Bourdél-Gringarten Type Curve: \(p_wD\) and \(p_wD'\) vs. \(t_D/C_D\) — Various \(C_D e^{2s}\) Values (Radial Flow Case — Includes Wellbore Storage and Skin Effects)

Model Conditions:
- Reservoir Type: Homogeneous
- Boundary Type: Infinite-Acting
- Well Type: Unfractured Vertical Well (Radial Flow)
- Effects: Includes Wellbore Storage and Skin Effects
- Format: 1"x1" format

Type Curve Format:
- \(x\)-axis: \(t_D/C_D\) Solved for \(C_D\).
- \(y\)-axis: \(p_wD\) and \(p_wD'\) Solved for \(k\).
- Family Parameter: \(C_D e^{2s}\) Solved for \(s_p\) (this is the "pseudoradial flow" skin factor and is often referred to as "s."

Type Curve Analysis Relations:

*Dimensionless Wellbore Storage Coefficient:*

\[
C_D = 0.0002637 \frac{k}{\phi \mu \nu \Delta t / C_D} \left[ \frac{\Delta t \text{ or } \Delta t'}{MP} \right]
\]

*Formation Permeability:*

\[
k = 141.2 \frac{qB \mu [p_wD \text{ or } p_wD']}{h [\Delta p \text{ or } \Delta p']} \left[ MP \right]
\]

*Skin Factor:*

\[
s_p = \frac{1}{2} \ln \left( \frac{C_D e^{2s}}{C_D} \right)
\]
Bourdet-Gringarten Type Curve: $p_{wD}$ and $p_{wD'}$ vs. $t_D/C_D$ — Various $C_D e^{2s}$ Values (Radial Flow Case — Includes Wellbore Storage and Skin Effects)
"Stewart" Type Curves: Unfractured Vertical Well with a Single or Multiple Sealing Faults (NO Wellbore Storage and Skin Effects)

Model Conditions:
- Reservoir Type: Homogeneous
- Boundary Type: Single or Multiple Sealing Faults
- Well Type: Unfractured Vertical Well
- Effects: Single or Multiple Sealing Faults — NO Wellbore Storage and Skin Effects
- Format: 1"x1" format
- Comment: Caution is advised, the number and/or orientation of faults can be difficult to assess using this type curve.

Type Curve Format:
- x-axis: \( t_D(L_D)^2 \) (Solved for \( L \) — i.e., distance to a fault).
- y-axis: \( p_{wD} \) "Force-matched" (not solved) from another analysis — graphically or using permeability.
- Family Parameter: number and/or orientation of faults

Type Curve Analysis Relations:

**Distance to Fault/Flow Obstruction:**

\[
l^2 = 0.0002637 \frac{k}{\phi \mu \kappa_I} \left[ \frac{[\Delta t \text{ or } \Delta e]}{[u_D / L_D]} \right]_{MP}
\]

**Formation Permeability:** ("force-matched" (not solved) from another analysis — graphically or using permeability)

\[
k = 141.2 \frac{qB \mu}{k} \left[ \frac{[\Delta p \text{ or } \Delta p']}{[\Delta p \text{ or } \Delta p']} \right]_{MP}
\]
"Stewart" Type Curves: Unfractured Vertical Well with a Single or Multiple Sealing Faults (No Wellbore Storage and Skin Effects)
"Cinco-Samaniego" Type Curve: \( p_D, p'_D \) and \( p_D' \) or \( p'_D' \) vs. \( t_Dxf \) — Various \( C_{fD} \) Values (NO WELLBORE STORAGE EFFECTS)

**Model Conditions:**
- Reservoir Type: Homogeneous
- Boundary Type: Infinite-Acting
- Well Type: Vertical Well with a Single Finite-Conductivity Vertical Fracture
- Effects: NO WELLBORE STORAGE EFFECTS
- Format: 1"x1" format

**Type Curve Format:**
- **x-axis:** \( t_{Dxf} \) Solved for \( x_f \)
- **y-axis:** \( p_{wD} \) and \( p_{wD}' \) Solved for \( k \)
- **Family Parameter:** \( C_{fD} \)

**Type Curve Analysis Relations:**

**Fracture Half-Length Squared:** (Liquid)

\[
x_f^2 = 0.0002637 \frac{k}{\phi \mu c_i C_{fD} t_Dx_f} \frac{1}{[\Delta v or \Delta c_v]_{MP}}
\]

**Formation Permeability:** (Liquid)

\[
k = 141.2 \frac{\mu B}{h} \frac{|p_{wD} or p'_D|_{MP}}{[\Delta x or \Delta p]_{MP}}
\]

**Fracture Half-Length Squared:** (Gas — Pseudopressure-Pseudotime)

\[
x_f^2 = 0.0002637 \frac{k}{\phi \mu c_i C_{fD} t_Dx_f} \frac{1}{[\Delta v or \Delta c_v]_{MP}}
\]

**Formation Permeability:** (Gas — Pseudopressure-Pseudotime)

\[
k = 141.2 \frac{\mu B}{h} \frac{|p_{wD} or p'_D|_{MP}}{[\Delta x or \Delta p]_{MP}}
\]
"Cinco-Samaniego" Type Curve: $p_D$, $p_D'$ and $p_{D/\beta_d}$ vs. $t_{Dx}$ — Various $C_{ID}$ Values (NO WELLBORE STORAGE EFFECTS)
"Cinco-Samaniego" Skin Factor Correlation: (used to relate the fractured well case to the Pseudoradial flow skin factor)

\[
\frac{r_w e^{-3}}{x_f} \approx \exp \left[ \frac{1.648546 - 3.002711 \times 10^{-1} u + 1.506532 \times 10^{-1} u^2}{1 + 2.136604 \times 10^{-1} u + 9.513761 \times 10^{-2} u^2 + 8.276998 \times 10^{-3} u^3} \right]
\]

Alternative Correlation:

\[
\frac{r_w e^{-5}}{x_f} = \frac{1}{2} \left[ 1 - 4.622848 \times 10^{-2} \exp(-4.354799 \times 10^{-3} C_{ID}) 
- 3.536031 \times 10^{-1} \exp(-1.314478 \times 10^{-1} C_{ID}) 
+ 5.874493 \times 10^{-1} \exp(8.119795 \times 10^{-1} C_{ID}) \right]
\]

Data From:
"Economides" Type Curve: \( p_{wD} \) and \( p_{wD}' \) vs. \( \frac{t_{DF}}{C_{DF}} \) — (Fractured Well Case — Includes Wellbore Storage Effects)

Model Conditions:
- Reservoir Type: Homogeneous
- Boundary Type: Infinite-Acting
- Well Type: Vertical Well with a Single Finite-Conductivity Vertical Fracture
- Effects: Includes Wellbore Storage Effects
- Format: 1"x1" format

Type Curve Format: Each type curve has a different value of fracture conductivity \( (C_{DF}) \)

- x-axis: \( \frac{t_{DF}}{C_{DF}} \) Solved for \( x_f \)
- y-axis: \( p_{wD} \) and \( p_{wD}' \) Solved for \( k \)
- Family Parameter: \( C_{DF} \) Solved for \( C_s \)

Type Curve Analysis Relations:

Fracture Half-Length Squared: (Liquid)

\[
x_f^2 = 0.0002637 \frac{k}{\phi \mu} \frac{1}{C_{DF} \left[ \frac{t_{DF}}{C_{DF}} \right]_{MP}} [\Delta \rho \text{ or } \Delta_p]_{MP}
\]

Fracture Half-Length Squared: (Gas — Pseudopressure-Pseudotime)

\[
x_f^2 = 0.0002637 \frac{k}{\phi \mu \rho_i} \frac{1}{C_{DF} \left[ \frac{t_{DF}}{C_{DF}} \right]_{MP}} [\Delta \rho_{ae} \text{ or } \Delta_{lae}]_{MP}
\]

Formation Permeability: (Liquid)

\[
k = 141.2 \frac{q \mu H}{h} \frac{[\Delta \rho \text{ or } \Delta_p]_{MP}}{[\Delta \rho \text{ or } \Delta_p]_{MP}}
\]

Formation Permeability: (Gas — Pseudopressure-Pseudotime)

\[
k = 141.2 \frac{q_B \mu_i H_i}{h} \frac{[\Delta \rho \text{ or } \Delta_p]_{MP}}{[\Delta \rho \text{ or } \Delta_p]_{MP}}
\]
"Economides" Type Curve: $p_{wD}$ and $p_{wD'}$ vs. $t_{Df}/C_{Df}$ — $C_{ID} = 1$ (Fractured Well Case — Includes Wellbore Storage Effects)
"Economides" Type Curve: $p_{wD}$ and $p_{wD}'$ vs. $t_{Dxf}/C_{Df}$ — $C_{fr} = 10$ (Fractured Well Case — Includes Wellbore Storage Effects)

Legend: $C_{fr} = \frac{(wk_f)/(kx_f)}{C_{Df}} = 10$

- $P_D$ Type Curve
- $P_{Dd}$ Type Curve
- $P_{D/td}$ Type Curve

Comment:
The $C_{fr} = \frac{(wk_f)/(kx_f)}{C_{Df}} = 10$ case is the only such case that appears to show both "Bilinear Flow" behavior (low $C_{fr}$) and "Formation Linear Flow" behavior (high $C_{fr}$).

Type Curve for a Well with Finite Conductivity:
Vertical Fracture in an Infinite-Acting Homogeneous Reservoir with Wellbore Storage Effects $C_{fr} = \frac{(wk_f)/(kx_f)}{C_{Df}} = 10$
"Economides" Type Curve: \( p_wD \) and \( p_{wD} \) vs. \( t_{DF}/C_{DF} \) — \( C_{ID} = 100 \) (Fractured Well Case — Includes Wellbore Storage Effects)
"Stewart and Ascharsobbi" Type Curve: $p_{wD}'$ vs. $t_{D\lambda}/4$ — (Naturally-Fractured Reservoir Systems — NO WELLBORE STORAGE AND SKIN EFFECTS)

Model Conditions:
- Reservoir Type: Dual-Porosity (Naturally-Fractured)
- Boundary Type: Infinite-Acting
- Well Type: Vertical Well in a Dual-Porosity (Naturally-Fractured) Reservoir System
- Effects: No Wellbore Storage and Skin Effects
- Format: 1"x1" format

Type Curve Format:
- $x$-axis: $t_{D\lambda}/4$ Solved for $\lambda$.
- $y$-axis: $p_{wD}'$ Solved for $k$.
- Family Parameter: $\omega$ Solved for $\omega$.

Type Curve Analysis Relations:

- Dimensionless Interporosity Flow Parameter: (Liquid)
  \[
  \frac{1}{\lambda/4} = 0.0002637 \frac{k}{\phi \mu \rho_w} \frac{[\Delta t \sigma \Delta_r]}{[t_{D\lambda}/4]_{MP}}
  \]

- Formation Permeability: (Liquid)
  \[
  k = 141.2 \frac{qB_H [p_{wD}']_{MP}}{h [\Delta p]_{MP}}
  \]
"Stewart and Ascharsobi" Type Curve: $p_{w0}'$ vs. $t_{D\lambda/4}$ — (Naturally-Fractured Reservoir Systems — NO WELLBORE STORAGE AND SKIN EFFECTS)
"Onur, Satman, and Reynolds" Type Curve: \( p_{wO}' \) vs. \( tD/\lambda(1-\omega) \) — (Naturally-Fractured Reservoir Systems — NO WELLBORE STORAGE AND SKIN EFFECTS)

Model Conditions:
- Reservoir Type: Dual-Porosity (Naturally-Fractured)
- Boundary Type: Infinite-Acting
- Well Type: Vertical Well in a Dual-Porosity (Naturally-Fractured) Reservoir System
- Effects: No Wellbore Storage and Skin Effects
- Format: 1 "x1" format

Type Curve Format:
- x-axis: \( tD/\lambda(1-\omega) \) Solved for \( \lambda \).
- y-axis: \( p_{wO}' \) Solved for \( k \).
- Family Parameter: \( \omega \) Solved for \( \omega \).

Type Curve Analysis Relations:

- **Dimensionless Interporosity Flow Parameter:** (Liquid)
  \[
  \frac{1}{\lambda(1-\omega)} = 0.0002637 \frac{k}{\phi \mu r_c^2} \left[ \frac{\Delta t \text{ or } \Delta_t \text{ or } \Delta_e}{[D/\lambda(1-\omega)]_{MP}} \right]
  \]

- **Formation Permeability:** (Liquid)
  \[
  k = 141.2 \frac{q_{BH} [p_{wO}']_{MP}}{h [\Delta p]_{MP}}
  \]
"Onur, Satman, and Reynolds" Type Curve: $p_w \delta' \text{ vs. } t \delta/(1-\omega)$ — (Naturally-Fractured Reservoir Systems — NO WELLBORE STORAGE AND SKIN EFFECTS)
"Angel" Type Curve: $p_wD$ and $p_{wD}'$ vs. $t_D/C_D$ — (Naturally-Fractured Reservoir Systems — Includes Wellbore Storage and Skin Effects)

Model Conditions:
- Reservoir Type: Dual-Porosity (Naturally-Fractured)
- Boundary Type: Infinite-Acting
- Well Type: Vertical Well in a Dual-Porosity (Naturally-Fractured) Reservoir System
- Effects: Includes Wellbore Storage and Skin Effects
- Format: 1"x1" format

Type Curve Format: Each type curve has a different value for the $\alpha (\alpha = \lambda C_D)$ and the $\omega$ parameters.
- x-axis: $t_D/C_D$ Solved for $C_D$.
- y-axis: $p_{wD}$ and $p_{wD}'$ Solved for $k$.
- Family Parameter: $C_D e^{2\omega}$ Solved for $s_{pr}$ (this is the "pseudoradial flow" skin factor and is often referred to as "$s$.")

Type Curve Analysis Relations:

Formation Permeability: (Liquid)

$$k = 141.2 \frac{qB_o [p_{wD}]_{MP}}{h [\Delta p]_{MP}}$$

Dimensionless Wellbore Storage Coefficient: (Liquid)

$$C_D = 0.0002637 \frac{k}{\phi \mu \rho_w r_w^2} [t_D/C_D]_{MP}$$

Skin Factor:

$$s_{pr} = \frac{1}{2} \ln \left( \frac{[C_D e^{2\omega}]_{MP}}{C_D} \right)$$
"Angel" Type Curve: \( p_{wD} \) and \( p_{wD}' \) vs. \( t_{D}/C_D \) — \( \alpha_D = \lambda C_D = 1 \times 10^{-1}, \omega = 1 \times 10^{-1} \) (Naturally-Fractured Reservoir Systems — Includes Wellbore Storage and Skin Effects)
"Angel" Type Curve: $p_w D$ and $p_w D'$ vs. $t_D/C_D$ — $\alpha = \lambda D = 1 \times 10^{-2}$, $\omega = 1 \times 10^{-1}$ (Naturally-Fractured Reservoir Systems — Includes Wellbore Storage and Skin Effects)
"Angel" Type Curve: $p_{wD}$ and $p_{Wd}'$ vs. $t_D/C_D$ — $\alpha_D=\lambda C_D=1 \times 10^{-3}$, $\omega=1 \times 10^{-1}$ (Naturally-Fractured Reservoir Systems — Includes Wellbore Storage and Skin Effects)
"Angel" Type Curve: $p_{wD}$ and $p_{wD}'$ vs. $t_D/C_D$ — $\alpha_D = \lambda C_D = 1 \times 10^{-4}$, $\omega = 1 \times 10^{-1}$ (Naturally-Fractured Reservoir Systems — Includes Wellbore Storage and Skin Effects)
"Angel" Type Curve: $p_{wD}$ and $p_{wD}'$ vs. $t_D/C_D$ — $\alpha D = \lambda C_D = 1 \times 10^{-1}$, $\omega = 1 \times 10^{-2}$ (Naturally-Fractured Reservoir Systems — Includes Wellbore Storage and Skin Effects)
"Angel" Type Curve: $p_{wD}$ and $p_{wD}'$ vs. $t_D/C_D$ — $\alpha_D=\lambda C_D=1\times10^{-2}$, $\omega=1\times10^{-2}$ (Naturally-Fractured Reservoir Systems — Includes Wellbore Storage and Skin Effects)
"Angel" Type Curve: $p_{wD}$ and $p_{wD}'$ vs. $t_D/C_D$ — $\alpha_D = \lambda C_D = 1 \times 10^{-3}$, $\omega = 1 \times 10^{-2}$ (Naturally-Fractured Reservoir Systems — Includes Wellbore Storage and Skin Effects)
"Angel" Type Curve: $p_{wD}$ and $p_{wD}'$ vs. $t_{D}/C_D$ — $\alpha_D=\lambda C_D=1 \times 10^{-4}$, $\omega = 1 \times 10^{-2}$ (Naturally-Fractured Reservoir Systems — Includes Wellbore Storage and Skin Effects)