Are Our Proved Shale Reserves Reasonably Certain?

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What’s the Problem?

- To forecast for unconventional reservoirs, we are using reserves estimation practices developed during the last century for conventional reservoirs – based on
  - Empirical observation of production declines for over a century
  - Modeling capabilities developed in second half of 20th century generally supporting simple decline models for estimating reserves
- But does this work for unconventionals?
How Do Unconventionals Differ?

- No experience of long-term declines
  - No way to validate models, simple or complex
- No modeling approaches totally, uniquely applicable, and relevant to physical processes involved
  - Long duration transient flow, unlike conventional
  - Unknown contributions from hydraulic fractures and reopened natural fractures
  - Unknown physical mechanisms that may control multiphase flow characteristics
So We Have a Problem: How Can We Solve It?

- SPE Reservoir Description and Dynamics (RD&D) Committee investigating formation of task force to study issues
  - Active participation from other technical society representatives sought for task force
    - SPEE, AAPG, SEG, WPC included
  - Active participation by representatives from industry ultimately sought
Who Are the Current Task Force Organizers?

- Members of SPE RD&D Committee
  - Oliver Houze, Kappa, Committee Chair
  - Tom Blasingame, Texas A&M, Committee Member
  - John Lee, University of Houston, Committee Member
Meanwhile, What Can We Do Today?
What We Assume Most of the Time

- Horizontal well with multi-stage fractures
  - Production only from Stimulated Reservoir Volume (SRV)
  - Two flow regimes
    - Transient (probably linear) flow to fracture interference
    - Boundary-dominated flow after fracture interference
Perhaps Closer to the Truth

- At least four flow regimes
  - Transient linear flow to fracture interference
  - Boundary-influenced flow after fracture interference
  - Transient linear flow from unstimulated matrix into SRV
  - Boundary-dominated flow when entire well spacing drained
Still More “Flow Regimes”?

- Early fracture fluid clean-up (uncorrectable)
- Early decline in bottom-hole pressure (correctable, but possibly time consuming)
- Inclusion of these early data in determining simple decline model parameters (Arps, Duong, Stretched Exponential) *inevitably* leads to error
More Complications

- What if fractures aren’t equally spaced?
- What if fractures aren’t of equal length?
- Are early decline trends likely to be sustained?
  - What if SRV permeability decreases with decreasing pressure?
  - What will be the longer-term effects of multiphase flow?
- How can we estimate reserves with confidence?
How Can We Deal with All This?

- Common approach: simple models
  - Rationale: hundreds of wells to analyze in short periods of time
  - Example: two-segment Arps model

- More time-consuming approach – but still simple
  - Identify flow regimes with diagnostic plot
  - Model each flow regime with appropriate model
  - Example:
    - Discard early data not reflecting longer-term trends
    - Follow with transient linear flow model \((b=2)\)
    - Follow with boundary-influenced model \((b\) is what it is\)
    - Finally, follow with second transient flow model \((b=2)\)
    - Watch for needed final BDF model (if needed, appropriate \(b\) found from available data)

- Perhaps ok for “simple” systems, but ...
Diagnostic Plot Indicating Early ‘Bad Data,’ Linear Flow, and BDF
Rate Transient Analysis (RTA) techniques can identify need for more comprehensive modeling
- Normalizing rates for BHP changes essential
- Diagnostic plots to identify flow regimes essential
- Rapid analytical solutions used to match history, forecast
- Models still may oversimplify complex reservoirs and completions

Equivalent ‘simple’ models identified at end of thorough study (not at start) to allow efficient processing of large numbers of wells
Another Alternative: Reservoir Simulation

- Good choice for complex situations
  - Variable length fractures
  - Unevenly spaced fractures
  - Complex fractures
  - Pressure-dependent rock and fluid properties
  - Multiphase flow
- Final goals still include equivalent ‘simple’ models for routine forecasting
Thoughts on Work Flow for Forecasting

- When BHP data available and time permits, normalize rates before analysis \( \frac{q}{p_i-p_{wf}} \) or \( q_{corr} = q_{obs} \left( \frac{p_i-p_{wf,stab}}{p_i-p_{wf,obs}} \right) \)

- Data from first 6-12 months (clean-up) may not reflect longer trends and should usually be excluded from analysis of historical decline
  - Plot water rate vs. time to identify fracture cleanup
  - Don’t use data during cleanup, since skin continuously decreasing, won’t fall on longer-term trend

- Determine flow regimes in available data
  - Minimum: log \( q \) vs. log \( t \)
  - Better: add log \( \frac{q}{p_i-p_{wf}} \) vs. log MBT (\( G_p/q, N_p/q \))
Estimate time to BDF if not observed in data
  ◦ Minimum: switch time from analogy
  ◦ Better: depth of investigation or analytical model

Don’t try to fit all history with single model
  ◦ Fit each flow regime with model appropriate for that flow regime
  ◦ Extrapolate rate to well life or economic limit only with final flow regime observed or expected – earlier flow regimes unimportant for extrapolation
Work Flow (Continued)

- Beyond simple, rapid modeling, may need to consider
  - Flow from unstimulated matrix to SRV and include in model when appropriate
    - Key: observation of new negative half-slope line, following BDF, on diagnostic plot
  - ‘Complete’ model that *may* include early transient flow, switch to BDF model after fracture interference, switch to linear flow model, final switch to BDF model – if present, each flow regime will appear on diagnostic plot
Summary

- We need a serious examination of forecasting techniques for unconventional resources
- Some in SPE leading exploratory effort to put together task force to examine issues
  - SPEE, AAPG, WPC members have indicated interest
- Simple models, RTA, reservoir simulators (none really validated) available in meantime
  - Logical workflows identified, show promise
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