# Forecasting in whitson+

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UPP

DCA, Auto-Forecast & Type Well Mathias Carlsen | Mohamad Dahouk Course held Virtually 4 December 2024



Main objective: Click every button and not rush.



### **Small Courses throughout the Year**

- Half-day courses (4 hrs)
- Hands-on focus with software and theory
- 7 Different Virtual Courses, 8 am 12 pm CST
  - PVT & Phase Behavior 14 Feb 2024
     Recording: <u>https://youtu.be/qxqzl8B\_l2A</u>
     Slides: <u>https://shorturl.at/gzBNW</u>
  - Bottomhole Pressure Calculations 24 April 2024
     Recording: <u>https://youtu.be/0pvojymb-5U</u>
     Slides: <u>https://shorturl.at/wLWZ9</u>
  - Analytical & Numerical RTA 26 June 2024
     Recording: <u>https://youtu.be/A2Ov8P6GrEI?feature=shared</u> Slides: <u>https://shorturl.at/XVS7H</u>
  - Flowing material balance 21 Aug 2024
     Recording: <u>https://youtu.be/7T3KPIc-MqM?feature=shared</u> Slides: <u>https://shorturl.at/ellc7</u>
  - Nodal Analysis 2 October 2024 Recording: <u>https://youtu.be/s5a0wM-dJYU?feature=shared</u> Slides: <u>https://shorturl.at/eTwBL</u>
  - Well Tests (CPG & DFIT) 16 October 2024 Recording: <u>https://youtu.be/bEpl19bK9uM</u> Slides: <u>https://shorturl.at/qQ03r</u>
    - DCA & Type Wells 4 December 2024

Send e-mail to <u>carlsen@whitson.com</u> if you haven't received the invite to the courses.

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### **Need Course Certificate?**

Contact carlsen@whitson.com





# Training

#### https://whitson.com/training/

SEP 18 2024	whitson+ software course 1-Day, In person course - Houston 8 am-16 pm Central Time (CT)	Register
OCT 02 2024	Nodal Analysis in whitson+ Virtual 1/2 Day Course 8-12 am Central Time (CT)   7-11 am Mountain Time (MDT)   3-7 pm Central European Summer Time (CEST)	Register
OCT 16 2024	Well Tests (CPG & DFIT) in whitson+ Virtual 1/2 Day Course 8-12 am Central Time (CT)   7-11 am Mountain Time (MDT)   3-7 pm Central European Summer Time (CEST)	Register
DEC 04 2024	DCA & Type Wells in whitson+ Virtual 1/2 Day Course 8-12 am Central Time (CT)   7-11 am Mountain Time (MDT)   3-7 pm Central European Time (CET)	Register
FEB 13 2025	PVT & Phase Behavior in whitson+ Virtual 1/2 Day Course 8-12 am Central Time (CT)   7-11 am Mountain Time (MDT)   3-7 pm Central European Time (CET)	Register
APR 24 2025	Bottomhole pressure calculations in whitson+ Virtual 1/2 Day Course 8-12 am Central Time (CT)   7-11 am Mountain Time (MDT)   3-7 pm Central European Summer Time (CEST)	Register
JUN 25 2025	Analytical and Numerical RTA in whitson+ 1/2 Day Course 8-12 am Central Time (CT)   7-11 am Mountain Time (MDT)   3-7 pm Central European Summer Time (CEST)	Register
AUG 20 2025	Flowing material balance in whitson+ Virtual 1/2 Day Course 8-12 am Central Time (CT)   7-11 am Mountain Time (MDT)   3-7 pm Central European Summer Time (CEST)	Register



## An all-in-one solution



Web-based solution
✓ DCA & Type Well
✓ PVT

- ✓ BHP Calculations
- ✓ FMB
- ✓ RTA
- ✓ Reservoir Simulation
- ✓ Nodal Analysis
- ✓ Well Testing (CPG, DFIT)

### **General Support**

# whitson+ software support@whitson.com (2 min response time)





# Software Basics

#### Access to whitson<sup>+</sup>



#### Access to whitson<sup>+</sup>



### Software Structure: Top Down



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#### whitson\*: More Screen Real Estate



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#### whitson+: More Screen Real Estate



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### whitson+: Navigation Panel



#### whitson\*: Software Hierarchy



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#### whitson+: Create Multiple Analyses for a Well



#### whitson+: Create Multiple Analyses for a Well



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#### whitson\*: Change Units



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#### whitson+: Input Card



#### whitson+: Support Ticket



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#### whitson+: Manual



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#### **Important Shortcut: Refresh**

• Refresh shortcut: "CTRL + R"

- Use if you experience
  - Bad connection
  - The browser is "stuck"





# Decline Curve Analysis

## **DCA: Outline**

- 1. Arps
- 2. Fetkovich
- 3. Segment Types
- 4. Decline Rate Type
- 5. Limiting Decline Rate, d<sub>lim</sub>
- 6. Ratio forecasting

# Flow Regimes 1.01

Infinite acting flow ends as pressure transient reaches one reservoir boundary

## Transitional flow (period in between)

# **Boundary dominated flow** starts when the wellbore pressure response is affected by *all* reservoir boundaries

### **Decline Curve Analysis (DCA)**



$$q(t)=q_i(1+ba_it)^{-1/b}$$

 $q_i$  = initial flow rate  $a_i$  = nominal decline rate at time zero b = rate exponent q(t) = flow rate at time t

### **Decline Curve Analysis (DCA)**



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### **Decline Curve Analysis (DCA)**



# **DCA: Fetkovich**



Tied DCA to reservoir/physical parameters

Inherent assumption that  $p_{\mbox{wf}}$  is constant

b ~ Recovery Efficiency

low b  $\rightarrow$  low recovery efficiency high b  $\rightarrow$  high recovery efficiency

#### **Boundary Dominated Flow**

b = 0 Single-phase oil, or gas at high pressure b = 0.1-0.4 solution gas drive b = 0.4-0.5 single-phase gas flow

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b = 0.5-1: layered reservoirs

#### **Infinite Acting / Transitional**

b >= 1: infinite acting, or transitional flow

### Segment Type: Decline (Arps)



### Segment Type: Linear



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### Segment Type: Constant



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### Segment Type: Semi-Log



### Segment Type: Power Law



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# **DCA: Segment Types & Straight Lines**



### **DCA: Decline Rate Type**

### $\left| \ q(t) = q_i (1+ba_i t)^{-1/b} ight|$

#### **Secant Effective**

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#### **Default in whitson+**

### **DCA: Limiting Decline Rate**



### **DCA: Hotkeys**

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### **Ratio Forecasting: Power-Law**

Given Arps Hyperbolic functions for oil rate and gas rate, we take the late-time asymptotic form where  $D_i bt \gg 1$  and simplify to a PowerLaw function.

$$q_{o} = q_{i,0} (1 + D_{i,o} b_{i,o} t)^{-\frac{1}{b_{i,o}}} = \frac{q_{i,o} (D_{i,o} b_{i,o})^{-\frac{1}{b_{i,o}}}}{t^{\frac{1}{b_{i,o}}}} = \frac{\alpha_{o}}{t^{\frac{1}{b_{i,o}}}}$$
$$q_{g} = q_{i,g} (1 + D_{i,g} b_{i,g} t)^{-\frac{1}{b_{i,g}}} = \frac{\alpha_{g}}{t^{\frac{1}{b_{i,g}}}}$$

We can then compute GOR as the ratio of the two simplified functions:

$$GOR = \frac{q_g}{q_o} = \frac{\alpha_g}{\alpha_o} \frac{t^{\frac{1}{b_{i,o}}}}{t^{\frac{1}{b_{i,g}}}} = \frac{\alpha_g}{\alpha_o} t^{\frac{1}{b_{i,o}} - \frac{1}{b_{i,g}}}$$

Noting that the Power Law slope  $n = -\frac{1}{b}$ :

$$GOR = \frac{q_g}{q_o} = \frac{\alpha_g}{\alpha_o} \frac{t^{-\frac{1}{b_{i,o}}}}{t^{-\frac{1}{b_{i,g}}}} = \frac{\alpha_g}{\alpha_o} t^{n_o - n_g}$$

Finally,  $a_o$  and  $a_g$  are constants, so define  $c = \frac{a_g}{a_o}$ . Define  $m = n_o - n_g$ :

$$GOR = ct^m$$

We note that this implies:

$$m = \frac{1}{b_{i,o}} - \frac{1}{b_{i,g}}$$



### **Ratio Forecasting: Power-Law**



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### **Auto-Forecast: Outline**

- 1. Initialize
- 2. Autofit, Review & Save
- 3. Roll-up



### **Auto-Forecast: Overview**



Provide a complementary set of tools and insights that can not be achieved by looking at production history alone.

Used to e.g.

- Characterize uncertainty
- Validate manual forecasts
- Starting point for manual forecasts
- Complete type well datasets with a variable prod history

### **Auto-forecast: Workflow**

#### Initialize

#### Autofit

#### **Roll-up**

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Set up your workflow by defining parameters and forecast settings.

Autofit data, review results, save, and export to multiple formats. Primarily used for data quality checks with visual analysis.



# **Type Well: Outline**

- 1. Why are Type Wells Important?
- 2. Type Wells vs Type Curves
- 3. Normalization
- 4. Condensing Time
- 5. Survivor Bias
- 6. Truncation Using Sample Size Cut-ff
- 7. Forecast the Average vs Average the Forecasts
- 8. Representing Uncertainty

# Why are Type Wells Important?

- Inform production forecasts or economic evaluations
- Scope out plays
- Build understanding of production-influencing factors (e.g. completion parameters, subsurface parameters)
- Reduce risk / uncertainty
- Justify and support multi-million dollar decisions

# **Clarification: Type Well vs Type Curve**

- "Type Wells" are often referred to as "Type Curves".
- "Type Curves" refer to idealized production plots (based on equations and/or numerical simulation) to which actual production results are compared.

 "Type Wells" are based on actual well production data and represent a typical<sup>[1]</sup> production profile for a collection of wells for a specified duration.

<sup>[1]</sup> The arithmetic average of a group of wells are commonly applied to estimate a type well. That said, experts (e.g. David Fulford) would argue that P50 is a better choice.

# **Clarification: Type Curve vs Type Well**



### **Type Well**



### Type Well Averaging: Geometric, Arithmetic, P50?



- The arithmetic mean is highly biased by outliers and is not reliable to use as a basis for a type well profile nor (by itself) as a diagnostic.
- The geometric mean is less biased by outliers, but susceptible to skewness in low values.
- The P50 (recommended) presents the least biased representation as it is wholly unaffected by values, only ordering.

### **Type Well: Charts**









**Probit** 



# **Type Well: Probit**



- Represent the statistical distribution of something (e.g. EUR, IP60, physical parameter) at a point in time.
- The shape can help to determine if the results trend towards a lognormal distribution.
- A "probit best fit" regression can yield statistical insights including a measure of uncertainty (e.g. P10/P90 ratio)

Normalization restructures data to improve comparability

- <u>Time Normalization</u>
  - Alignment to a common date or event
  - Example: first production date or peak rate date
- Dimensional Normalization
  - Scaling production values relative to a well design parameter
  - Example: production/lateral length
- Advanced Normalization
  - E.g. non-linear scaling of laterals
  - Example: a 10,000 ft lateral is 1.8x better than a 5,000 ft

### **First Production**

### **Peak Rate**





### **Time Align on First Production**

<u>Strength:</u> on larger well sets, communicates the production profile considering time to peak.

<u>Weakness</u>: may not accurately reflect production decline behavior.

### **Time Align on Peak Rate Date**

Strength: more accurately reflects production behavior.

<u>Weakness</u>: excludes ramp up time which might have a small impact on EUR but is important to first year revenue projection.

Dimensional normalization puts wells into a meaningful comparative context.

### **Not-Normalized**

### Normalized



### **Type Well: Condensing Time**

Flowing time only includes producing time steps

#### Normalized Time

Normalized Flowing Time



Beware of flush production spikes when removing zero production time steps

### **Type Well: Survivor Bias**



# **Type Well: Survivor Bias**

Include only producing wells in averaging calculation

Include only producing wells in averaging calculation (?)



Applying survivor bias controls will include zeros in the average for wells after they are identified as depleted (e.g. no production in last 12 months).

# **Type Well: Truncation using Cut-offs**

- Sample sets with a range of production history will have a late time portion biased by the older wells.
- "Sample size cut-off": when producing wells contributing to average drops below as specific percentage.
- Common value are: 50% or greater.
- Common to select wells by vintage to ensure contributing wells have a similar amount of production history.

# **Type Well: Truncation using Cut-offs**



### Forecast the Average vs. Average the Forecasts

### Forecast the Average

- Apply a decline to the truncated type well to obtain a full life profile of EUR
- Time effective, but does not provide distribution of EURs

### Average the Forecasts

- Time consuming without auto forecast option
- Useful for statistical evaluation and P10/P90 quantification of EUR

### Forecast the Average vs. Average the Forecasts

Forecasts the Average

Average the Forecasts



### **Type Well: Percentile Trendlines**



# **Next Release Preview**

### **Release Preview: Partial Fit of Data**



### **Auto-Forecast: Ratio-Forecast**



# DCA & Type Well: Month Toggle Option

-



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Main 
SPE-DATA-REPOSITORY-DATASET-1-WELL-4-KITE

-4-KITE Vain

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### **Comparison Plot: Append DCA**



### **Type Well & Comp Plot: Append Mix**

	<b>whitson</b> <sup>+</sup> Field Default	Project Plot Main - 20 wel	ls 👻		😁 🖓 २° 🖄 🗟 🖉
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^	Search Wells and Scenar Q	<b>∀</b> RESET	HALEY 9-13-9 1H   Main	← HALEY 9-13-9 1H   my scenario ← HALEY 9-13-9 7H   Main	o ╺━╾ HALEY 9-13-9 4H   Main ╺━╾ HALEY 9-13-9 5H   Main • HALEY 9-13-9 2H   Main  ━━ HALEY 9-13-9 3H   Main  ━━ HALEY 9-13-9 8H   Main
	Well/Scenario Name	<b>^</b>		- ← LEMKE 25-13N-9W 6H   Ma	Main — LEMKE 25-13N-9W 3H   Main — LEMKE 25-13N-9W 2H   Main
~	✓ HALEY 9-13-9 1H	Custom DCA Forecas	ts		3SON 26-13N-9W 7H   Main - HOBSON 26-13N-9W 8H   Main
	HALEY 9-13-9 4H	DCA Forecast to Apply			
	HALEY 9-13-9 5H	None	APPLY FORECAST TO ALL (?	) Forecast Name	
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	HALEY 9-13-9 2H	HALEY 9-	13-9 1H (my scenario) Y 9-13-9 4H (Main)	Current Case all streams case	
	HALEY 9-13-9 3H	HALE	Y 9-13-9 5H (Main)	gas case oil case	
~	HALEY 9-13-9 8H	HALE	Y 9-13-9 6H (Main) Y 9-13-9 7H (Main)	None	·
	LEMKE 25-13N-9W 4H	HALE	Y 9-13-9 2H (Main)	None	·
		HALE	Y 9-13-9 3H (Main) Y 9-13-9 8H (Main)	None	·
lel	PRIVATE GROUPS	LEMKE 2	25-13N-9W 4H (Main)	None	·
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#### whitson

We support energy companies, oil services companies, investors and government organizations with expertise and expansive analysis within PVT, gas condensate reservoirs and gas-based EOR. Our coverage ranges from R&D based industry studies to detailed due diligence, transaction or court case projects.

We help our clients find best possible answers to complex questions and assist them in the successful decisionmaking 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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## **Arps Physical Significance**

#### Appendix B: Providing Physical Significance to DCA Parameters

DCA parameters, i.e.,  $q_i$ ,  $D_i$  and b, represent underlying, physical parameters. To convince ourselves that this is the case, a single-phase oil well, producing at a constant bottomhole pressure is analyzed. The well is an idealized multi-fractured horizontal well (MFHW), as exemplified in Fig. 1, with negligible production beyond the fracture tips. Linear flow is perpendicular to the fractures. For such a model, there will first be a period of infinite acting flow (IAF). The duration of this period depends on parameters such as permeability and distance to the closest offset fracture. Boundary-dominated flow (BDF) occurs after pressure at the no-flow boundary between fractures declines to less than the initial reservoir pressure. For such a case, the generalized Arps equation **Eq. B1** can be tied to the analytical solutions for both infinite acting and boundary dominated flow periods as presented in **Eqs. B2-B8**.

$$q(t) = q_i (1 + bD_i t)^{-\frac{1}{b}}$$
,....(B1)

$$q_{i} = \begin{cases} \frac{hx_{f}\sqrt{k}}{31.3B_{o}} \sqrt{\frac{\varphi c_{t}}{\mu_{o}}} p_{i} - p_{wf} = \frac{LFP\sqrt{\varphi}}{125.2B_{o}} \sqrt{\frac{c_{t}}{\mu_{o}}} p_{i} - p_{wf}, \ t_{elf} < 0\\ \frac{4hx_{f}k}{141.2B_{o}} \frac{p_{i} - p_{wf}}{\mu_{o}\pi y_{e}} = \frac{LFP\sqrt{k}}{141.2B_{o}} \frac{p_{i} - p_{wf}}{\mu_{o}\pi y_{e}}, \qquad t_{elf} \ge 0 \end{cases},$$
(B2)

$$D_{i}(t) = \begin{cases} \frac{1}{2}, & t < t_{elf} \\ \frac{\pi^{2}}{4} \frac{0.00633k}{y_{e}^{2} \varphi c_{t} \mu_{o}}, & t \ge t_{elf} \end{cases},$$
(B3)

$$b(t) = \begin{cases} 2, & t < t_{elf} \\ 0, & t \ge t_{elf} \end{cases},$$
(B4)

$$t_{elf} = \frac{y_e^2 \mu \phi c_t}{0.159 k}, .....(B5)$$

## **Decline Curve Analysis (DCA)**

Туре	Decline Rate	Producing Rate, q	Elapsed Time, t	Cum. Production, $Q_t$
Exponential	$a_t = ln(rac{q_i}{q_t})/t$	$q_i e^{-a_i t}$	$ln(rac{q_i}{q_t})/a_i$	$\frac{q_i - q_t}{a_i}$
Hyperbolic	$rac{a_i}{a_t} = (rac{q_i}{q_t})^b$	$q_i(1+ba_it)^{-1/b}$	$rac{\left(q_{i}/q_{t} ight)^{b}-1}{ba_{i}}$	$rac{q_i}{a_i(1-b)}ig(1-rac{q_t}{q_i}^{1-b}ig)$
Harmonic	$rac{a_i}{a_t}=rac{q_i}{q_t}$	$q_i(1+a_it)^{-1}$	$rac{(q_i\!-\!q_t)}{a_iq_t}$	$rac{q_i}{D_i}ln(rac{q_i}{q_t})$

#### More info: https://manual.whitson.com/modules/well-performance/decline-curve-analysis/

# "How does the new well compare against the type well!?!?"

## **Type Well: Analogue Selection**

- Analogue wells should have a similarity on which a reasonable comparison may be made and represent the range of possible outcomes (i.e. don't just select the best wells).
- Selecting wells with similar characteristics may reduce the range of uncertainty.
- Common criteria:
  - Geology
  - Reservoir
  - Well Design
  - Well Density
  - **Operational Design**

# **Type Well: Survivor Bias**



- In WWII, Abraham Wald, a math expert, looked at how to protect bombers from enemy fire.
- He and his team at Columbia University studied damage on returning planes.
- They suggested adding armor where planes had less damage due to survivorship bias.
- Wald advised reinforcing untouched areas, thinking those were at higher risk.

## **Type Well Averaging Diagnostic**



- David Fulford has proposed a new diagnostic.
- The deviation of the arithmetic and geometric means from the P50 indicates data stability issues.
- Stable periods of history should be relied upon more than unstable periods of history.

### **Type Well Averaging Diagnostic**





### **Type Well: Percentile Trendlines**



### **Type Well: Percentile Trendlines**



Representing uncertainty with percentile trendlines can also be done in cumulative space.

Combined with autoforecasts, percentile trendlines can provide a visual projection of the range of EUR outcomes.

## **DCA: Want to Learn More?**



#### https://www.youtube.com/watch?v=XF9IZI2DUuQ&list=PLgk tb39S1tGcAar8zYnmNC9\_aJNgdvCD\_

# Type Wells: Want to learn more?



### https://sagawisdom.com/