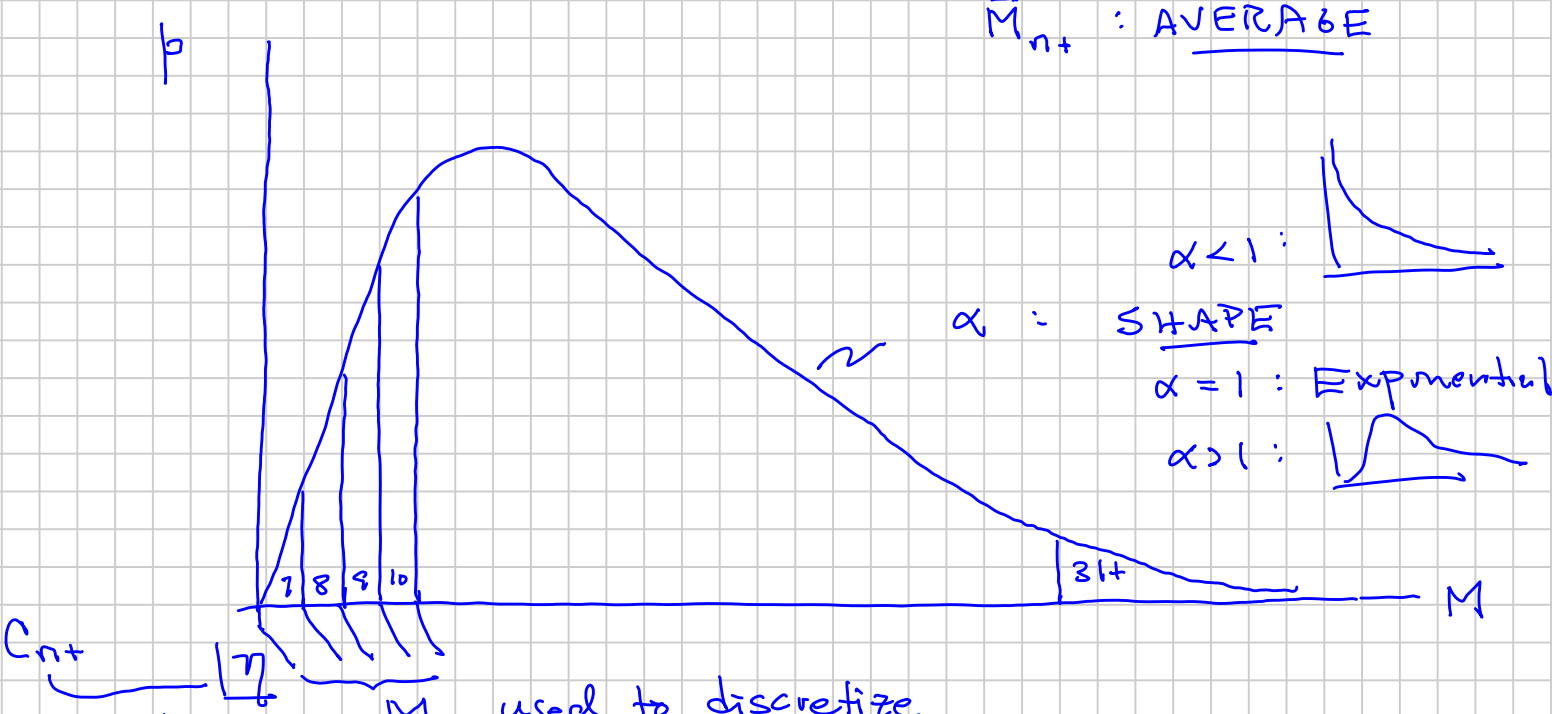


$\Sigma = x$ of C_{N+}

- Gamma Distribution Model

$0.6 < \alpha < 2$ most reservoirs

$\bar{M}_{nt}$: AVERAGE



α : SHAPE

$\alpha < 1$:

$\alpha = 1$: Exponential

$\alpha > 1$:

$\alpha = \infty$: Log-norm.

$$\int_{\eta}^{\infty} p \, dM = 1$$

$$\hat{z}_i = \int_{M_{Li}}^{M_{Li+1}} p \, dM$$

$$\bar{M}_{nt} = \frac{\int_{\eta}^{\infty} p M \, dM}{\int_{\eta}^{\infty} p \, dM = 1}$$

$$m_i = \hat{z}_i \bar{M}_i$$

$$\bar{M}_i = \left(\int_{M_{Li}}^{M_{Li+1}} p \cdot M \, dM \right) / \hat{z}_i$$

mass / moles

Exponential (PVTsim) - discrete SCN model

$M_i = 14 \cdot i + h$ PVTsim: $h = -4$

$\hat{z}_i = z_n \cdot \exp\left[A(i-n) \right]$ SHAPE = 1

$\vec{M}_{nt}$ AVERAGE — BOUND

How to match GC (TBP) data to Gamma Model

① Only GC data

w_i z_i but not M_i Matching Amounts

* Set M_{Li} fixed (how?)

Minimize mismatch between GC z_i (w_i) and the Gamma model values z_i (w_i) } Find Γ ($\vec{M}$, α)

② TBP data w_i z_i $(\vec{M}_i)_{Lab}$

Guess Γ $(\alpha, \eta, \vec{M})$

minimize $(\vec{M}_i)_{Lab}$ vs $(\vec{M}_i)_\Gamma$

Find M_{Li} to get an exact match of w_i (or z_i)

$\Rightarrow (\vec{M}_i)_\Gamma$ from gamma model

Matching $\vec{M}_i$ (MW)

SAMPLING

* Methods of Sampling

Mobility-Average

- 0 - Surface separator } (Production test to Surface)
- 0 - Cased hole BHS } Average over perf'd interval
- 0 - Openhole Formation Testers (MDT) BHS @Depth
  - Preferred for Fluid Initialization $z_i(I, J, K)$
- { - Wellhead samples | Thurton | Petrotech } Unusual

* Why Sample ?

① Collect samples for PVT measurements
to BUILD or VERIFY or IMPROVE an EOS Model

These samples do NOT need to be In-Situ Representative

~ Most all samples EXCEPT OBM-contaminated

② Compositions to help in Fluid Initialization
(In-Situ Fluid Mapping)

- All samples
- OFT samples are ~~best~~ (Uncontaminated)

$z_i(I, J, K)$

$R_s, \gamma_s (I, J, K)$

SPE 28829 : ECM

Gas Cap - Oil (Saturated)

Separator Sampling in Gas Condensates (Vol. Oils)

GOR > 2000 scf/STB

Recombination of Sep Gas & Sep Oil ⇒ Wellstream

should use $GOR_{sp} = \dfrac{q_{gsp}\ [\text{scf/D}]}{q_{osp}\ [\text{sep-bbl/D or sep-m}^3\text{/D}]}$

Get this Right!

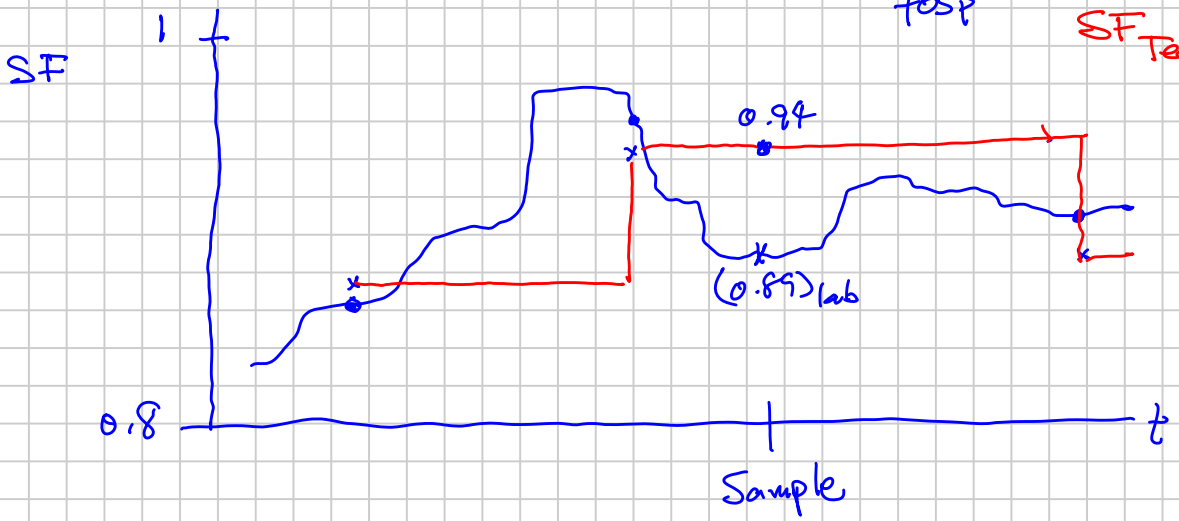
Often report $q_{\bar{o}}$ STB/D

$q_{\bar{o}} = q_{osp} \cdot SF(\text{spot})$ Test Company

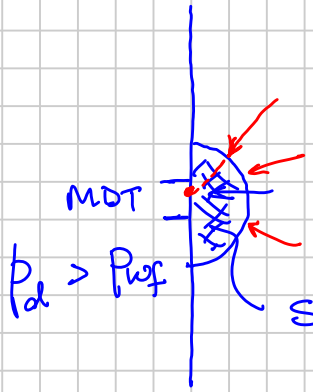
$q_{\bar{o}} = q_{osp} \cdot SF(T_{sp}, P_{sp})$ Correct

q_{osp} metered

$$q_{osp} = \frac{(q_{\bar{o}})_{Test}}{SF_{Test}}$$



Gas Condensate



Steady-State Flow Region

λ_0 is exactly what is needed to guarantee that what flows into the region, flows out of the region (into the MDT tool)