Production Analysis Decline Type Curves
Library of Decline Type Curves:

● Fetkovich Type Curves — Radial Flow:
  ■ Original Fetkovich Decline Type Curve
  ■ "Rate Derivative" Decline Type Curve
● Fetkovich-McCray Type Curves — Radial Flow:
  ■ Fetkovich-McCray Type Curve
  ■ Fetkovich-Carter-McCray Type Curve (Gas)
  ■ Boundary Flux (do not use...)
● Fetkovich-McCray Curves — Fractured Wells:
  ■ Infinite Conductivity Vertical Fracture
  ■ Finite Conductivity Vertical Fracture
● Fetkovich-McCray Curves — Horizontal Wells
● Agarwal, et al. Methodology:
  ■ Radial Flow Case
  ■ Vertically Fractured Well Cases
● Crafton, et al. Methodology:
  ■ Rate normalization only...
Fetkovich Radial Flow Type Curves

- Palacio, et al (1993): "Fetkovich-McCray Original" (radial flow) — auxiliary functions. ($t_{Dd}$ format)
- Doublet, et al (1994): "Fetkovich Derivative" (radial flow) — not practical for analysis. ($t_{Dd}$ format)
- Doublet, et al (1994): "Fetkovich-McCray Material Balance Time" (radial flow) — w/aux. functions. ($t_{Dd,bar}$ format)

Radial Flow Decline TC:
- "Fetkovich-McCray Original"
- "Fetkovich Derivative"
- "Fetkovich-McCray Material Balance Time" — Uses material balance to rigorously incorporate variations in rate and pressure over time. This technique substantially improves the analysis of variable-rate data.
Discussion: *Palacio/Blasingame Type Curve (constant $p_{wf}$ case)*

- Auxiliary functions (rate integral and integral derivative) enhance flow features.
- Need to use material balance time to account for variable rate.
- This plot includes the "Arps' relations," these are not included in general.
Discussion: Doublet/Blasingame Type Curve (constant $q_o$ equivalent)

- Note "convergence" of late stems to unique trends (material balance time).
- Type curve is valid for variable-rate/variable pressure drop cases.
- Original "RTA" plot — there is a companion plot for rate normalized pressure.
Doublet/Blasingame Type Curve — Vertically Fractured Wells


c. Pratikno (2002): "Fetkovich-McCray" format — FINITE conductivity vertical fracture ($F_{CD}=0.5$).

Decline Type Curves: Fractured Wells

- Infinite fracture conductivity:
  - Less complex solution, but somewhat ideal for use in practice.

- Finite fracture conductivity:
  - $F_{CD}=10$: Moderate to high fracture conductivity case.
  - $F_{CD}=0.5$: Low fracture conductivity case.
**Discussion: Doublet/Blasingame Type Curve (infinite conductivity fracture)**

- Note the transient flow behavior of the auxiliary functions (linear flow).
- Use of material balance time provides unique late time behavior.
- Can estimate fracture half-length, permeability, and reservoir volume.
Discussion: Doublet/Blasingame Type Curve (Finite conductivity fracture)

- Note the transient flow behavior of the auxiliary functions (bilinear flow).
- Individual type curves generated for each $F_{cD}$-value.
- Can estimate fracture half-length, permeability, and reservoir volume.

Horizontal Well Cases:
- "Infinite-conductivity" horizontal well case(s).
- Dimensionless reservoir model requires several parameters.

Doublet/Blasingame Type Curve Format — Horizontal Wells

Petroleum Engineering 648 — Pressure Transient Testing

Lecture 17 — Production Analysis Decline Type Curves
Decline Type Curves — Boundary Flux Cases

Decline Type Curve Analysis:
- "Break-glass-in-case-of-fire" cases
- Do not use (unless absolutely necessary) — and it should never be necessary.

Unpublished — Marhaendrajana (2002)
(multiwell analysis — do not use)
Decline Type Curves — Boundary Flux Cases

Multiwell Analysis: SPE 71514

- Multiwell case can be "recast" into single well case using cumulative production for entire field.
- Homogeneous reservoir example shows that all cases (9 wells) align — same behavior observed for heterogeneous reservoir cases.

Dimensionless "decline variables" plot for the single well and multiwell performance cases — simulated performance used to validate the multiwell concept.

Log-log plot of rate/pressure drop functions as a function of total material balance time (homogeneous reservoir example).
Decline Type Curves — Agarwal, et al Methodology

Agarwal, et al Methodology: SPE 57916

- Basically the same as Blasingame, et al work.
- More like pressure transient test analysis/interpretation.

Rate-time production decline-type curves for radial systems using $t_D$ based on area ($r_e/r_w = 100$, $1,000$, $10,000$).

Rate-time production decline-type curves for infinite conductivity fracture using $t_D$ based on area ($x_e/x_f = 1, 2, 5, 25$).

Rate-time production decline-type curves for finite conductivity fracture using $t_D$ based on area ($x_e/x_f = 1, 2, 5, 25$ and $F_{CD} = 0.05, 0.5, 500$).
Crafton, et al Methodology: SPE 37409

- Rate normalized pressure drop versus production time ($\Delta p/q$ vs. $t$).
- Also analogous to pressure transient test analysis/interpretation.
- Very serious limitations — production time is not sufficient for general case of rate variation.
**Single-Phase Liquid (Black Oil) — \( \frac{c_t}{\lambda_t} \) vs. Time**

**Discussion: "Solution-Gas Drive" Behavior — \( \frac{c_t}{\lambda_t} \) vs. time**

- **Observation**: \( \frac{c_t}{\lambda_t} \) ≈ constant for \( p > p_b \) and later, for \( p < p_b \).
- **\( p_{wf} \)** = constant — but probably valid for any production/pressure scenario.

**Multiwell Analysis — Governing Relation**

\[
\frac{q_k(t)}{(p_i - p_{wf})} = \frac{1}{Nc_t q_k(t)} \int_0^t \sum_{i=1}^{n_{well}} q_i(t) dt + c(t)
\]

**Production Data (Pressure & Rate)**

**Total Material Balance Time**

**c(t) becomes constant at long times**

\[
t_{tot} = \frac{N_{p, field}}{q_{well}}
\]

**Discussion: Multiwell Analysis — Governing Relation**

- A general formulation of the "Arps' Exponential Decline" case.
- **CONCLUSION**: A single well decline type curve can be used to analyze the performance of a single well in a multiwell system.
Reality Check

Reservoir Volume-Averaging

- Pressure transient analysis.
- Production data analysis.
- Reservoir simulation.

Advanced Solutions

- Same view of the reservoir — just more "knobs" (i.e., parameters).
- Time-pressure-rate data will always "see" a pressure/volume-averaged reservoir system.

Prediction of Future Work in PTA/PA

- Additional reservoir models.
- Full incorporation of PVT character.
- Reservoir scaling for PTA/PA.
- Handling poor quality data.
- Continuously measured $p_{wf}$ data.
- Multiple well analysis/integration.
- Coupling of analysis/interpretation with numerical modeling (3D/3P).

From: Simulator Parameter Assignment and the Problem of Scaling in Reservoir Engineering — Halderson (1986).
References — Production Data Analysis

Historical Methods — Production Data Analysis:

Decline Type Curve Analysis: