Bridging the Gap Between Drilling and Completions

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Presentation Format

- Define the challenge
- Evolution of technologies
- Establish today’s baseline
- What does the future hold
- Conclusions
The Challenge

Economic development of unconventional reservoirs necessitated the development of leading edge horizontal drilling and well completion techniques.
The question for today

Can we drill longer wells than we can effectively complete?
Scope: Stimulated horizontal wells

Horizontal wells...

- Are getting longer and longer
- Require more stimulation stages
- Must be optimized; not just efficient and economical
- Environmental concerns can not be ignored
Let’s start with some history

First HZ Well Multi-Stage Fracturing Treatments
The Dan Field Today

Western Flank

2.5 miles

Central Platform Complex

Original well

Reference: Danish Energy Agency “Oil and Gas Production in Denmark” (2013)
Halfdan Field (2000)

The Challenges

• Thin, flat reservoir requiring stimulation in order to produce at economical rates

• Lateral sections up to 20,000 ft

• > 50% of laterals outside of coiled tubing reach

Reference SPE 71322, 76220, 78318 and SPE 106531
The Halfdan Field Today

4-D seismic confirms effective drainage along the full length of the laterals

Reference SPE 71322, 78220, 78318, and SPE 108531
Unlocking reserves through horizontal drilling and completion technologies

US Energy Information Administration: “Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States” (June 13, 2013)
By 2010, 90% of the wells in the Bakken were horizontal with multi-stage fracs and the operators were preparing to ramp up in the Eagle Ford.
Bridging the gap between drilling and completions

What are today’s challenges?

• Time and money
• Laterals are getting longer
• Availability of materials, especially water
• Public perception and environmental regulations
• Selecting the optimum completion for a given area
• Access to service providers
The composite cost of wells in the USA has fallen between 10-50%, depending upon the play.
Brief Introduction to the Bakken

Bakken Petroleum System

Gamma Resistivity

Lodgepole
Upper
Middle
Lower
Birdbear

MB, TF1, TF2
MB or TF1
MB, TF1, TF2 & TF3
MB & TF1
MB & TF1

18 Miles

Map showing the distribution of MB, TF1, TF2 & TF3 in the Bakken region.
Tight Oil Breakeven Prices
2016 “High Grading” Example

Source: Morgan Stanley, Rystad Energy, EIA, AlexPartners (March 2016)
What will happen in 2016, 2017?

Drilled Uncompleted Wells

- 4,000 DUCs (~ 2 billion bbl oil)
  - 930 DUCs in Bakken
- 800 less DUCS by year end*
  - 300,000-350,000 BPD

Important questions:

- Where is the opportunity in this challenge?
- How do we prepare for the recovery when it happens?

*Note: The term DUCS refers to Drilled, Uncompleted, and Shelved Wells.
Enhanced Completions

EUR Up Another 5% From 4Q 2015

35% – 45% increase in EUR

Production Uplift
~60% Slickwater (53 Wells)
(10% higher than last quarter)

~45% Hybrid (65 Wells)
(10% higher than last quarter)

Average Standard Completion
Offsetting Legacy Wells

Source: Continental Resources May 2016 Investor Presentation
Water Requirements – Horizontal Wells
Drilling vs. Completions

• Significantly more water is used during completion compared to drilling; however,
• The amount is a small percentage of all industrial water usage

Source: US Geological Survey Fact Sheet 2014-3010 (March 2014)
Produced Water Recycling Facility
Reference SPEPOS Panel Session on Water Management for Hydraulic Fracturing, March 2015

Components
• Produced water storage
• Skim or flocculation
• Treatment to remove organics
• Underground water transfer pipelines

Economic Benefits
• Low OPEX ~ $0.30-$0.50/bbl
• Facilities generate revenue
• Minimizes salt water disposal
• 30% reduction in fresh water consumption

Note: Temporary recycling facilities are available which do not require CAPEX

OPEX is $2.50-$3.60/bbl, depending upon produced water quality and throughput
Pushing the limits of lateral length

- 1st horizontal Bakken well with multiple frac stages
- 1st 2-mile lateral
- 1st 3-mile lateral

Timeline:
- 1985
- 1987
- 1989
- 1991
- 1993
- 1995
- 1997
- 1999
- 2001
- 2003
- 2005
- 2007
- 2009
- 2011
- 2013
- 2015
Drilling Efficiency Gains with Longer Laterals

Challenge:

• Accessing “offshore reserves”
• Surface constraints
Drilling Efficiency Gains with Longer Laterals

Solution:

• Directional drilling
• Extended lateral developments
Chasing the drilling rig

- Steering the lateral
- Where to perforate
- Toe stimulation
- Stage isolation
- Post frac cleanout
Challenge: Steering the Lateral

- Geo-steering
- Mud logging
- Cuttings analysis
- Gas analysis
- Biostratigraphy
- Logging while drilling
- Thru-bit logging
- Paleo-environmental analysis

Is this what your lateral looks like?
Challenge: Quantifying rock properties

Is your rock brittle or ductile?

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<th>Fracture Geometry</th>
<th>Stress Anisotropy</th>
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Reference SPE 115258, 152704, 164271, 167726, 168763
Challenge: Stage Isolation

- Plug-and-perf
- Ball activated sleeves
- Coiled tubing activated
Plug-and-Perf Completions

P’n’P; along with “zipper fracturing” reduced completion times significantly
Challenge: Frac plug mill-out

Solutions:
• Larger ID coiled tubing
• Large ID frac plugs
• Dissolvable frac plugs

Images courtesy of Halliburton Energy Services, Baker Hughes, Magnum Tools, and Schlumberger
Challenge: Reducing Completion Time
Ball Activated Sleeves Systems

Historically: open hole with single ports

Today: fully cemented with multiple ports

Images courtesy of Halliburton Energy Services
Coiled Tubing Fracturing

Sleeves are run in the liner, then shifted with coiled tubing during stimulation operations.
Coiled Tubing Fracturing

C: Coiled tubing inside the work string provides a circulation path for the frac fluid and proppants

A: Resettable plug grips and shifts the sliding sleeve

B: Frac is pumped down the annulus between the coiled tubing and the liner then exits out the frac port

D: Precise fracture placement, with theoretically unlimited stages

Images courtesy of NCS Energy Services
Full circle in horizontal well completion technologies

Today and Future:
Completion technologies developed onshore being applied offshore

North Sea:
• Directional drilling
• Extended reach wells
• Horizontal wells with multi-stage stimulations

Unconventionals:
• Fracturing technologies
• Completion techniques
• Completion hardware

Onshore conventional reservoirs:
• Tight gas
• Mature fields
• Horizontal wells
  – Austin Chalk, Texas
  – North Slope, Alaska

Inspiration credit: Martin Rylance, JPT, April 2015
Technology sharing

• Collaborate
  – All disciplines: geosciences, drilling, completions, production
  – With service providers and other operators

• Accelerate learning curve
  – Learn from both successes and failures
  – Think outside the box when looking for analogs

• Be prepared
  – There will be a shortage of skilled people
  – Keep focus on being effective not just efficient
In conclusion:

Does completion technology lag behind drilling technology?

- Drilling envelope is pushed first
- Completion technology is a fast follower
Your Feedback is Important

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