Rate Transient Analysis Theory/Software Course

RTA Theory / Software Course: Part 1

- Introduction
- Review of Traditional Decline Analysis Techniques
  - Arps
  - Fetkovich
- Modern Decline Analysis Theory
  - Pseudo S.S. Equation for Oil
  - Significance of Harmonic Equation
  - Comparison of Constant Rate and Constant Pressure Conditions
  - Concept of Material Balance Time
  - Extending Concepts to Work for Gas Wells (Pseudo-time)
- Data Analysis Methods - Theory
  - Blasingame
  - Agarwal-Gardner
  - NPI (Normalized Pressure Integral)
  - Transient (tD format)
  - Flowing Material Balance

Traditional Decline Analysis

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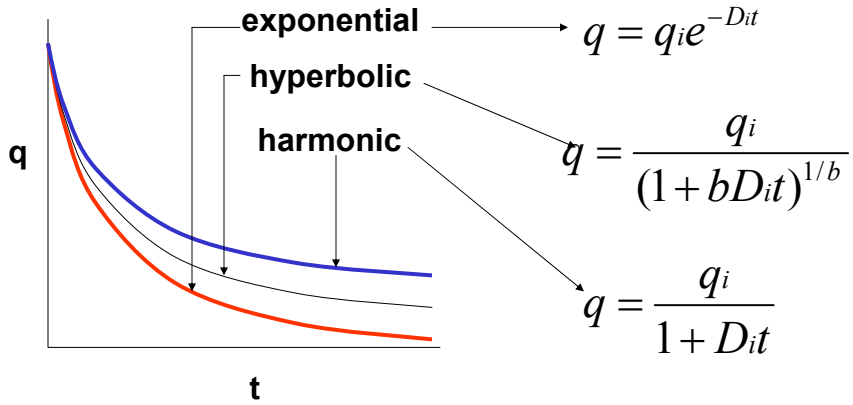
Exponential, Hyperbolic and Harmonic Equations



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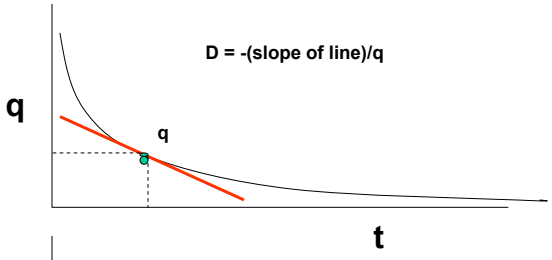
SPEE Definitions of Decline Rate

Nominal (true) Decline Rate:

$$D = -\frac{\frac{dq}{dt}}{q}$$

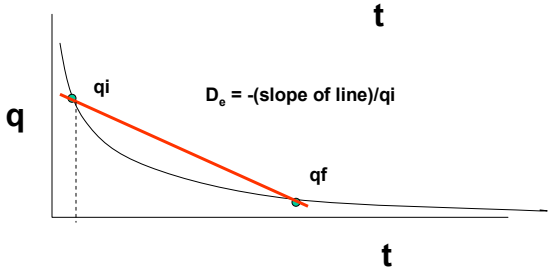
$$D = -\ln(1 - D_e)$$



Effective Decline Rate:

$$D_e = \frac{q_i - q_f}{q_i}$$

$$D_e = 1 - e^{-D}$$



In RTA, "D_e" is refered to as "d", and is expressed as a percentage

Exponential Decline

-D (decline rate) is constant with time $D = Kq^0$

$$q = q_i e^{-D_i t}$$

$$q = q_i - D_i Q$$

Rate (q) has a linear relationship to Cumulative Production (Q)

Hyperbolic Decline

-D (decline rate) varies with time $D = Kq^b$

$$q = \frac{q_i}{(1 + bD_i t)^{1/b}}$$

Linear relationship cannot easily be formed with hyperbolic parameters

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Harmonic Decline

-D (decline rate) is proportional to rate $D = Kq$

$$q = \frac{q_i}{(1 + D_i t)}$$

Linear relationship between log rate (q) and cumulative (Q)

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Notes About Recovery Mechanism and b Value (from Arps)

-Single-phase liquid production, high-pressure gas, tubing-restricted gas, poor waterflood performance: b = 0

-Solution gas drive: 0.1 < b < 0.4; depends on relative permeability k_{rg}/k_{ro} curves

-Production data above bubble point should not be analyzed with data below (Arps decline analysis is only valid when recovery mechanism doesn't vary with time)

-Typical gas wells: 0.4 < b < 0.5

-Conventional oil reservoirs under edge water drive (effective water drive): b = 0.5

-Commingled, layered reservoirs: 0.5 < b < 1.0

-Field experience presented by Arps suggests 0.1 < b < 0.9

-Exponential decline appears to be a rare occurrence in nature, even though it is the most commonly used decline technique

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Fetkovich Theory

-Developed because traditional decline curve analysis is only applicable when well is in boundary dominated flow

- Fetkovich used analytical flow equations to generate typecurves for transient flow, and combined them with empirical decline curve equations from Arps

-Resulting typecurves encompass entire production life of well

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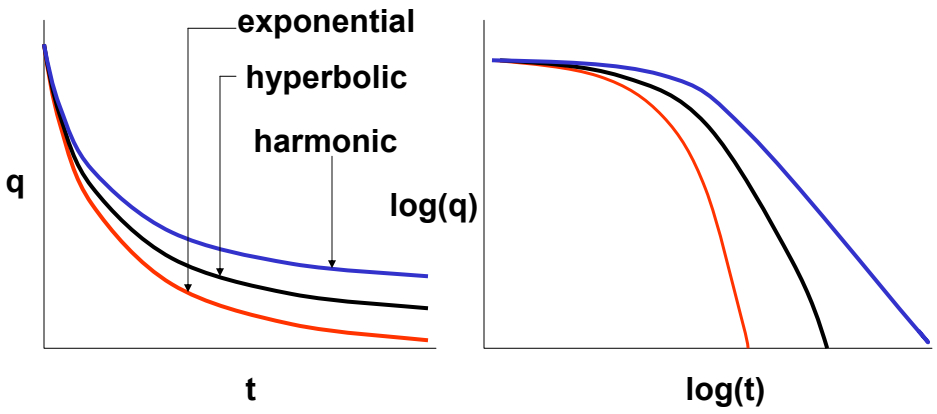
Fetkovich Theory – Depletion Stems



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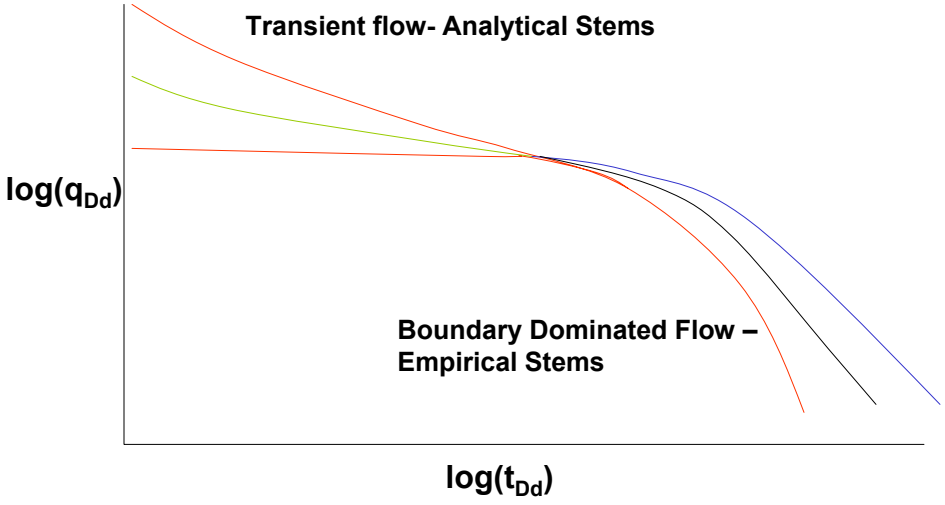
Fetkovich Theory – Boundary Dominated and Transient



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Modern Decline Analysis

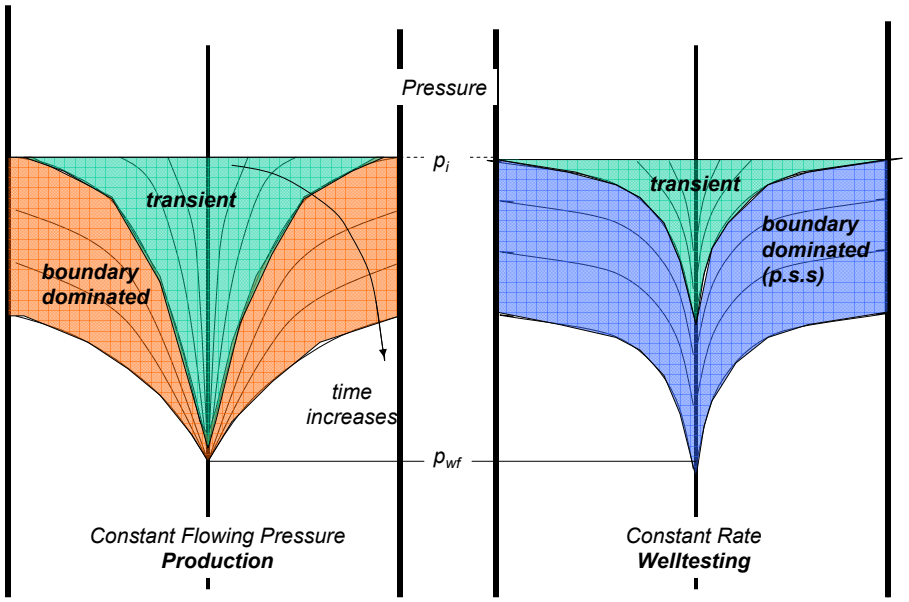
Modern Decline Analysis

- **Incorporates the effect of flowing pressure**

- **Uses pressure transient theory**

- **Relies on the equivalence between the constant rate and constant pressure solutions**

Equivalence of Constant Pressure and Constant Rate



Modern Decline Analysis: How to Choose a Base Model

- **Constant Pressure Model**
  - **Emulates unrestricted flow to pipeline**
  - **Most production data behaves this way**
  - **Difficult to model analytically**
- **Constant Rate Model**
  - **Emulates deliverability restricted production**
  - **Common assumption of welltesting**
  - **Easier to model because many solutions already exist in welltest literature**

Data Analysis Methods:

-Blasingame
-Agarwal Gardner
- Flowing Material Balance
-NPI
-Transient

Blasingame Typecurve Analysis

Blasingame typecurves have identical format to those of Fetkovich. However, there are three important differences in presentation:

1. Models are based on constant RATE solution instead of constant pressure

2. Exponential and Hyperbolic stems are absent, only HARMONIC stem is plotted

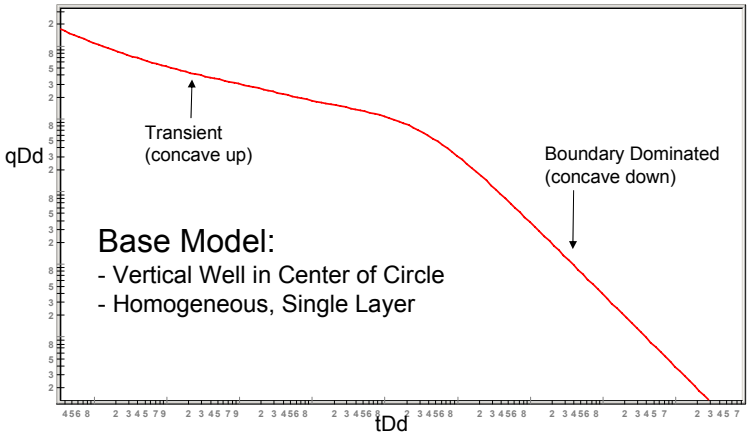
3. Rate Integral and Rate Integral - Derivative typecurves are used (simultaneous typecurve match)

Data plotted on Blasingame typecurves makes use of MODERN DECLINE ANALYSIS methods:

- NORMALIZED RATE ($q/\Delta p$)

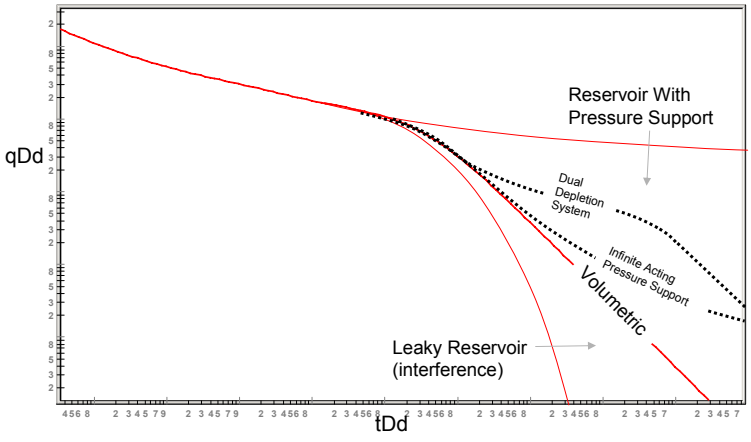
- MATERIAL BALANCE TIME / PSEUDO TIME

Diagnostics using Typecurves



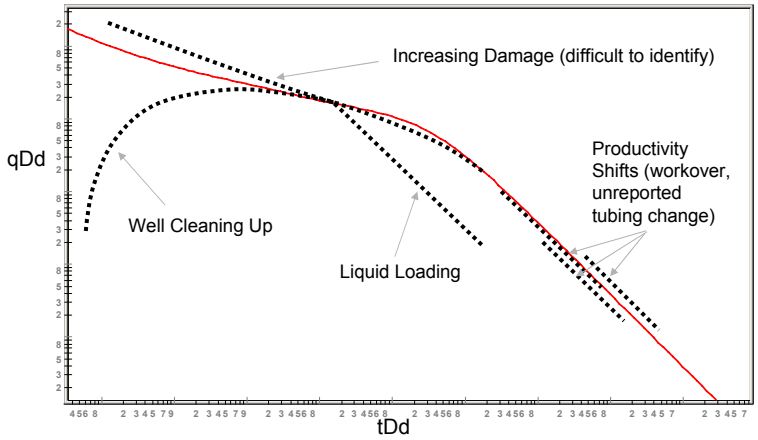
Diagnostics using Typecurves

Material Balance Diagnostics



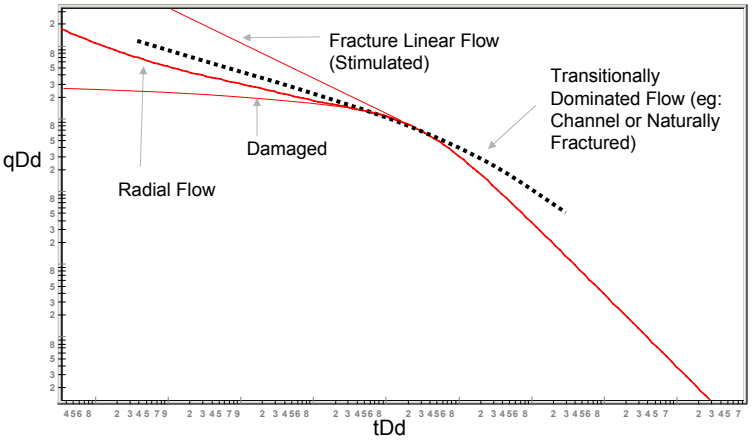
Diagnostics using Typecurves

Productivity Diagnostics



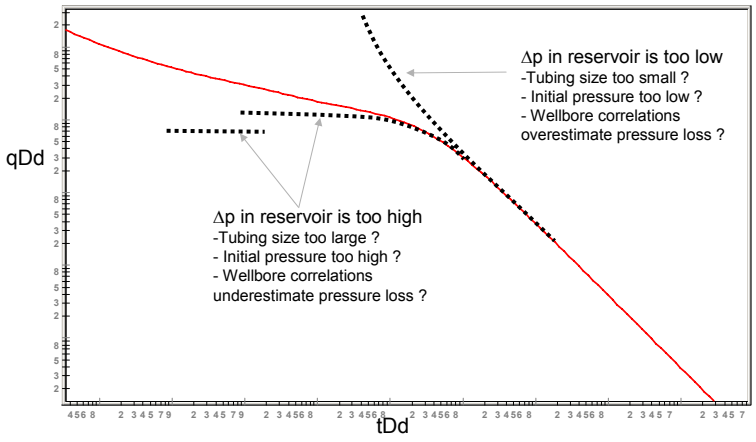
Diagnostics using Typecurves

Transient Flow Diagnostics



Diagnostics using Typecurves

"Bad Data" Diagnostics



Flowing Material Balance

FMB analysis plots a normalized RATE versus normalized CUMULATIVE PRODUCTION, on a LINEAR scale (x and y). No typecurves are plotted.

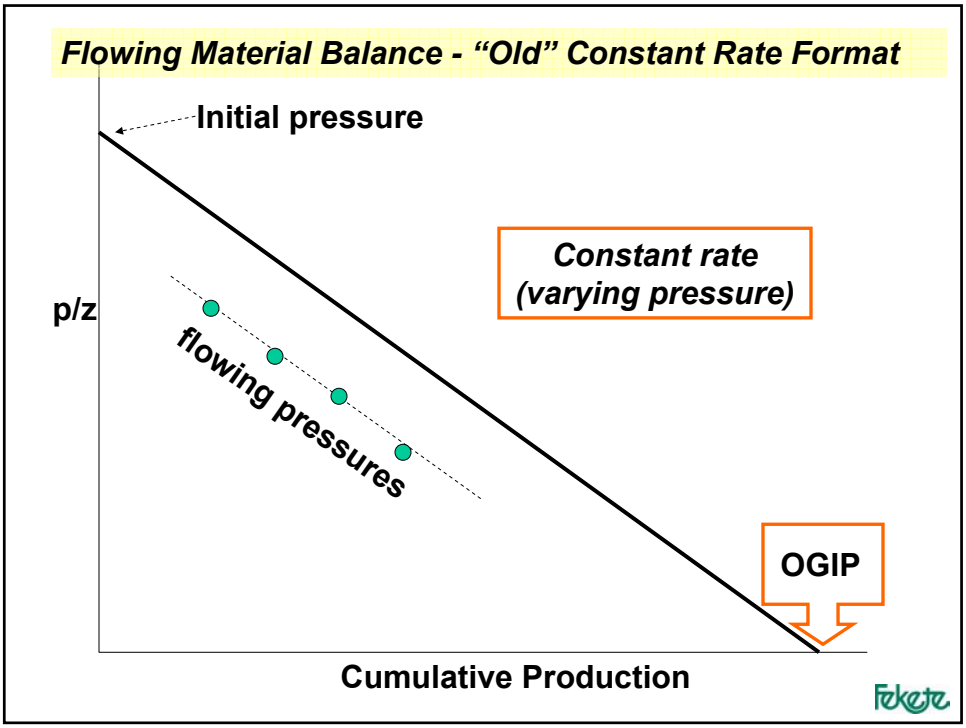
The FMB methodology combines concepts from two individual methods:

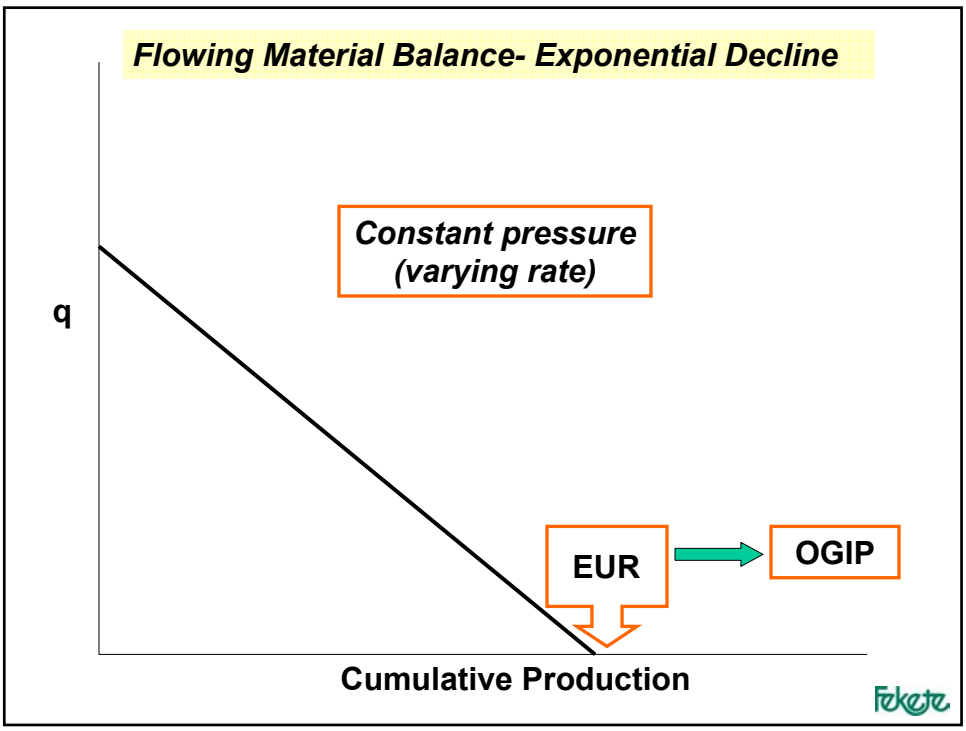
1. **"Old" flowing material balance (after Mattar and McNeil)**

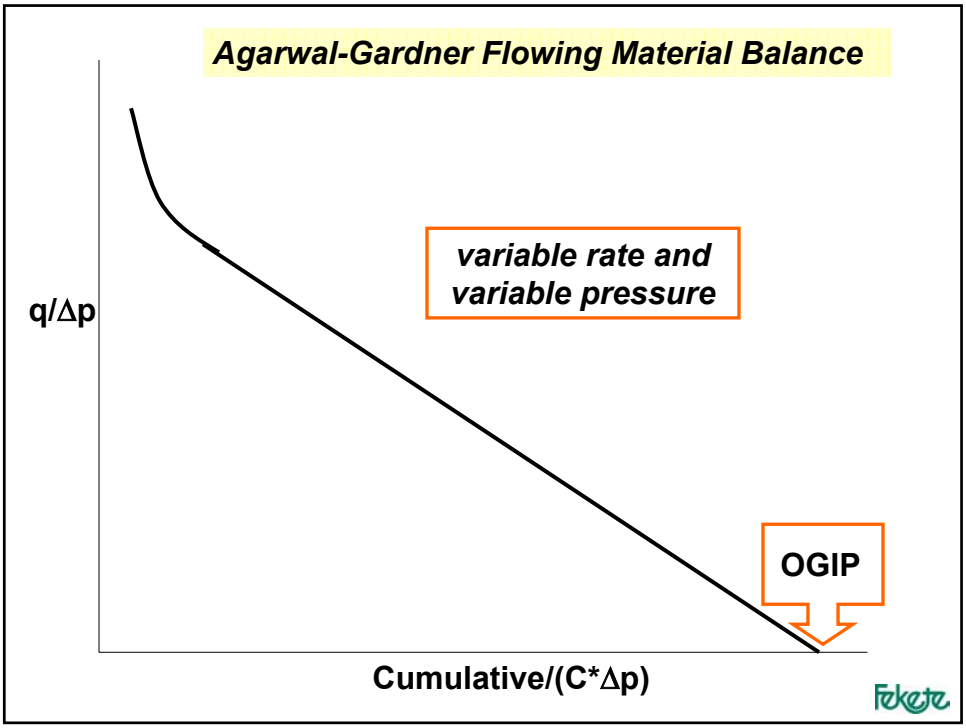
2. **Agarwal-Gardner Rate vs. Cumulative production typecurves**

- The FMB plot provides an easy and effective way for estimating fluid-in-place, using data that is BOUNDARY DOMINATED

- FMB methodology utilizes the concepts of material balance time and pseudo-time.


Flowing Material Balance - "Old" Constant Rate Format
Initial pressure
Constant rate
(varying pressure)
p/z
flowing pressures
OGIP
Cumulative Production


Flowing Material Balance- Exponential Decline
Constant pressure
(varying rate)
q
EUR
OGIP
Cumulative Production


Agarwal-Gardner Flowing Material Balance
variable rate and
variable pressure
q/Δp
OGIP
Cumulative/(C*Δp)
Fekete