Limitations to Using Simple P.I. Equation & How ODSI Can Help

Limitations to Using Simple P.I. Equation

Changing P.I. value tells you that the performance of the well is changing, but it doesn't tell you **WHY it's changing!**

$$P.I. = J = \frac{DP\ term}{Q}$$

Simple P.I. Equation

$$Q = \frac{kh\ (DP\ term)}{141.2\ \mu B[\ln\left(\frac{r_e}{r_w}\right) + S_T - 0.75]}$$

$$S_T = s + D^*q$$

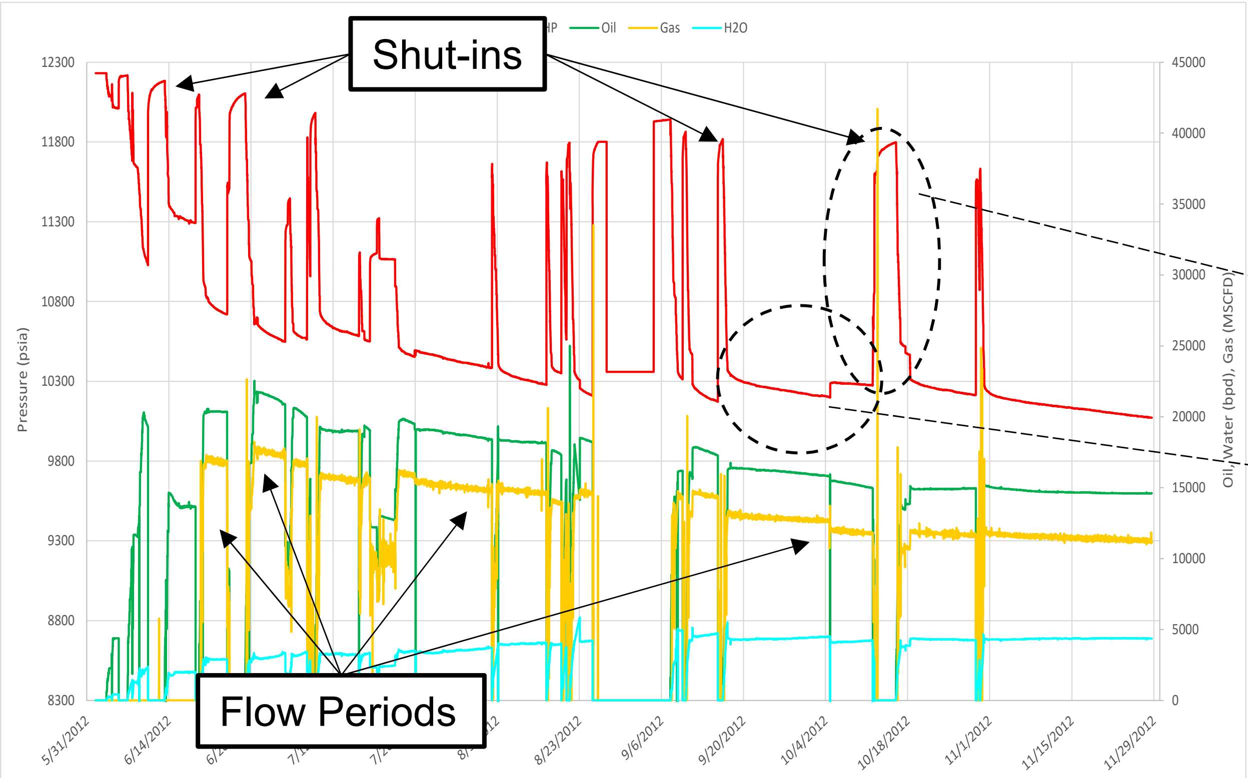
There are more terms that matter!

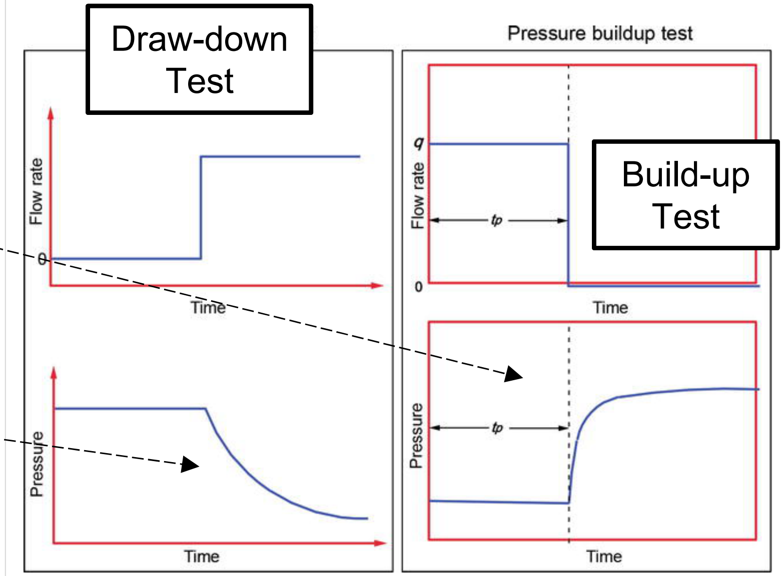
DP Term is some form of: $P^n_{reservoir} - P^n_{wf}$

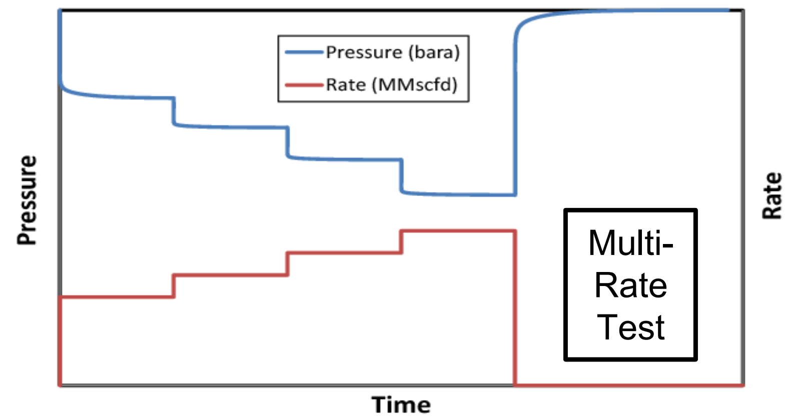
- Is kh changing?
- Is Reservoir Pressure or P_{wf} changing?
- Are Fluid Properties changing?
- Is skin (S_T) changing?
- Is r_e changing?
- Is there additional pressure drop in the well bore?

ODSI can help identify why your P.I. is changing based on which of these terms in the P.I. equation are changing

How We Do It: Data Screening & Analysis







<u>Identify what is affecting the P.I.:</u>

- Changes in Permeability
- Changes in Skin Damage
- Changes in Productivity Index
- Changes in Reservoir Pressure
- Changes in PVT

$$\text{P.I.} = J = \frac{Q}{P_r - Pwf}$$

Simple P.I. Equation…
There are more terms that matter!

How We Determine the Changes in the Components

Components that change in the P.I. Equation:

- **kh**: Build-ups, Drawdowns, 2-rate tests using WHPs or DHGPs*
  ODSI Method: Automatic PTA

- **$P_{reservoir}$**: Build-ups, 2-rate PBUs using WHPs or DHGPs*
  ODSI Method: Automatic PTA
- **P_{wf}**: Calculated Flowing BHP
  ODSI Method: Real-time BHP calculation from WHPs or DHGPs and Rates
  (Can also Calculate Rates if Provided both WHP & DHGP)

- **Total Skin**: Build-ups, Drawdowns, 2-rate tests using WHPs or DHGPs
  ODSI Method: Automatic PTA

- **Rate-Dependent Perm & Rate-Dependent Skin**: PBU + Multi-Rate Test
  ODSI Method: Automatic AOF/Multi-Rate Analysis

How We Determine the Changes in the Components

- **Calculating r_e from PSS data:**

r_e [=] Effective Circular Drainage Radius = ft

h [=] Net Pay = ft

HCPV [=] Hydrocarbon Pore Volume (S.T. or s.c.) = $\frac{\pi r_e^2 h * \emptyset * (1 - S_w)}{5.615\ B}$

B [=] Formation Volume Factor = ResBBL/(units of Q/d)

Vc [=] Compressibility Volume = $\frac{Q}{\frac{DP}{DT} * C_t}$ (STB or MMscf)

DP/DT [=] PSS Decline Slope = psi/d

C_t [=] Total System Compressibility = 1/psi

Set s.c. HCPV = Vc; solve for r_e

$$r_e = \sqrt{\frac{5.615\ B * Q}{\pi h * \emptyset * (1 - S_w) * \frac{DP}{DT} * C_t}} = \sqrt{\frac{5.615\ B * Vc}{\pi h * \emptyset * (1 - S_w)}}$$

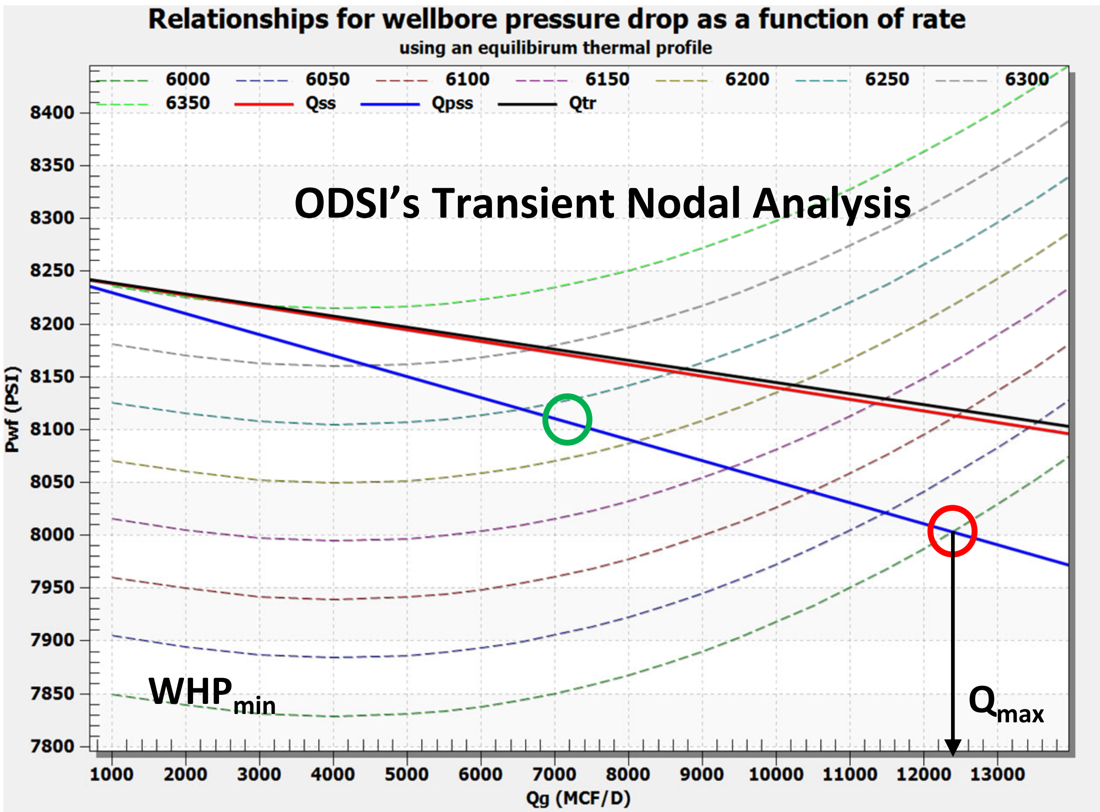
How We Determine the Changes in the Components

Recognizing Excessive Wellbore Friction (Scale):

- Using WHP data only, there is no way to quantitatively differentiate between completion skin and wellbore scale
- To split skin from scale, a downhole gauge must be run in combination with high-resolution WHP measurements
- However, a well can still be screened for excessive pressure drop using just the high-resolution WHP data. These wells can then be flagged as wells that have excess pressure loss (due to skin, scale or both) and can be designated as candidates for a downhole gauge survey and PBU
- With downhole gauges (flowing survey & PBU), the pressure drop in the well bore and the pressure drop due to skin can easily be quantified. The incremental production improvement of treating the issue can also be calculated

ODSI's Additional Tool: Nodal Analysis

We can also provide Nodal Analysis as an additional tool to further supplement your current well performance analysis



Calculate well's Qmax for given minimum WHP pressure

IPR Equations:

$$q_g = \frac{0.703kh(p_R^2 - p_{wf}^2)}{T\mu_g Z[\ln(r_e/r_w) - 0.75 + s_T]}$$

$$q_o = \frac{kh(p_R - P_{wf})}{141.2\mu_o B_o[\ln(r_e/r_w) - 0.75 + s_T]}$$

R_e, effective radius can be rate dependent

k, perm can be rate dependent

S_T, Total skin can be rate dependent

P, **kh**, **r_e**, **S_T**, and fluid properties can all change with time