Overcoming Challenges for Drilling High-Dogleg-Severity Curves

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Content

• Challenges of current drilling systems in unconventional oil & gas applications

• Technology solution:
  – High-build rate Rotary Steerable System
  – Background and principles

• Case Study – Eagle Ford Shale
• Case Study – Granite Wash Tight Sands

• Conclusion and Outlook
**Unconventional Hydrocarbon Challenges**

- Typical unconventional hydrocarbon drilling applications:
  - 10-14°/100-ft dogleg severity curve and long horizontal section
  - Drilling predominantly with steerable motor systems

- Common Challenges:
  - Toolface Control with high-performance drill bits
  - Low ROP while sliding/ steering
  - BHA trips between curve and lateral (change of motor settings)
  - Tortuous wells complicate completions

- Rotary Steerable Systems promise improvements
  - Current systems not fully fit-for purpose
Addressing Drilling Challenges with RSS

- Benefits of rotary steerable drilling proven in complex well profiles and long lateral sections:
  - Better drilling performance and lower risk with constant drill string rotation
  - Easy steering control via surface command
  - Better wellbore placement and horizontal reach
  - Improved wellbore geometry facilitates completions and production

- Constraints:
  - Commercial RSS for 5-8°/100-ft build rates
  - Small leases on land require higher BUR
  - Today: Curve drilled with Motor, lateral with RSS

- Need for high build-rate RSS to drill curve and lateral in one run
The Technology Concept

• High build-rate RSS technology requirements:
  – Increase bit deflection and BHA flexibility
  – No compromise of reliability and performance rating
  – Conserve good steering control and good hole quality

• Solution Principles:
  – Highly reliable rib-steering system with modified geometry
  – Actuators decoupled from string rotation
  – Dedicated drill bit design
  – Increased flex section in BHA
High-Build Rate RSS Components

• Bottomhole Assembly:

  - Engineered gage geometry and side-cutting properties
  - Depth-of-cut control features
  - Balance of aggressiveness and stability
  - High drilling performance and good hole quality

• Specific PDC Drill Bit:
  - Engineered gage geometry and side-cutting properties
  - Depth-of-cut control features
  - Balance of aggressiveness and stability
  - High drilling performance and good hole quality
Case Study I – Eagle Ford Shale

• Challenges
  – Inconsistent BUR in curve interval
  – Low ROP’s in Slide
  – PDC Bit Vibrations, High Stick-Slip, High Torque
  – Staying in Zone while Drilling Lateral
  – Hole Cleaning, Balling
  – Wellbore Stability, Pack Offs, Stuck
Eagle Ford Well #1 – Well Profile

- High-Build rate RSS, Well #1:
  - Kick-off at 8,500-ft MD
  - Build curve at 8°/100-ft
  - Left turn at 1.5°/100-ft turn rate
  - Target Inclination 89°, 6.370-ft lateral section

- Offset Well benchmark:
  - Steerable motor assembly in curve and part of lateral
  - Motor-powered standard RSS in majority of the lateral
Eagle Ford Well #1 – High-Build Rate RSS Results

- Drilled 6,970 ft from kick-off to TD in single run
- Consistently met 8°/100-ft DLS requirement
- Saved 4.7 drilling days (40%) vs. offset
- Superior hole quality

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Eagle Ford Well #1 – Borehole Quality

- Offset wells (steerable motor systems):
  - High tortuosity - high friction
  - Lubricant required to drill out plugs after fracturing
  - Additional completion cost

- High build-rate RSS well:
  - Smooth profile
  - No need for additional lubricant
  - Reduced time to drill out plugs
  - Significant reduction in completion cost
Eagle Ford Well #2 – Well Profile

• High-Build rate RSS, Well #2:
  – Kick-off at 8,582’ MD
  – Combined build & left turn in curve section
  – Build rate 10°/100’, turn rate 1.5°/100’
  – Target Inclination 91.6°, 5,500-ft lateral section

• 4 Offset wells:
  – Steerable motor assemblies in all curve sections
  – Standard RSS with and without motor addition in laterals
Eagle Ford Well #2 – High-Build Rate RSS Results

- Drilled Curve and lateral to 14,187-ft MD
- Well profile drilled to plan
- Met/ Exceeded required 10°/100-ft DLS
- Saved 2.64 days (25%) vs. best offset well, despite one trip
Case Study 2 – Granite Wash Tight Sands

- Challenging sequence of interbedded sandstones, silts, and shales

- Steerable Motor experience:
  - High bend settings to achieve BUR
  - Difficult toolface control
  - Limited rotary RPM
  - Unacceptable ROP

- Conventional RSS:
  - BUR limited to ~4°/100-ft
  - Inconsistent directional performance
Granite Wash – Well Profile

- Drill curve and lateral with PDC bit
- Improve penetration rates
- Land curve at 89.4°, 12,158-ft TVD
- Build rate: 10°/100-ft
- 3,926-ft lateral section
Granite Wash – HBUR RSS results

- Drilled curve and part of lateral until bit trip
- Met 10°/100-ft BUR requirement
- Drilled precisely to well plan
- 28% ROP improvement vs. best offset (from 18 to 23-ft/hr)
- 47% cost per foot improvement vs. best offset

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Conclusion and Outlook

• Successful collaboration between operators and service provider to address drilling challenges

• High-Build rate RSS concept proven:
  – Dedicated component, BHA and drill-bit design
  – Consistent BUR >8-10°/100-ft
  – Curve and lateral drilled with one BHA
  – Improved drilling performance
  – Precise Steering per well plan
Conclusion and Outlook

• Straight tangents and smooth curves reduce completion time and cost:
  – Trouble-free casing runs
  – Optimized plug & perf process

• Outlook:
  – Further expand RSS build-rate capabilities
  – Optimize BHA and application-specific drill bit for further drilling performance increase
Thank You!

Questions?