CGR Normalization

Convert Rates to a Common Surface Process

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Agenda

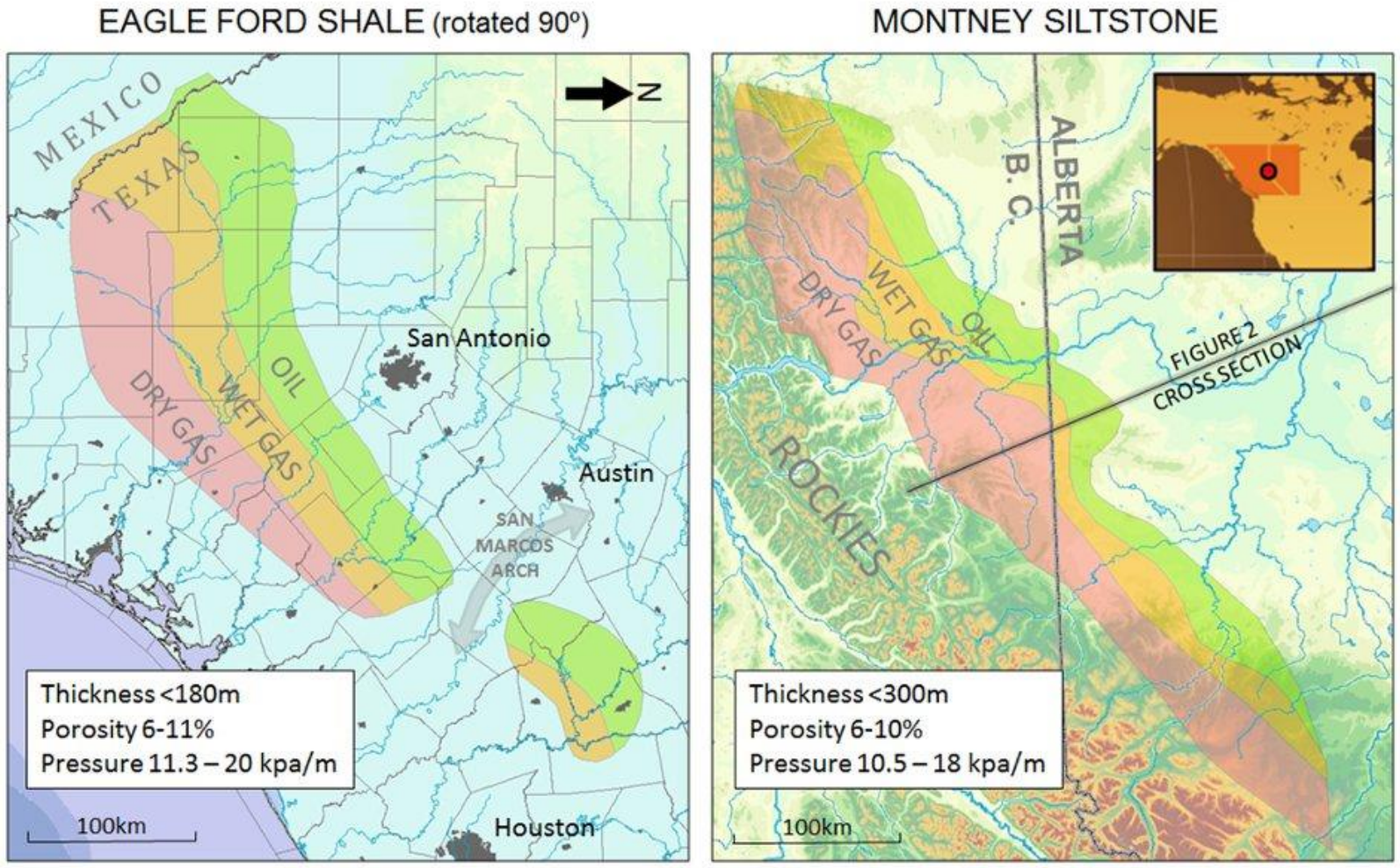
- Tight Unconventionals
- CGR Normalization “Crash Course”
- Example
- Closing Remarks …

1.Tight Unconventionals

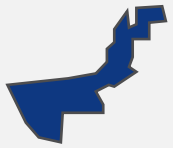
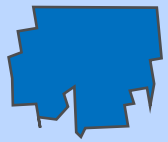
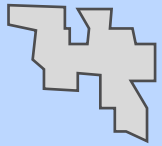
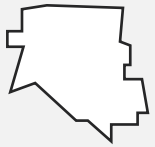
“Shale” Characteristics … a PVT Perspective

1. Span a wide range of fluids (low to high GOR)
2. Initially slightly undersaturated / saturated
3. Rapid decline in bottomhole pressure (p_{wf})
4. Producing GOR – $f(p_{wf})$

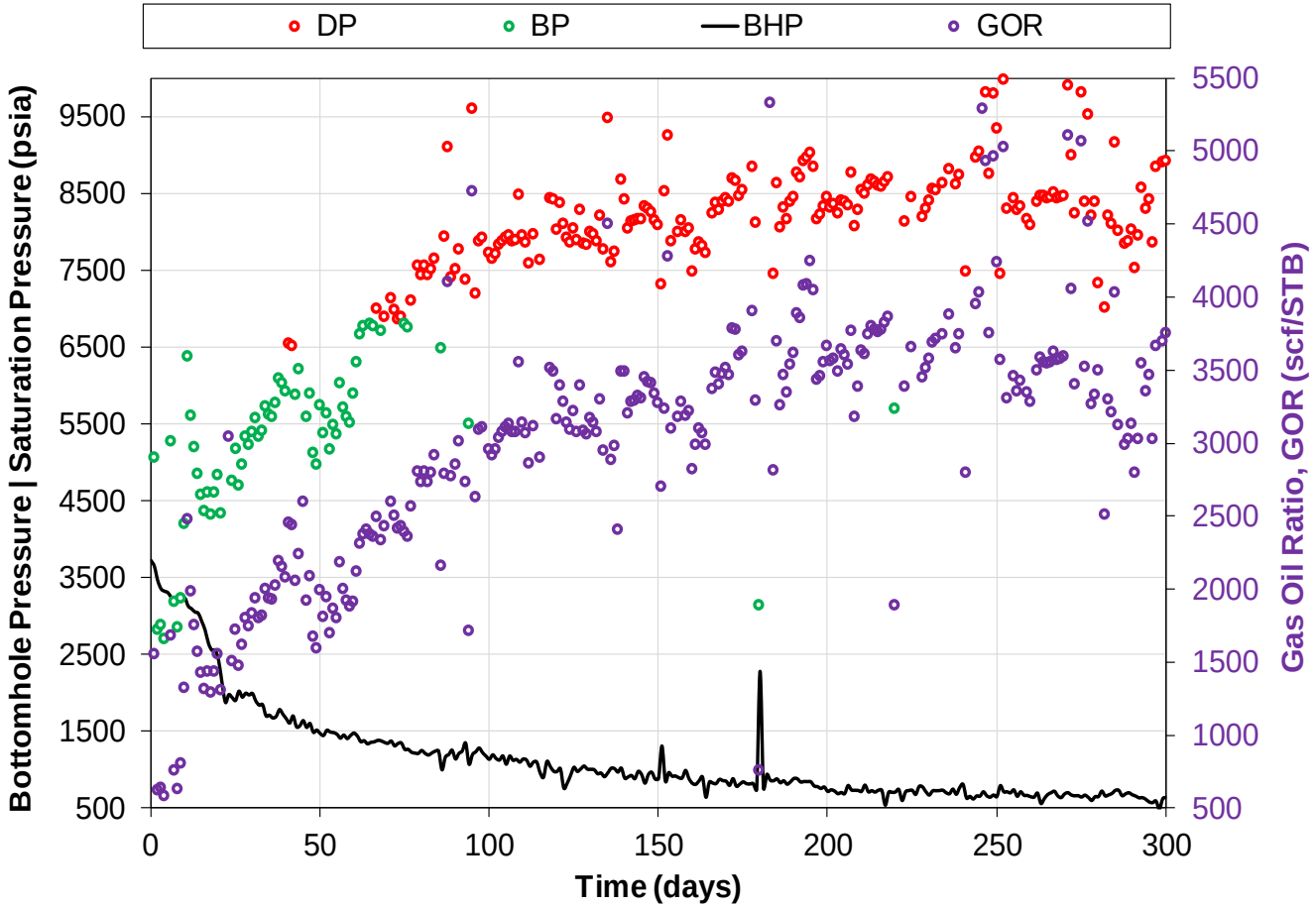
1 “Shale” Basins Span a Wide Range of Fluids



2 Slightly Undersaturated/Saturated

Basin	
 Eagle Ford	✓
 Bakken	–
 Montney	✓
 SCOOP/STACK	✓
 Permian	✓

3 Rapid decline in bottomhole pressure (p_{wf})



Source: Fluid Sampling in Tight Unconventionals (Carlsen et al. 2019)

4 “Unconventional” Well Performance

- Producing GOR strong function of
  - Flowing bottomhole pressure – GOR(p_{wf})
  - Degree of undersaturation
- *“Conventional” reservoirs – GOR(p_{avg})*

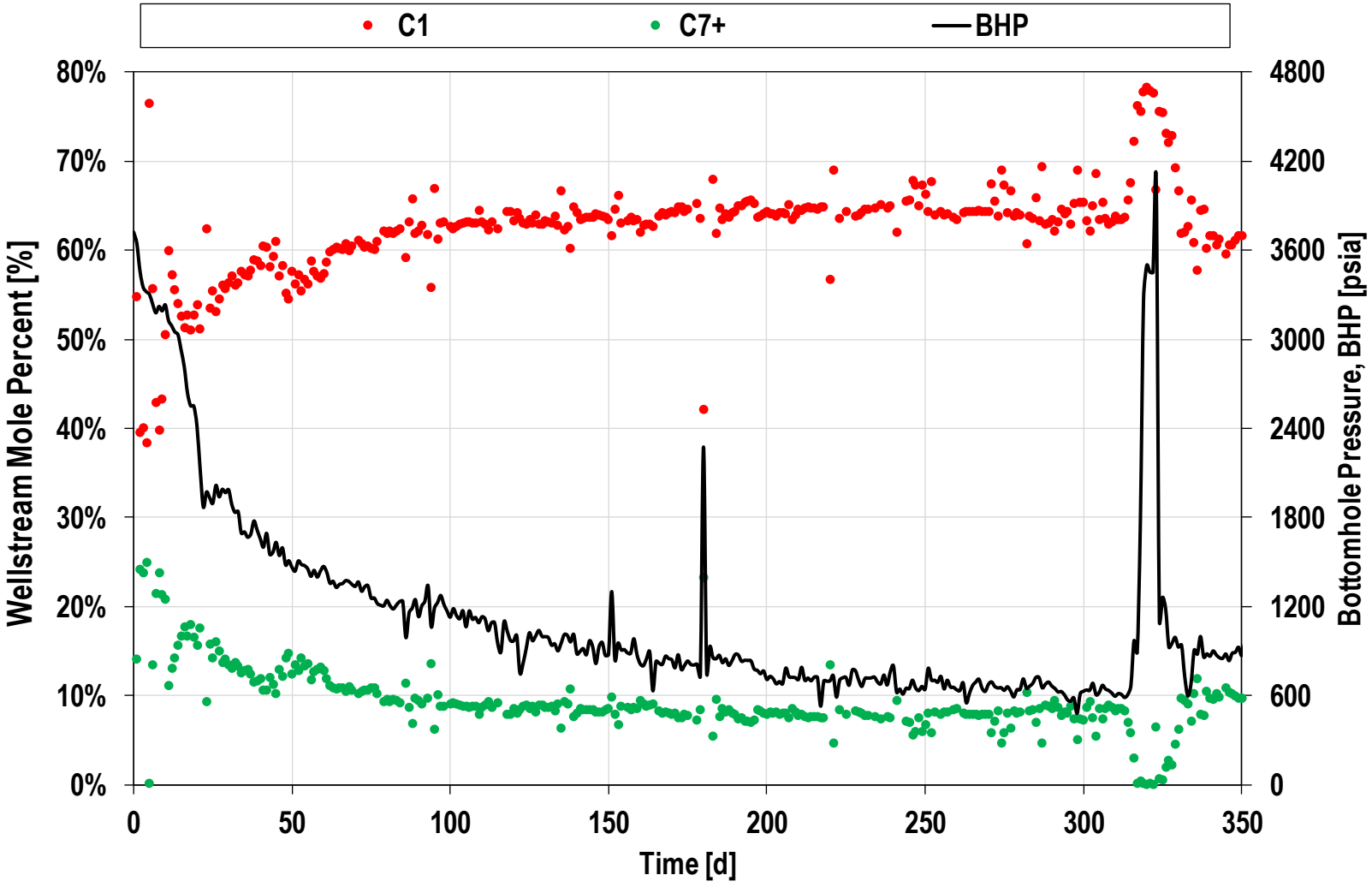
Sources: Whitson and Sunjerga 2012; Jones 2017

What does this Imply?

- Change in “produced fluid properties”
  - i.e. GOR | STO API

- Produced compositions are changing!

Produced Compositions are Changing Fast!



2. CGR Normalization – “Crash Course”

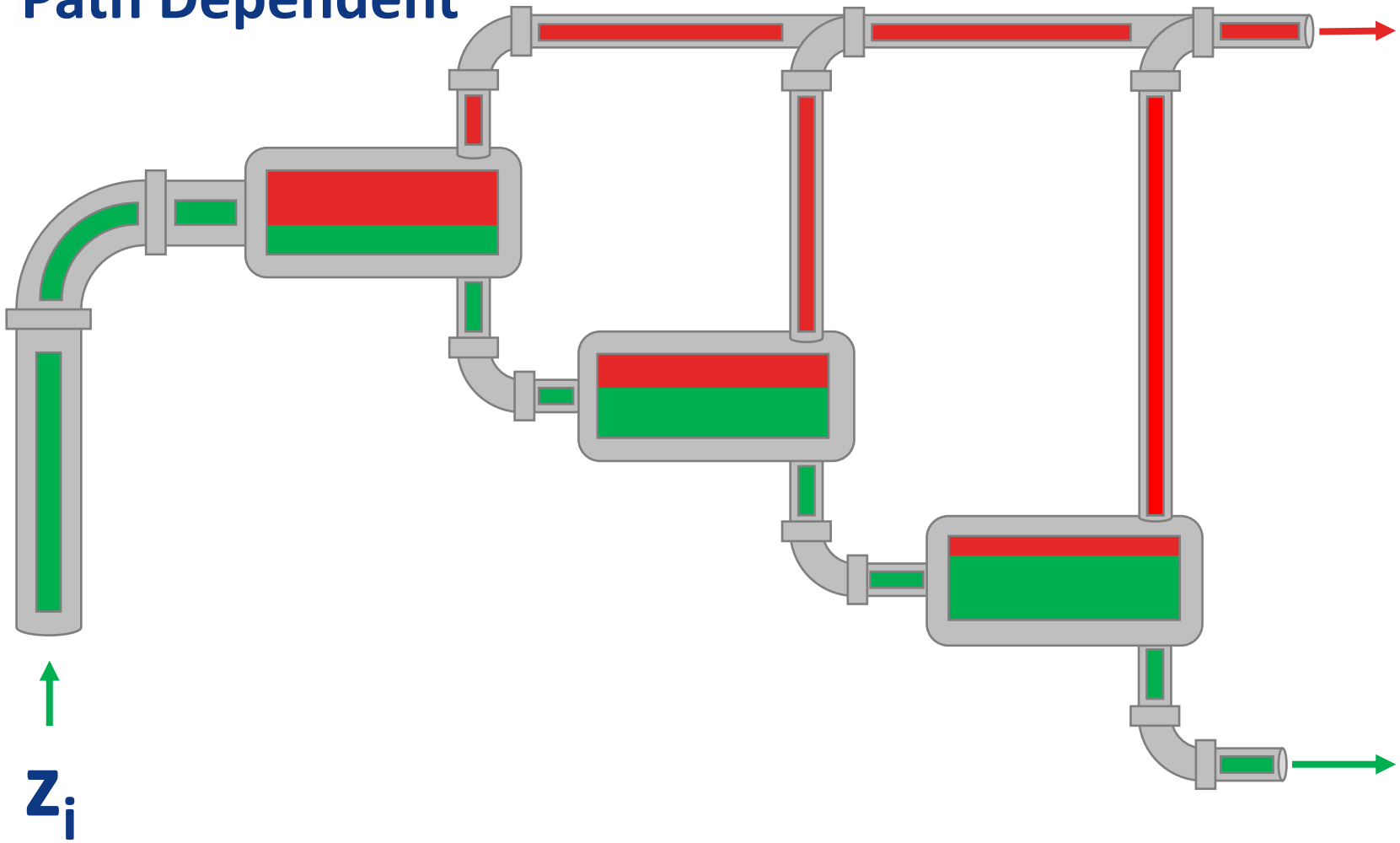
We will Investigate …

1. What is CGR Normalization is
2. A method to convert daily rates into a common surface process
3. Under what circumstances it is important and why

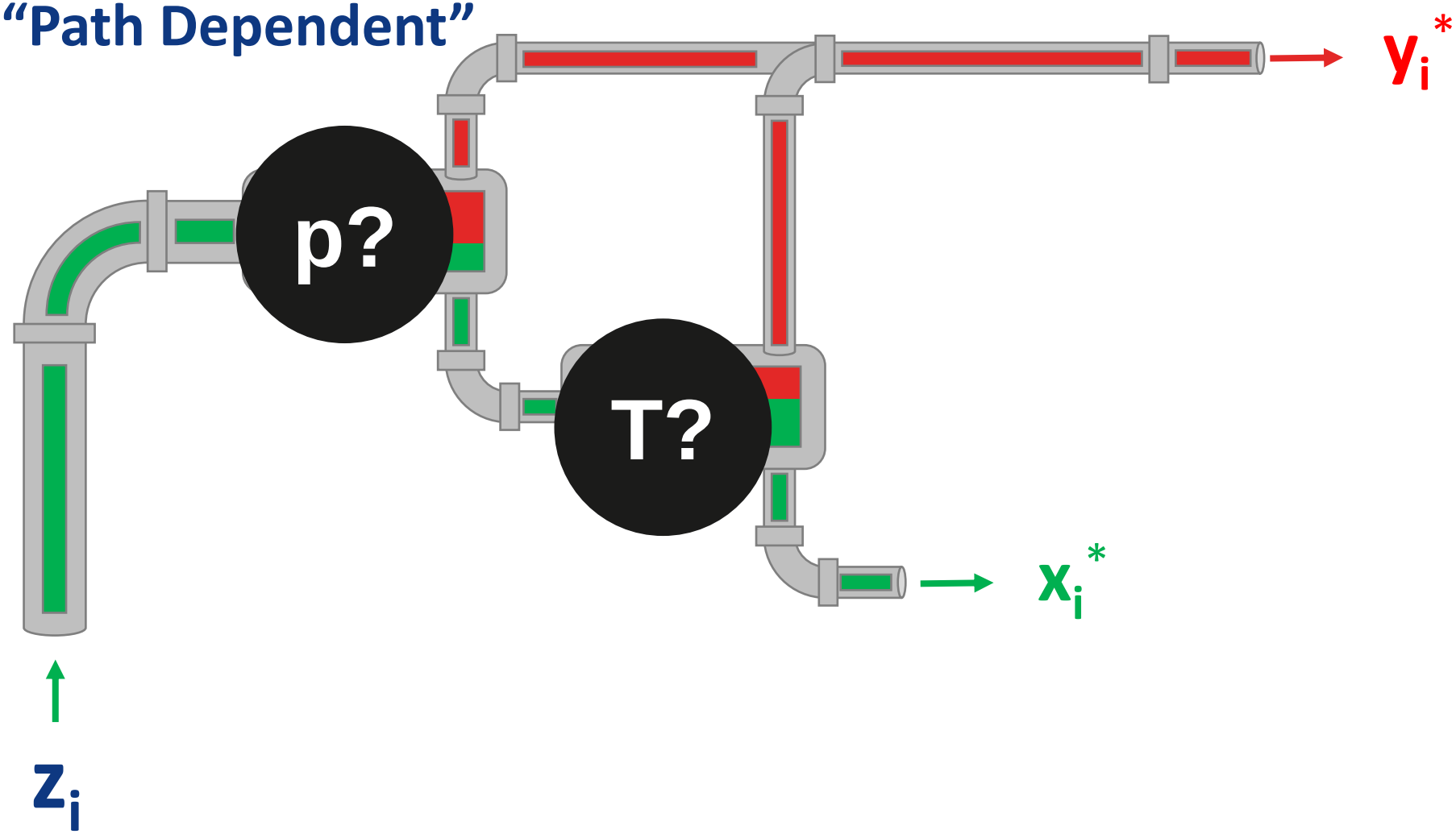
PVT is “Path Dependent”

(Recap from University)

PVT is "Path Dependent"

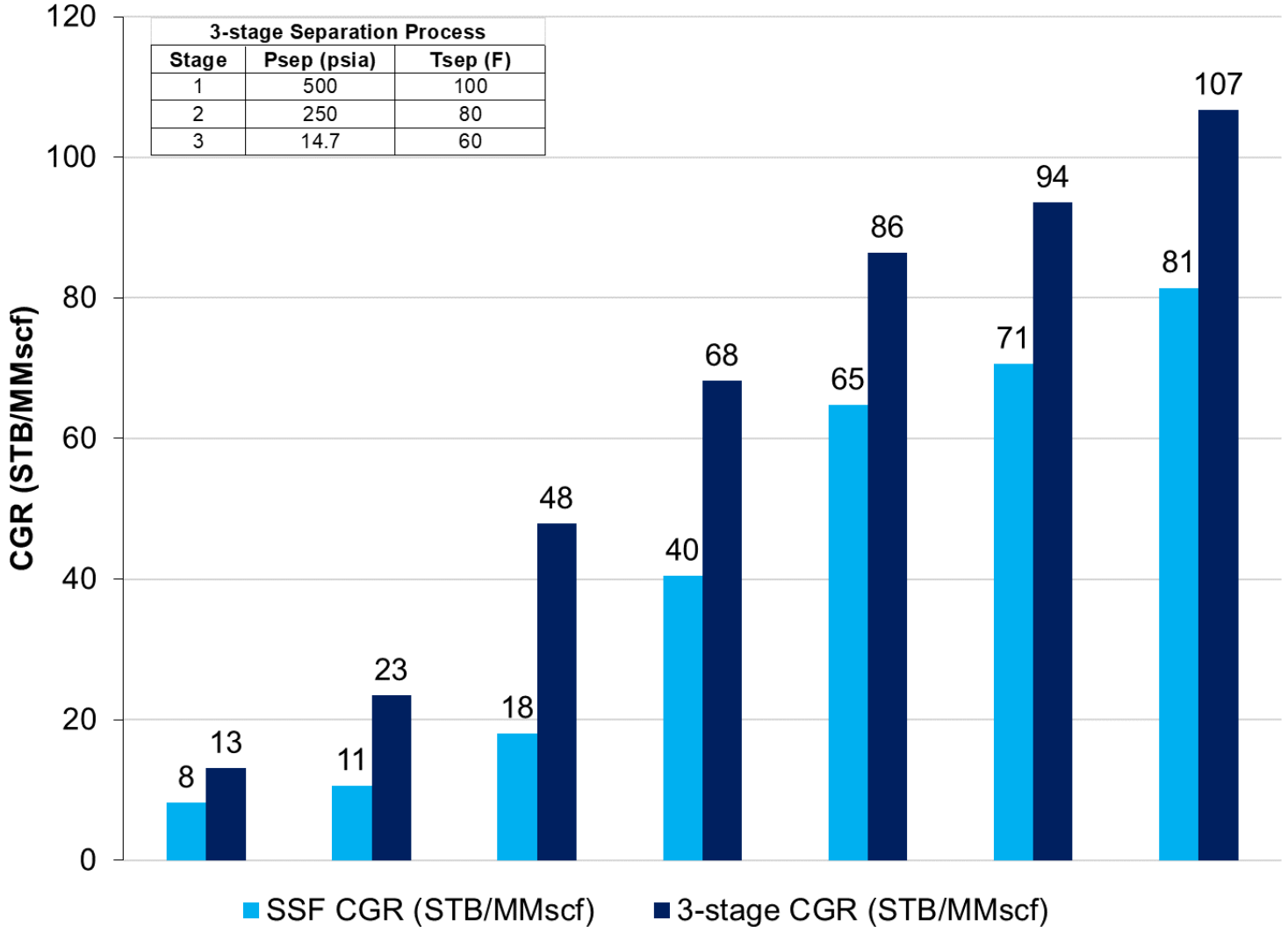


PVT is "Path Dependent"



1 Black Oil PVT Tables

3-stage Separation Process		
Stage	Psep (psia)	Tsep (F)
1	500	100
2	250	80
3	14.7	60

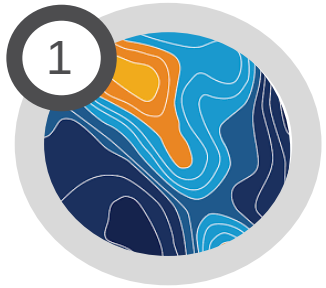


1 Black Oil PVT Tables

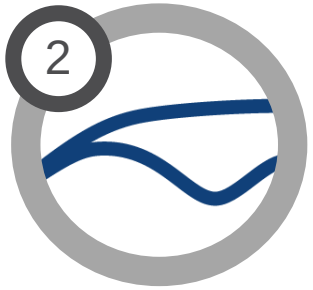
@ T = constant

Pressure	Oil			Gas		
p	R_s	B_o	μ_o	r_s	B_{gd}	μ_g
	...	...	...	...	...	...
	...	...	...	...	...	...
	...	...	...	...	...	...

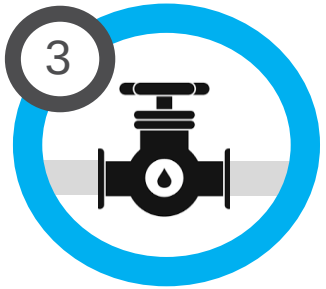
Res. Simulation



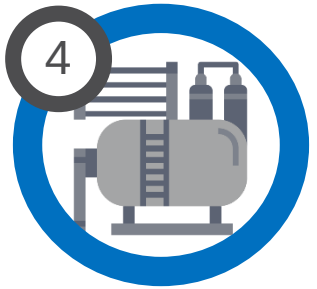
RTA/PTA



Pipe Flow



Process



1 Black Oil PVT Tables

- B_o | B_{gd} – surface process dependent
- R_s | r_s – surface process dependent
- μ_o | μ_g – surface process independent

→ 99.99% of reservoir engineering analysis is performed with black oil tables

1 Condensate Gas Ratio (CGR) Normalization

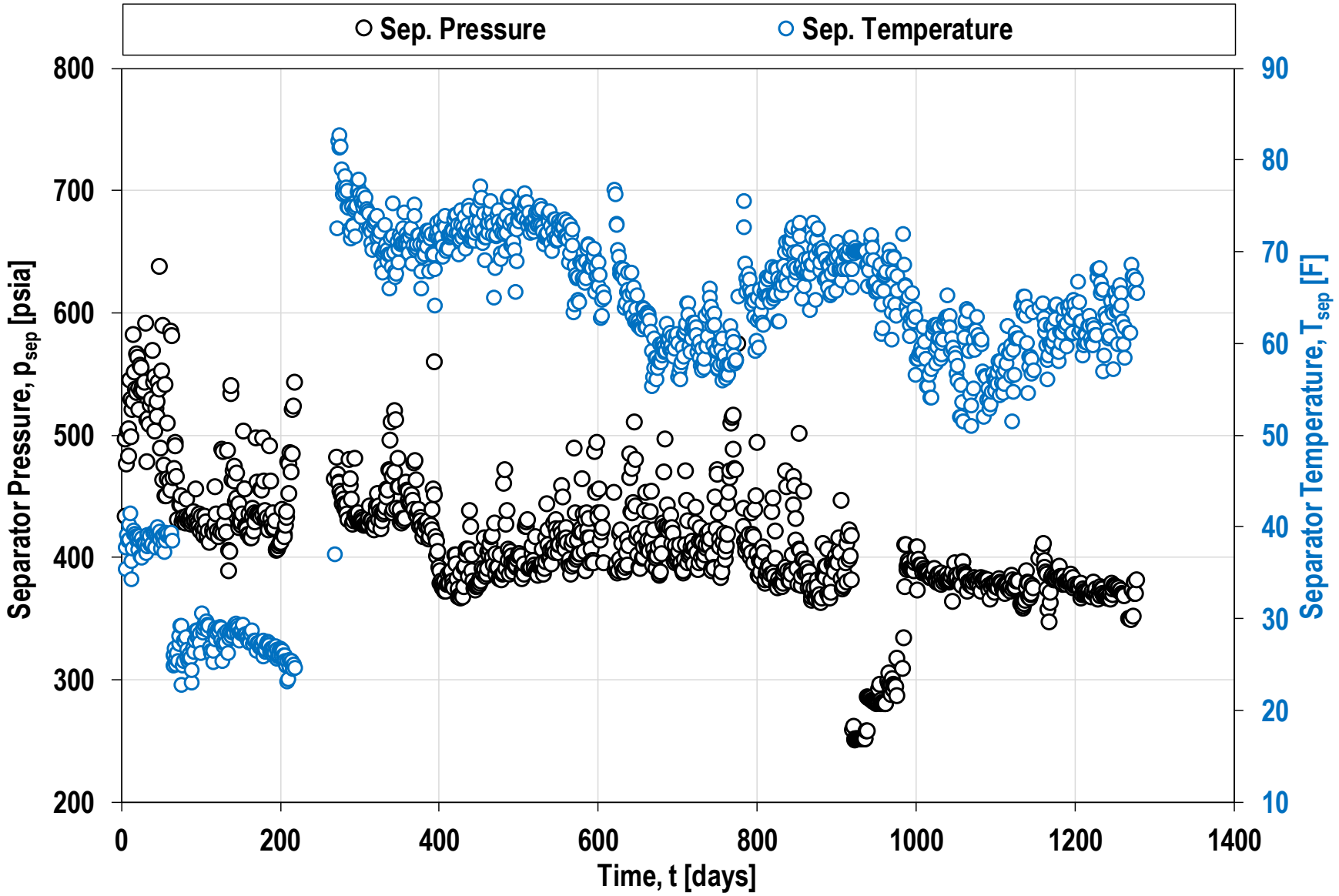
- BOT tables assumes fixed surface process

  #stages, p_{sep}, T_{sep}

- In reality, separator conditions change with time

  sometimes a lot

1 CGR Normalization



1 CGR Normalization

- Risk of inconsistencies between:

1. Rates used for history matching
   → Assumes Constant Surface Process
2. Actual measured rates
   → Changing Surface Process

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2. A method to convert daily rates into a common surface process
3. Under what circumstances it is important and why

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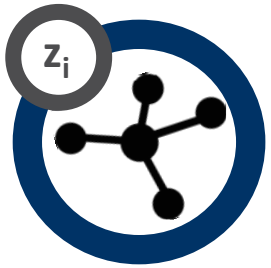
2 CGR Normalization - Procedure

Two Steps

1. Estimate flowing wellstream composition
   → z_i(time)
2. Re-process the wellstream composition
   → Fixed through time

2 What is a Composition?

"The amount of different components"

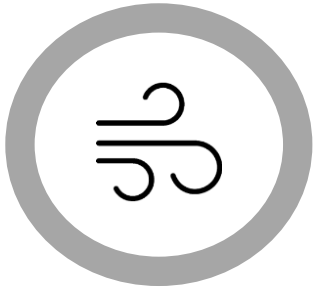
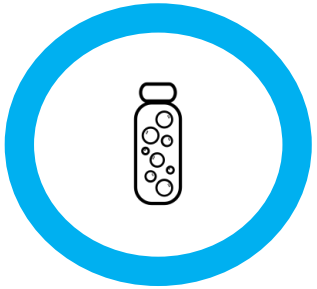


usually expressed in mol%

$$z_i = n_i \,/ \sum_j n_j \;|\; y_i = n_{Vi} \,/ \sum_j n_{vj} \;|\; x_i = n_{Li} \,/ \sum_j n_{Lj}$$

Total *Vapor* *Liquid*

2 What is a Composition?

Air	Sparkling Water	Petroleum Fluids
		
z_i	z_i	z_i
N_2 = 78%	H_2O = 99%	C_1
O_2 = 21%	CO_2 = 1%	C_2
...	...	...
		C_{7+}
Total = 100%	**Total = 100%**	**Total = 100%**

2 What is a Wellstream Composition?

Wellstream:
composition a well produces
at one point in time

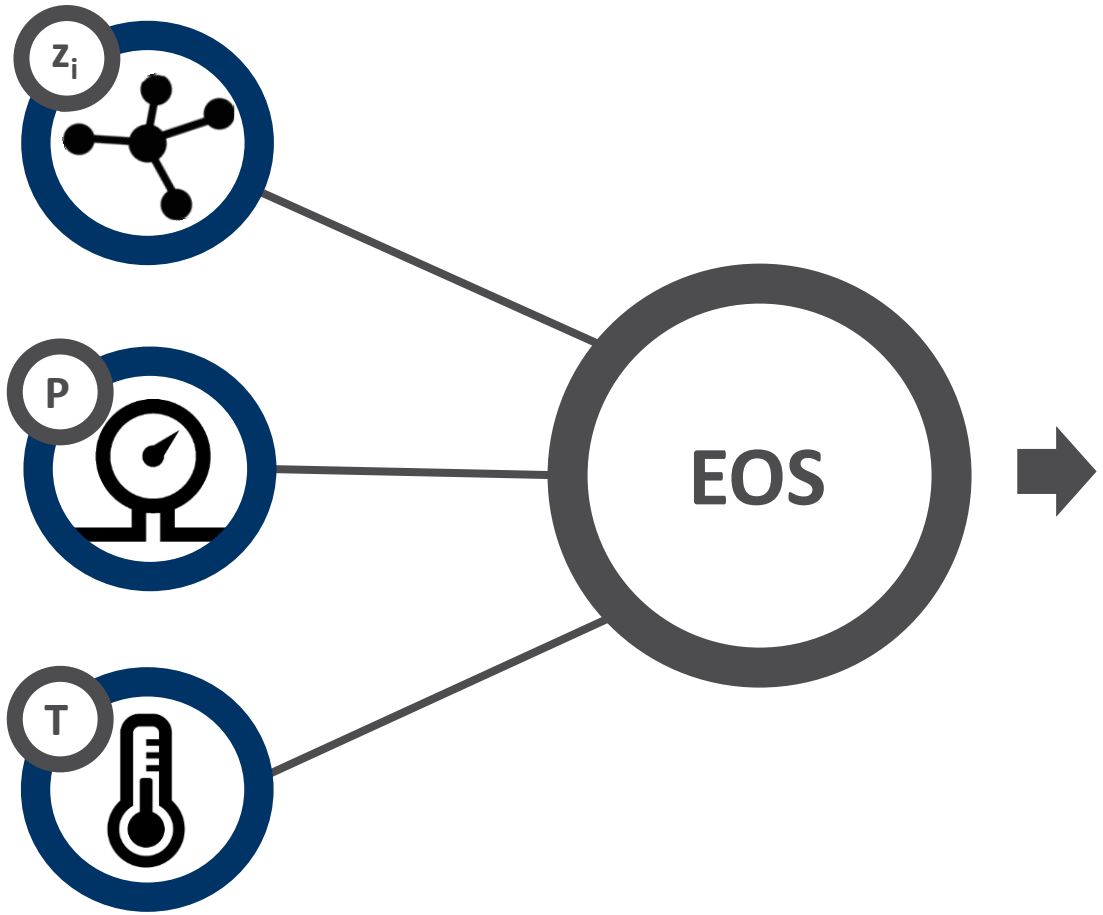
Wellstream compositions ≠
in-situ representative fluid compositions

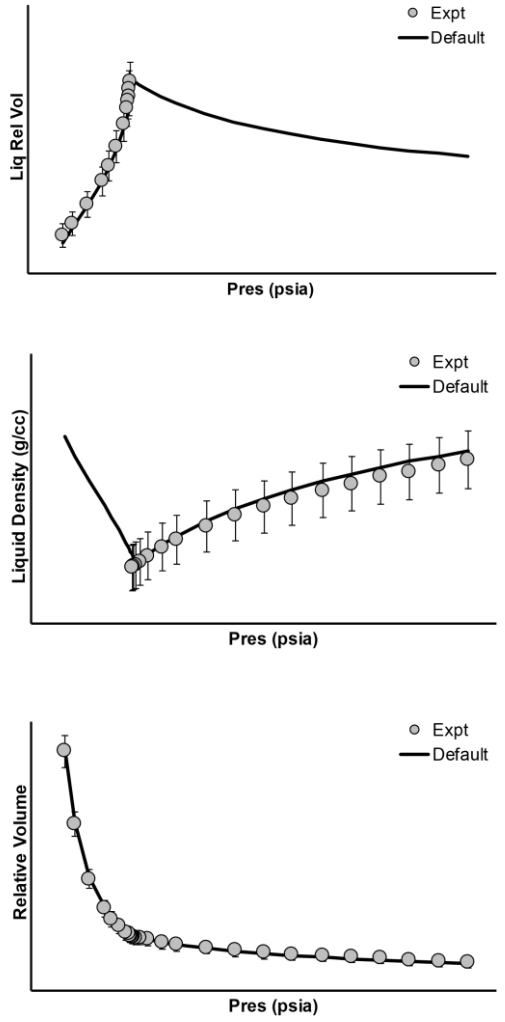
2 What is “Compositional Tracking”?

=How produced wellstream compositions change with time

- Non-hydrocarbons (H_2S, CO_2, N_2)
- Known hydrocarbons (C_1, C_2, …, C_6)
- Single carbon number components (C_{7+})

2 What is an EOS Model?





2 Estimate Wellstream Composition

Requirements:

- A properly tuned EOS Model
- Separator rates (GOR_{sep})
- Separator conditions (p_{sep}, T_{sep})
- "Seed feed" – estimate of z_i

2 Estimate Wellstream Composition

Method:

- Flash “seed feed” to p_{sep} | T_{sep} → y_i, x_i
- Recombine y_i | x_i at GOR_{sep} → z_i

$$n_i = x_i\left(\frac{q_{om}}{v_o}\right) + y_i\left(\frac{q_{gm}}{v_g}\right)$$

v: molar volume – M/ρ (calculated from EOS model)

2 Estimate Wellstream Composition

Method:

Regress until z_i + EOS matches

- Sep. gas. (yi) ≈ N_2, CO_2, C_1, …,C_6
- Sep. GOR ≈ C_{7+} amounts
- Liquid API ≈ C_{7+} component distribution

2 Reprocess Using Common Surface Process

- Defined same in all modeling tools

  → Res sim, nodal analysis, pipeflow

- Common surface process
  - Multi-stage flash process
  - K-value based surface process
  - Full process (HYSYS/UNISIM)

  →”Normalized CGR”

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3 When is it Important and Why?

Understand how changing separator conditions can impact producing CGR over time

- wide range of wellstream compositions
- changing separator conditions

T_{sep} = 50 – 150 F

p_{sep} = 50 – 1000 psia

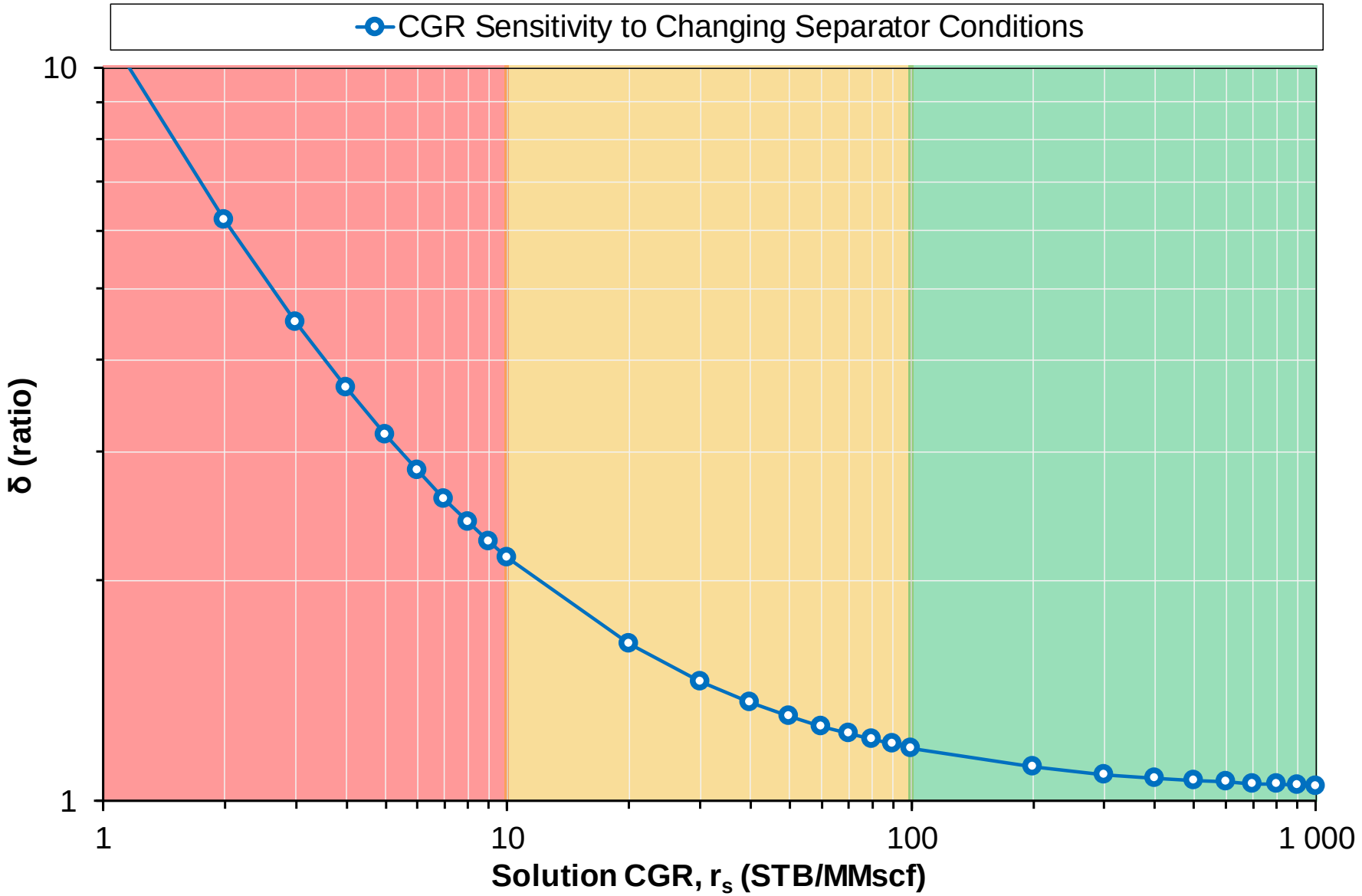
3 When is it Important and Why?

Quantify sensitivity to different separator conditions

$$\delta = CGR_{max}/CGR_{min}$$

E.g. $\delta = 2$, max CGR is twice of min CGR

3 When is it Important and Why?



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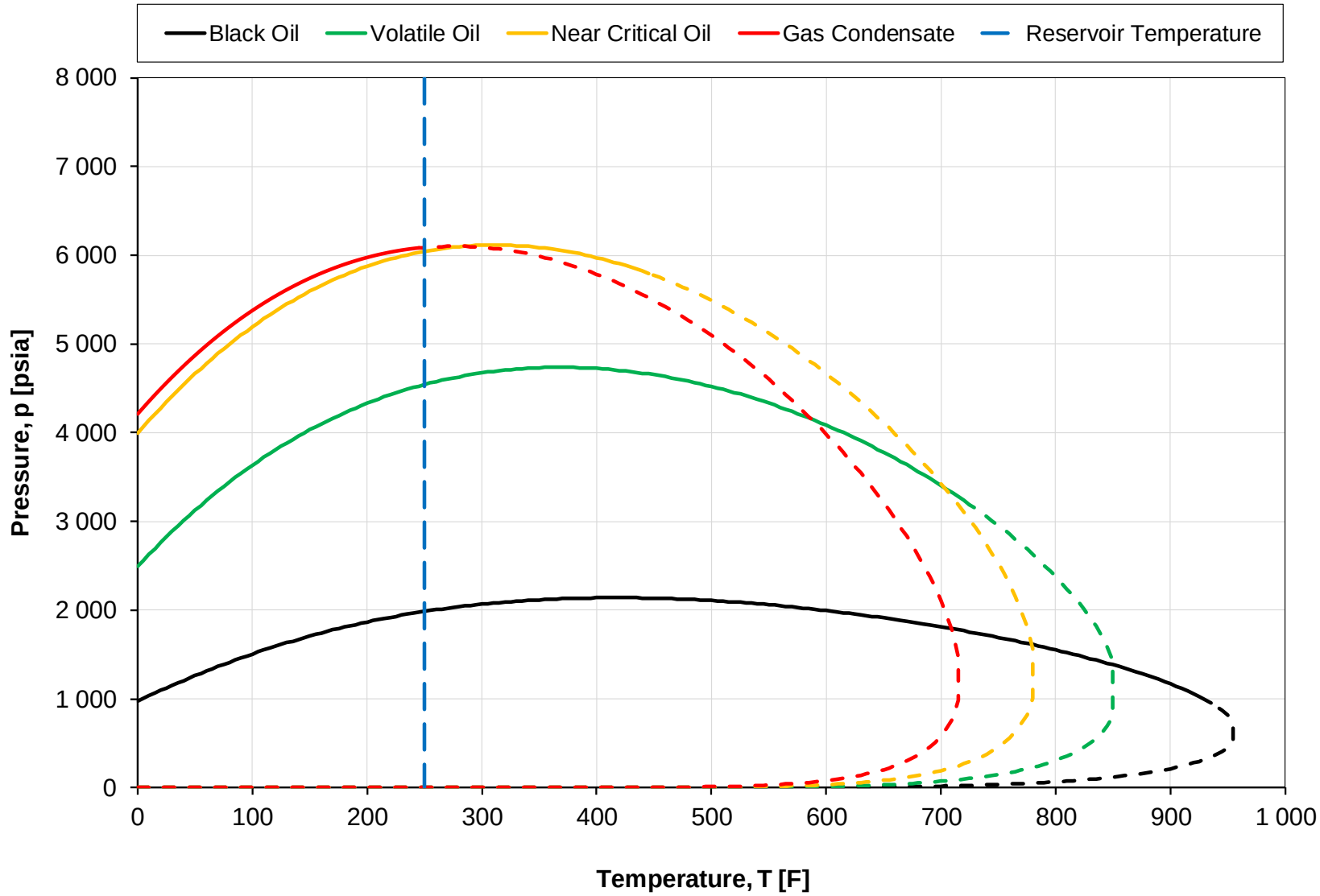
3.Example

Example: Reservoir Simulation



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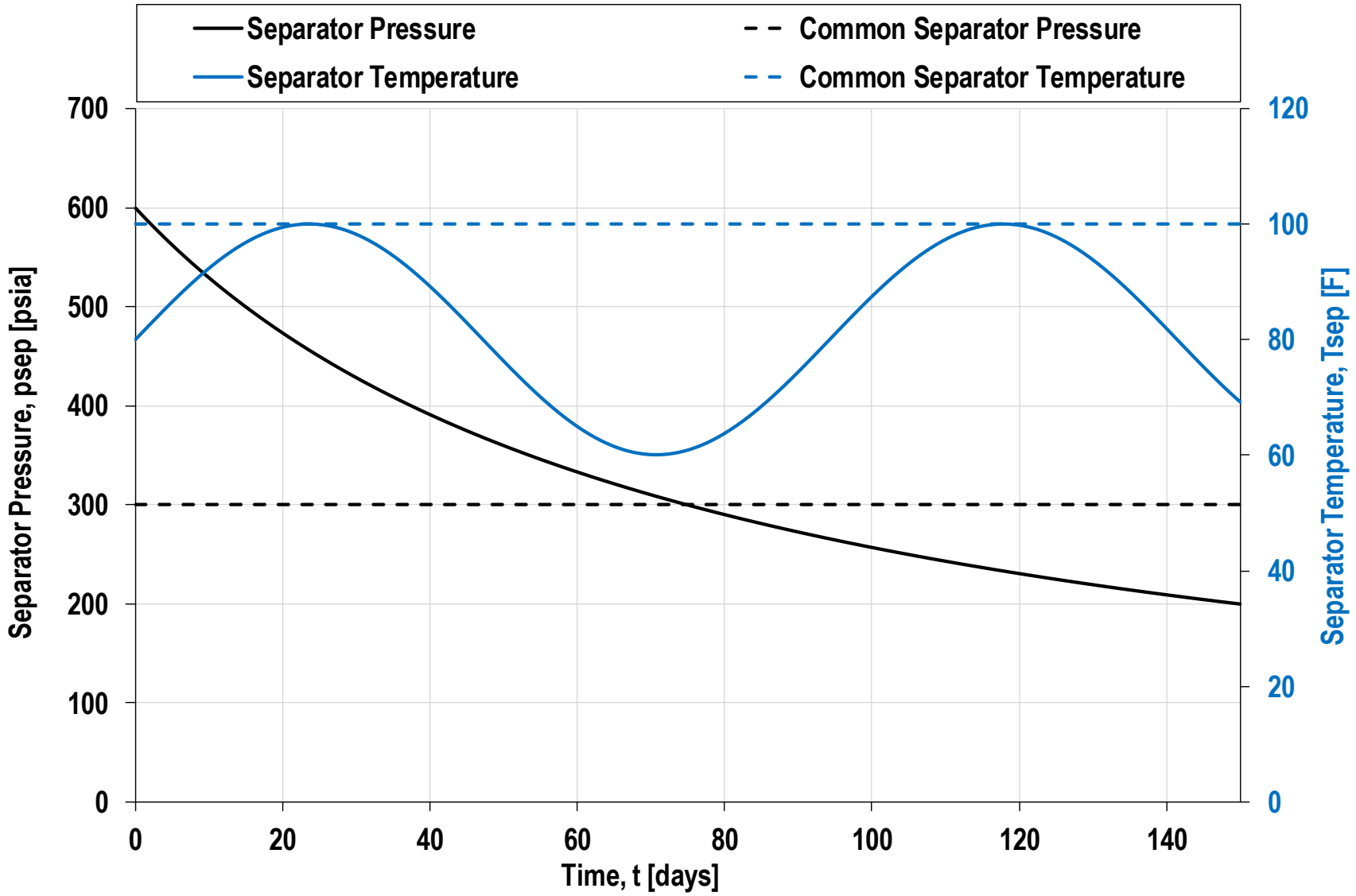

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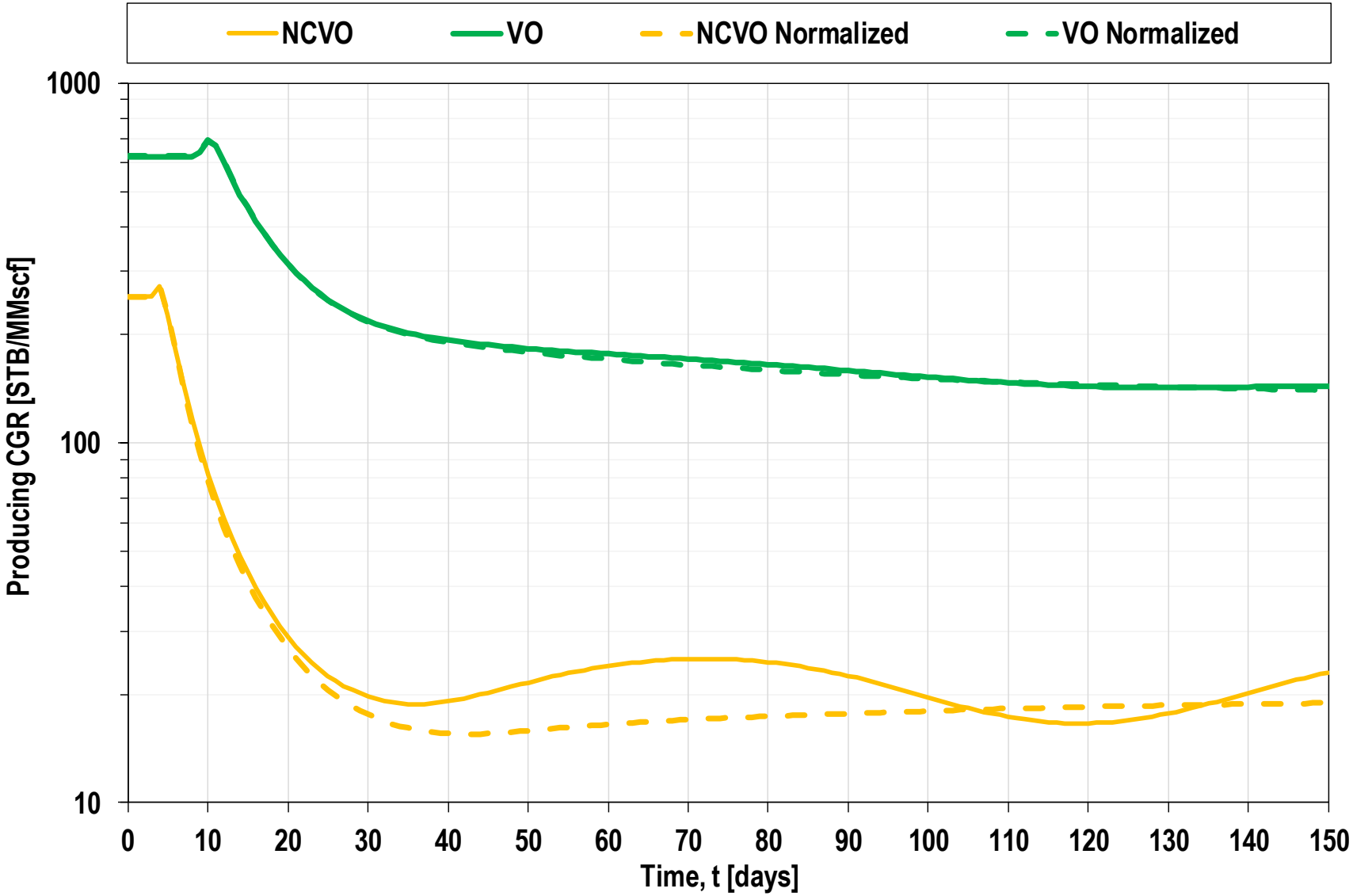

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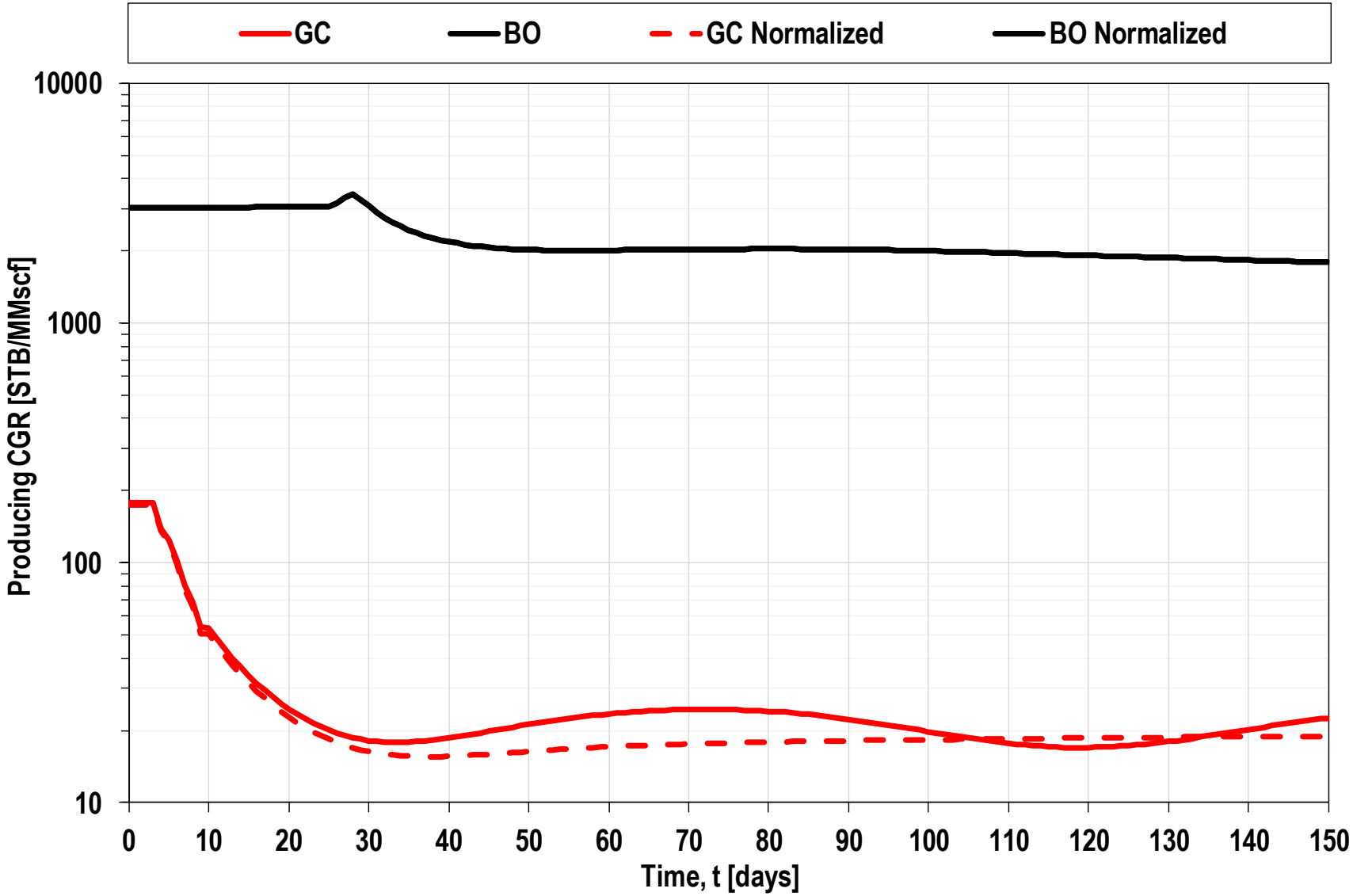
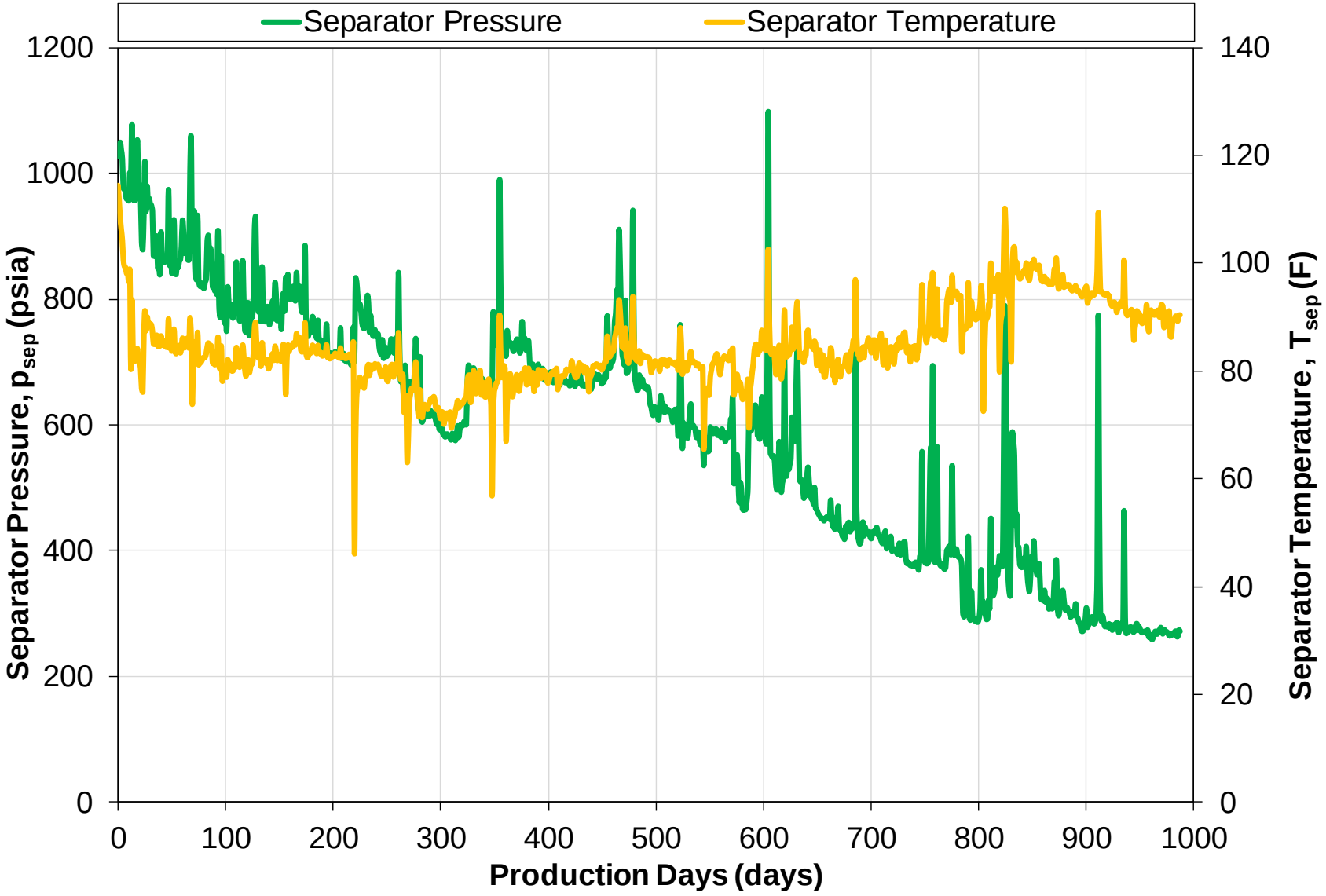


Example: Field Example 1



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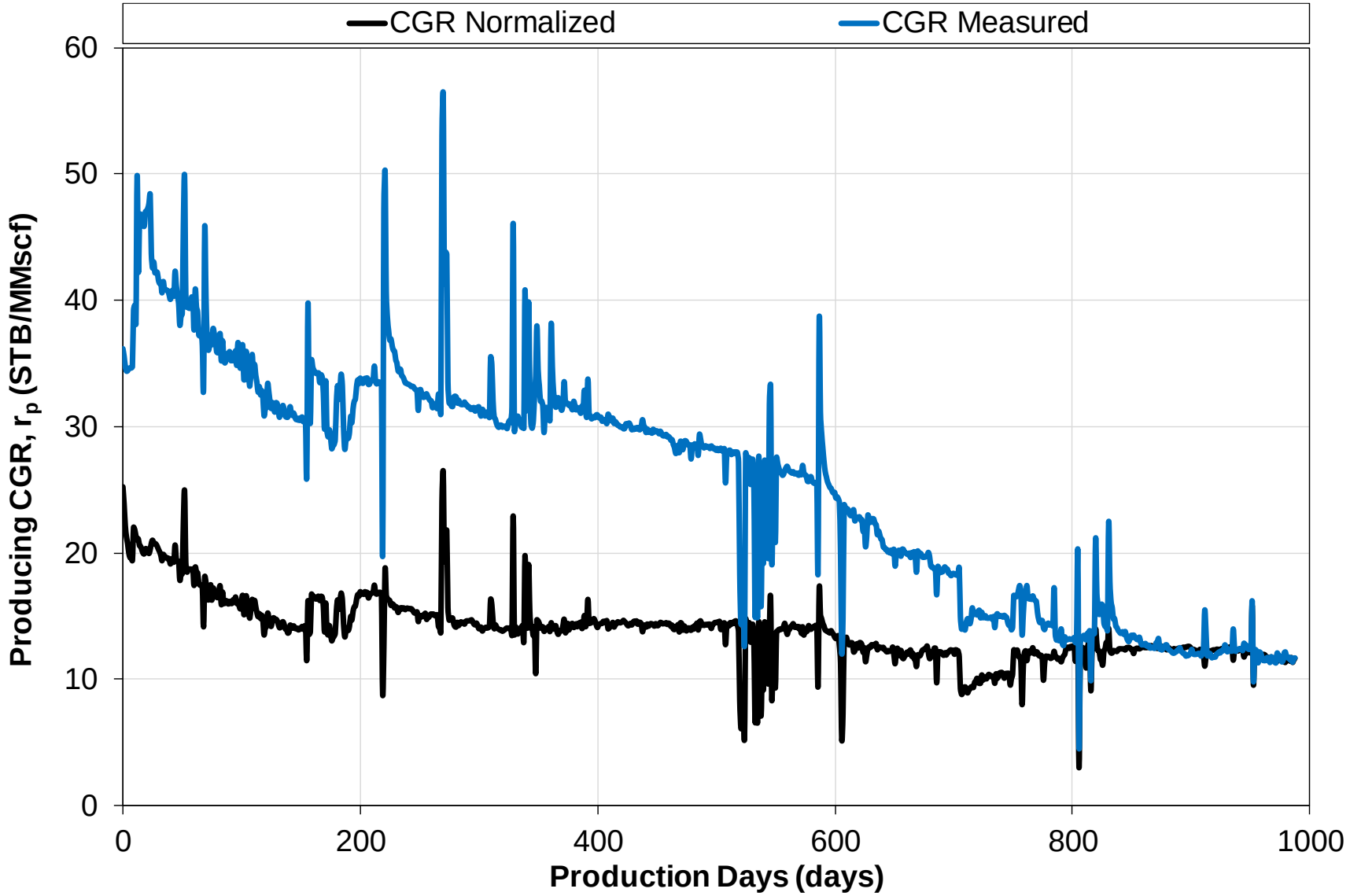
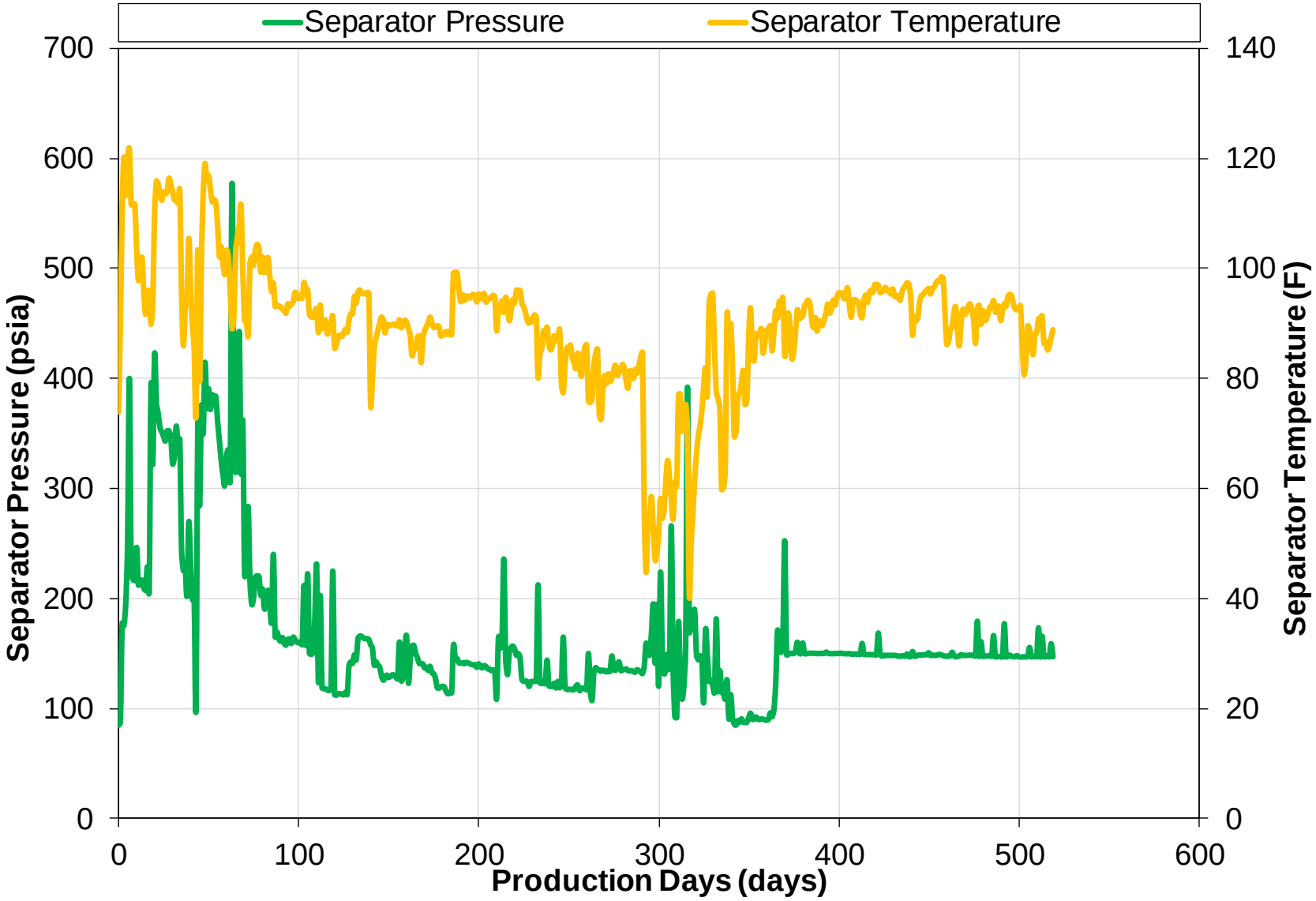


Example: Field Example 2



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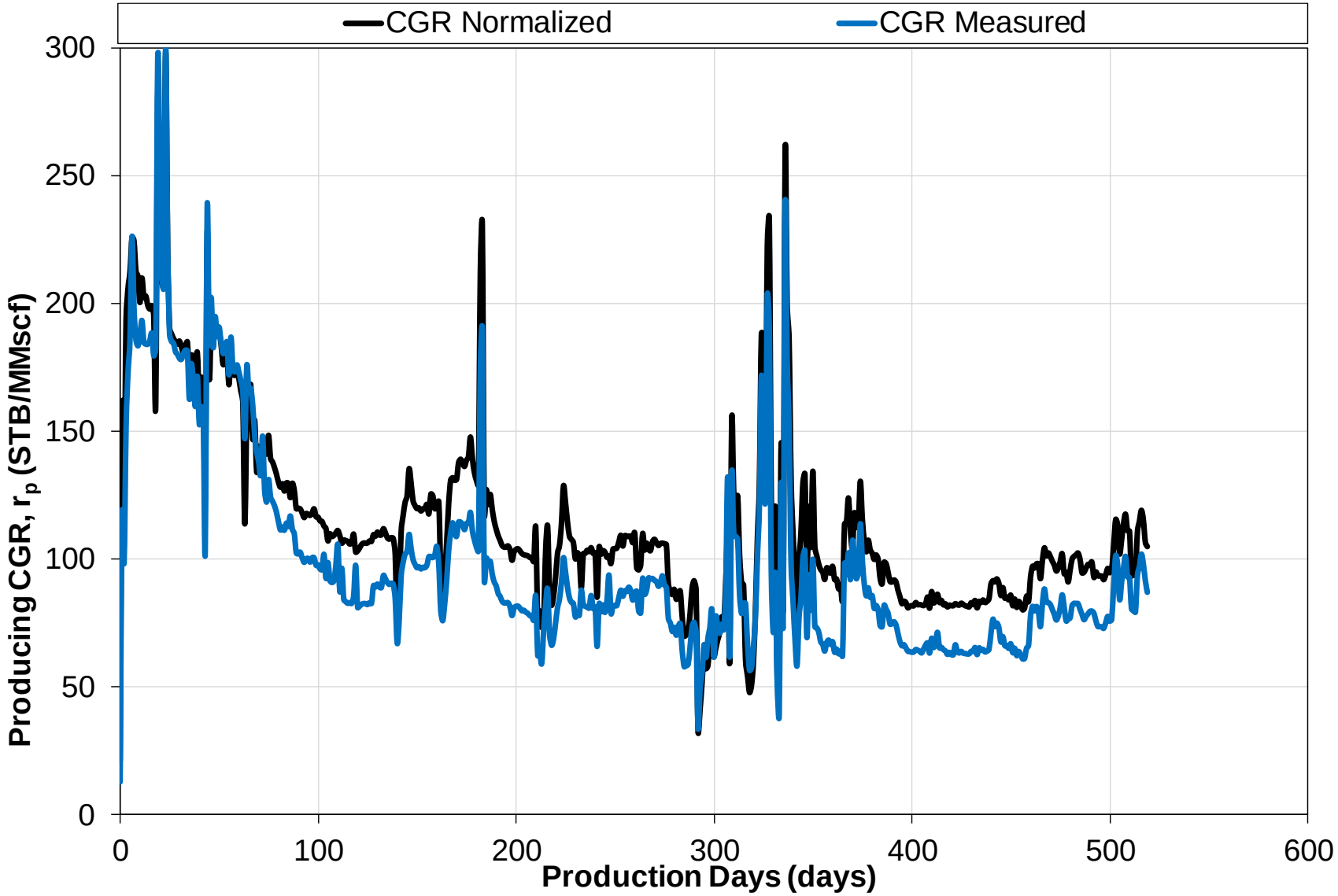

4.Closing Remarks

1 CGR normalization is …

- Not important for black and volatile oil

  e.g. $GOR_i < 2500$ scf/STB

- But is important for near-critical fluids and gas condensates

  e.g. $GOR_i > 2500$ scf/STB

CGR normalization is …

- Especially important when both

  i) “produced fluid properties” (GOR / API)

  ii) separator conditions

  change significantly with time

3 The Proposed Scheme …

- Can be used to calculate a set of consistent oil and gas rates for all wells in an asset

→ Consistent / “apples-to-apples” comparison throughout a field

i. CGR performance analysis

ii. HM purposes

Thank You

Innovation Norway

Norwegian Research Council

Colleagues at **whitson**