Model-based Production Analysis

Production diagnostics is the key to understand flow performance

Discussion:
- Well clean-up effects (flowback) dominate early time behavior.
- Half-slope indicates linear flow regime is prevailing for Field A.
- Unit slope indicates fracture interference or depletion type signature (decreasing well productivity) for Field B.
- Long time well cleanup effects and operation issues prevent better diagnostics for Field C.
- Field C wells demonstrate linear and/or bilinear flow type signatures.
Application of Production Diagnostics

Performance comparison of multiple wells to identify characteristics.

**Discussion:**
- Diagnosis of the performance of 9 wells producing in the same area (plot of productivity index).
- Differences in the productivity can be attributed to completion and operational issues.
Application of Model-based Production Analysis

D&M workflow for well performance combines diagnostics and analysis

■ DIAGNOSTICS
  – To be integrated into a workflow for addressing uncertainty.
  – To identify certain features/characteristics.
  – To detect flow regimes.
  – To review data consistency and correlation.

■ ANALYSIS
  – Rate-time decline relations.
    • Modified hyperbolic decline.
    • Power-law (stretched) exponential decline.
  – Bi-linear/Linear flow solutions.
  – Analytical/semi-analytical solutions.
    • Horizontal well with multiple fractures.
  – Numerical solution.
    • Non-linearities (pressure-dependent properties, desorption, etc.)
Application of Model-based Production Analysis

Nonlinear numerical simulation is used to analyze well performance

- **Analysis:**
  - **Model**: Horizontal well with multiple fractures, non-linear analysis accounting for multiphase flow and pressure-dependent reservoir properties.
  - **Multiphase Flow**: Rigorous fluid characterization (non-linear solution).
  - **Pressure-dependencies**: Approximate degradations in productivity.
  - Model-based analysis must be guided by production diagnostics.

Perspectives on the Well Performance Analysis and Forecasting in Unconventional Resources
SPE PRMS Workshop -- Brisbane, Australia
Eagle Ford Shale (Oil) Example

Production forecast is performed once model parameters are obtained.

- Oil and gas rates are extrapolated using the model (80 acres)
- $EUR_{OIL} = 0.23$ MMSTB, $EUR_{GAS} = 1.05$ BSCF
Application of Model-based Production Analysis

Time-rate profile may be obtained from characteristic well performance model.

Well performance is extrapolated to 30 years to estimate EUR after model parameters are obtained.
Eagle Ford Shale (Oil) Example

Multi-well numerical simulation is run to investigate well spacing

- Assumed development wells have the same well configuration
- Assumed development wells have the same reservoir and fluid properties.
- Vary distance between two wells to investigate the effect of spacing on EUR
Eagle Ford Shale (Oil) Example

80 acres well spacing is assumed for the multi-well simulation run.

Pressure Distribution — 1 Year

Pressure Distribution — 5 Years

Pressure Distribution — 3 Years

Pressure Distribution — 8 Years
Eagle Ford Shale (Oil) Example

200 acres well spacing is assumed for the multi-well simulation run

Pressure Distribution — 1 Year

Pressure Distribution — 5 Years

Pressure Distribution — 3 Years

Pressure Distribution — 8 Years
Eagle Ford Shale (Oil) Example

Results from multi-well simulation runs may suggest favorable well spacing.

- EUR is a function of well spacing for less than 100 acres drainage area assumption (not affected over 100 acres).
- EUR values are estimated at 30 years of production.
Conclusions
Procedure for analysis and forecasting of well performance is presented
Conclusions

Production forecasts have to be classified according to reserves categories

- **Proved reserves (1P):** "... reasonable certainty — to be recovered much more likely than not"
- "Reasonably certain" EUR is much more likely to increase or remain constant with time
- **Proved plus Probable reserves (2P):** "... as likely as not to be recovered" (50% prob.)
- **Proved plus Probable plus Possible reserves (3P):** "... possibly but not likely to be recovered" (10% probability)
Conclusions

Key points for well performance analysis and forecasting in unconventional resources:

- Decline curve analysis is currently the primary tool for forecasting, although it may not be fully representative.
- Flow mechanisms are not well understood in unconventional reservoir systems. Therefore, performance/production evaluation and forecasting must consider advanced methods and systematic procedures.
- Production (model-based) analysis and modeling are critical to estimate per well rates, recoveries and development well spacing during the first few years of production.
- Production forecasts are defined by stimulation, geology, and fluid type.