Horizontal Drilling – Technology Review, Current Applications, and It’s Future in Developing Kansas’ Petroleum Resources

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Outline

• 1. Types of horizontal wells
• 2. Basic engineering and geology that define drainage radius in horizontal wells, design, and evaluation
• 3. Statistics on current horizontal drilling in Kansas and types of reservoirs being drilled with laterals
• 4. Case study in Kansas – New lateral in Hunton dolomite, Unger Field, Marion County
• 5. Expectations for horizontal drilling in the future
1. Types of horizontal wells

Reservoir Applications

- Naturally fractured reservoirs
  - Austin Chalk Niobrara Chalk (NW KS)
  - Bakken Shale Chattanooga Shale (OK)
- Formations with water & gas coning
  - Gulf of Mexico
  - Elk Hills, California
    - Arbuckle, Hunton
    - Mississippian, Morrow
- Heavy oil reservoirs/Thermal application
  - California
- Coal Bed Methane
  - Southeast Kansas Cherkee

Naturally fractured reservoir – Gas-bearing shale

Completion → vertical well with induced lateral fractures
→ horizontal well with induced vertical fractures
History of Horizontal Wells

• Short Radius
• Medium radius, downhole motors, 1985
• Re-entry drilling, 1995
• Coil tubing drilling – underbalanced
• Rotary steerable system
• Fracture stimulation of horizontal wells
Extended Reach – Option 1
Water-Jetted Laterals

Comparing Radial Drilling Penetration vs. Conventional Perforation

Conventional Perforation
Average 20”-60”

Radial Drilling Perforation
Average Up to 300 ft.

Radcan Energy Services, Inc.
Extended Reach – Option 2

Coil-tubing conveyed horizontal lateral
--First Highly Efficient Hybrid CT Rig

Built and Operating on U.S. Soil

World Oil Awards 2005
New Horizons Nominee

Advanced Drilling Technology, Yuma, CO
& Rosewood Resources, Inc.

- Rapid mob/demob
- Four trailer loads
- 2800 ft completed in <24 hrs
- Important in Niobrara play >1 TC
- Lateral drilling capability

About 300,000 feet of hole in 7 months
Niobrara Chalk, NW Kansas

Photo courtesy Tom Gipson, Advanced Drilling Technologies, LLC
Extended Reach – Option 3

*Lateral Drilling with Conventional Tools*

- **Minimal technical risk – mature technology used worldwide**
  - Tight directional control
  - Unlimited lateral length – to drain multiple karst compartments

- **Cost-effective in mature field environment**
  - Relative ease to contract conventional rigs – low mobilization costs
  - Easy to get directional tools, drillers, and, tool push logging tools from OK

- **Highest operator comfort – least steep learning curve**

- **Post-drilling tool-push logging helps quantify production potential of the horizontal well and assess level of success**
Horizontal Drilling in Kansas

Definitions & Terms

Common terms used to describe horizontal wells

\[
\text{VERTICAL PROFILE: 332 NW}
\]

\[
\begin{align*}
\text{Kick Off Point} & \\
\text{Bend} & \\
\text{Radius in Ft.} & \\
\text{Degrees / 100 Ft} & \\
\text{Degrees / Ft.} & \\
\text{Deepest TVD: 2371 ft} & \\
\text{Lateral Heel} & \\
\text{Lateral Length} & \\
\text{Lateral Toe} & \\
\text{MD: 4031 ft} & \\
\text{TVD: 2364 ft} &
\end{align*}
\]

MWD - "Measurement While Drilling"
Azimuth, Inclination, Measured Depth

LWD - "Logging While Drilling"
most standard vertical hole e-logs

PIF - "Productivity Improvement Factor"
multiplier of production increase over offset vertical wells

Gerlach (2000)
Horizontal Well Planning

- Well plan
- Target
- Geosteering
- Formation evaluation
- Completion
- Drilling tools, methods - limitations, costs
- Production equipment
Halliburton
GABI™ Sensor - Gamma/At-Bit
Inclination
Azimuthal gamma ray – detect and avoid shale roof rock at top of the oil reservoir
Completion of Horizontal Wells

• Open hole
• Slotted liners
• Case and perforate – to isolate oil and gas bearing intervals
• Install sensor and valves in multilaterals to control flow as laterals water out
• Acidizing
• Fracture stimulation

Sidetrack to top of pay zone
Lateral drilled in Chester sandstone

most recently released report

### Scientific Drilling International

**Survey Report**

<table>
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<tr>
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<td>Survey</td>
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**Survey Details**

- BX: Burchard 14-41-23/23-23
- Well: Chester 14-1-1
- Date: August 2007
- Time: 2007-08-01
- Page: 3

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**Detailed reporting of well trajectory**

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**Received and compared with conventional methods**

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**MAY 2007**

**CONSERVATION DISTRICT**

**WICHITA, KS**
Multilaterals with conventional horizontal drilling technology
Example of Complex Laterals

J. Rush, KGS
300 ft thick limestone reservoir with oil accumulation on broad structural trap

Laterals drilled from offshore platforms

Field produces ~135,000 BOPD
2) Basic engineering and geology that define drainage radius in horizontal wells, design, and evaluation
Productivity Improvement Factor

Distribution of Productivity in 96 horizontal wells

Joshi Technologies International, Inc.
Reservoir with Uniform Horizontal Permeability \( (k_y/k_x = 1) \)

Vertical Well
Drainage Area = 40 Acres
\( x_{ev}/y_{ev} = 1 \)

Horizontal Well
Drainage Area = 100 Acres
\( x_{eh}/y_{eh} = 2.5 \)

Note extended drainage area off ends of the lateral

Joshi Technologies International, Inc.
Models used to predict recovery of a horizontal well

Ness City North Cellular Models

Facies recognition is critical to reservoir characterization, geomodeling and reservoir simulation.

4-Layer Model, 110 foot grid cells

Work of Saibal Bhattacharya

Residual Oil Sat.
Simulation modeling of drainage and oil recovery from horizontal well -- Ness City North Field

Ness City North Horizontal Infill Well – Production Potential, Drainage & Interference on Existing Wells

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<td>2013</td>
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Reservoir properties strongly affect how horizontal wells behave.

Drilling Outcome -- Ness City North

Reservoir Heterogeneity

- Strong Horizontal Heterogeneity
  - 10’ - 100’ Interval
  - Karst Controlled
- Result Poor Lateral Drainage
3. Statistics on current horizontal drilling and types of reservoirs being drilled with laterals
## U.S. Horizontal Completions - State Summary

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<th>2008</th>
<th>2009</th>
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<td>717</td>
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<td><strong>5,012</strong></td>
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**Kansas** | 86 | 3 | 3 | 36 | 16 | 11

**JTI**

Joshi Technologies International, Inc.
Horizontal Wells in Kansas (October 2010) – Mississippian highlighted

- Cherry Creek & Goodland Gas Areas (Niobrara)
- Warsaw & Osage (Mississippian) Dolomite and chert
- Bradshaw & Hugoton Fields Gas Wells (Chase Group)
- Osage (Mississippian) Cherty dolomitic oil reservoirs
- Coal-bed methane Wells (Cherokee Group)
- Morrow/Chester
- Arbuckle
# Horizontal Wells in Kansas

**Total producing oil wells**: 238

**Wells with oil production**: 20

**Success rate (%)**: 8.4

- Niobrara chalk shallow gas: 61
- Chase-Council Grove: 10
- Lansing-Kansas City: 2
- Cherokee CBM: 15
- McLouth Sandstone: 9
- Morrow-Chester: 16
- Mississippian carbonates: 22
- Viola: 7
- Arbuckle: 8

**403,430 bbls** -- Best horizontal well drilled in Kansas to date – an infill well drilled in 1997 by Ensign Operating Company in Mississippian Warsaw Dolomite in Aldrich NE Field, Ness County -- 1400 ft lateral drilled and completed open hole by Halliburton services. Initially, low productivity due to mud damage; cleaned up with acid for excellent well.
4. Case studies in Kansas - Mississippian Warsaw dolomite reservoir in Ness County and Hunton dolomite in Marion County
**Section 19**

Unger Field
Structure map and cross section index
Contour Interval = 5 ft

Upper blue number = thickness of Hunton reservoir

Original O/W ~-1420 ft

Proposed Location of Lateral

DST data from:
- Slocombe 5, 6
- Mellot 4
- Rood 1, 2, 3, 4, 5, 7
NW-SE Structural Cross Section #1

Target zone for lateral Paralleling cross section

900 ft

SP-Caliper-Microlog curves shown – SP depicted in color delimiting magnitude
Horizontal Drilling Plan – Unger Field, Marion County, Kansas

American Energy Corporation

Unger Field

WELL PROFILE DATA

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<th>MD</th>
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1,700 ft lateral
Partners in Unger Field Drilling

Design and well site supervision on over 300 horizontal wells drilled including multi-laterals in Oklahoma Hunton, Arbuckle, Barnett Shale and others – up to 8,000' lateral displacement

Focus Gamma (sensor) -- To avoid shale caprock above reservoir

FIG. 1
5. Expectations for horizontal drilling in the future
Hugoton Embayment
Chester, Morrow sandstones, St. Louis limestone

Central Kansas Uplift
Lansing-Kansas City Arbuckle

West Flank CKU
Mississippian Osage, Warwaw chert and dolomite reservoirs

Northwest Shelf
Shallow gas
Niobrara Chalk

Sedgwick Basin
Mississippian Viola & Hunton

Hugoton Gas Field
Mississippian Chert Oil Reservoirs

Pratt Anticline
Mississippian oil sands

Cherokee Basin
CBM
Pennsylvanian oil sands
Producibility problems addressed with horizontal wells

• Mature fields – often have high water cut, strong water drive
• Current production practice – use conventional vertical wells
• Limited lateral drainage in vertical well
• Significant variation in producibility between adjacent wells
• Residual pockets of oil possibly located in the interwell areas outside the drainage reach of vertical wells
• Often reservoirs are compartmentalized (karstification and subcropping strata)
  – Wells located in small compartment have short production life, uneconomic cumulative volumes
  – Wells located (by chance) in large compartments – long production life
• Effective pay zones in Kansas are thin (less than 20 ft)
• Limited resource-reach of operators – financial and technical
Proposed solution – cost-effective extended reach horizontal lateral

- Has to be cost-effective – drilling, logging, and completion
- Has to be have minimal technical risks – for independent operators to be interested and apply for infill drilling
- Must have tight directional control to --
  - Reach and drain targeted pockets of remaining reserves in the inter well region
  - Have trajectory constrained within thin pay
- Would have significant added advantage, if one targeted well could drain multiple karst compartments
- Needs to produce economic volumes under constrained drawdown in order to reduce water cut
  - Low water cut – helps keep oil relative permeability high in the near well region
  - Results in better sweep of residual oil