Optimized Unconventional Shale Development with MPD Techniques

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U.S. Shale Plays

- 16,696 exploratory and development wells drilled on US land during year 2010 (eia published data)
- 2544* wells spudded during FY 2014 on federal lands.

*Bureau of Land Management published data
Global Shale Plays

Legend:
- Red: Assessed basins with resource estimate
- Yellow: Assessed basins without resource estimate
- Light gray: Countries within scope of report
- Dark gray: Countries outside scope of report
Mechanical Specific Energy

Concept of Mechanical Specific Energy (MSE)

\[ MSE = \left( \frac{W}{A} \right) + \left( \frac{2\pi}{A} \right) \left( \frac{NT}{\mu} \right) \]

Where:
- \( W \) = Thrust force or weight on bit
- \( A \) = Area of the hole
- \( N \) = Rotational speed, rpm
- \( T \) = Torque
- \( \mu \) = ROP
Differential Pressure Effect on ROP

Effect of overbalance on drilling rate in Berea sandstone for clay/water mud and 1.25-in. rolling cutter bit.\(^{19}\)

Source: Applied Drilling Engineering – SPE textbook, Bourgoyne et al.
Mechanical Specific Energy

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Mechanical Specific Energy

Typical approach to Minimize MSE using open to atmosphere circulating system

Limited to only minimizing the numerator

\[ \text{MSE} = \frac{W}{A} + \frac{(2\pi/A)(NT/\mu)}{ } \]

- Decrease weight on bit (W)
- Decrease rpm (N)
- Decrease torque (T)

This approach limits drilling performance
MSE and Differential Pressure

Correlates ROP and differential pressure between hydrostatic of mud column and pore pressure

\[ ROP_2 = ROP_1 e^{cD(MW1 - MW2)} \]

Where:
- ROP = Rate of Penetration
- MW1 = Mud weight at ROP1
- MW2 = Modified mud weight
- D = Well depth
- C = constant based on formation, bit type, & WOB
Managed Pressure Drilling (Definition per IADC)

“Managed Pressure Drilling (MPD) is an adaptive drilling process used to precisely control the annular pressure profile through out the wellbore. The objectives are to ascertain the down hole pressure environment limits and to manage the annular hydraulic pressure profile accordingly. MPD is intended to avoid continuous influx of formation fluids to the surface. Any influx incidental to the operation will be safely contained using appropriate process.”
Optimized performance & enhanced control by closing the loop
ECD Components

- **Conventional**
  - ECD = Hyd Pressure + Frictional Pressure

- **MPD**
  - ECD = Hyd Press + Frictional Pressure + Back Pressure
Monitoring of Critical parameter trends

Flow In & Out
Mud Density In & Out
Choke Pressure, Stand Pipe Pressure & Bottom Hole Pressure
Choke Position
Dynamic Pore Pressure Test
Benefits of MPD for Shale Drilling

- MPD allows for added control and optimization of ECD
  - Allows for enhanced mud weight management during drilling

- Direct versus Invisible NPT
  - Elimination of Non productive events through better control and handling of downhole issues
    - High pressure low volume Gas stringers
  - Improvement of drilling efficiency (i.e. ROP) via mud weight optimization
Mechanical Specific Energy

CLD approach to Minimize MSE using closed circulating system

- Maximize the denominator

\[ \text{MSE} = \frac{W}{A} + 2\pi \frac{N\tau}{\mu} \]

- Increase rate of penetration (\(\mu\))

Decrease of MSE (via \(\mu\)) allows for lighter weight drill pipe, less rpm and torque

- Therefore allows for utilization of smaller rigs and less capable and less expensive rigs
ROP Impact on MSE

- ROP With Increasing MW (ft/hr)
- ROP with Constant MW (ft/hr)
- Increasing Mud Weight (ppg)
- Constant Mud Weight = 14.1 ppg

Rate of Penetration (ft/hr)

Mud Weight (ppg)

Depth (ft)
Haynesville Gas Shale – Results

- Reduced overall drilling time on 4 wells by 49% and saved more than $2 million USD.
- Improved ROP at curve and lateral through use of 14.8 vs 16.5 ppg mud.
- More time drilling and not circulating out kicks at high temperature.
- MPD enhanced safety through managing large quantities of gas at surface.
- Reduce NPT through early influx detection and precision control chokes used to deplete the high volume-low volume fractures within hours.
- Enhanced nuisance gas management capability.
- Augmented well control from flow change identification via coriolis and mass balance (even in high gas environment).
Haynesville Gas Shale – Results

Well #2 Depth vs. Days
Plan vs. Actual

DEPTH in FEET

DATE

15 Days Ahead of Plan

48% Improvement in Depth vs. Days Against Planned # of Days
Haynesville Gas Shale – Results

10 Well Campaign Depth vs Days
(Last 4 With MPD)
Argentina – Shale Oil

- Vaca Muerta – Shale formation
- Pore pressure uncertainty
- LOC / Influx ~ differential stick
- UBD/MPD (42 wells since 2009)
- Drilling optimization = Reduce NPT and risk management
  - Balloning, LOC, Influx
  - Ability for dynamic well control
  - Improve in safety (gas management)
- Pore pressure validation
- Early identification of production
- Minimize formation damage
MPD Benefits - Non Conventional Resource Development

- Consideration of “Assembly Line” approach in shale drilling & completion technologies is important. Even marginal increase in drilling efficiency can lead to significant saving in field development cost.
- Improving drilling efficiency in shale drilling requires reduction in both visible and invisible non-productive time (NPT due to slow ROP). Improving ROP requires MSE optimization and improved drilling efficiency.
- Real-time optimization of MSE by monitoring and control of drilling parameters is effective way to increase drilling efficiency and increase rate of penetration. Real-time adjustment of WOB, rotational speed and torque has proved helpful to optimize MSE.
MPD Benefits (Continued)

- Wellbore pressure (BHP) affects rate of penetration in a significant manner. Optimizing BHP / ECD by manipulating mud density, surface back pressure and mud properties will improve ROP by optimizing MSE.

- Managed Pressure Drilling (MPD) Techniques enables real-time monitoring and optimization of Bottom Hole Pressure. CBHP technique of MPD can reduce mud weight required to drill the well as compared with conventional drilling.

- Real-time monitoring and control of ECD / BHP using automated MPD system will reduce amount of overbalance, yielding improved ROP and increased drilling efficiency.

- MPD techniques have proven very effective in drilling challenging wells into conventional reservoirs. Similar success can be replicated with drilling into shale plays as well.
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