Knowledge of Reservoirs Helps Us Understand Where We Are & Where We Are Going

Robert Kleinberg
Schlumberger

Center for Strategic & International Studies
20 May 2015
Schlumberger is a provider of hydraulic fracturing services that
• develops and provides fracture fluid chemicals
• designs and executes hydraulic fractures using its own personnel and equipment

These remarks will often, but not necessarily always, reflect the views of Schlumberger.
Tight Oil = Difficult Oil

<table>
<thead>
<tr>
<th></th>
<th>Annual Decline Rate</th>
<th>Recovery Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Oil Wells</td>
<td>5% – 10%</td>
<td>50%</td>
</tr>
<tr>
<td>Tight Oil Wells</td>
<td>&gt; 50%</td>
<td>5% – 10%</td>
</tr>
</tbody>
</table>

rough numbers
Recovery Methods

Conventional Oil

Primary Recovery
- Depletion Drive
- Solution Gas Drive

Secondary Recovery
- Pressure Maintenance
  - Water Drive
  - Gas Drive

Tertiary Recovery
- Carbon Dioxide
- Steam
- Miscible Solvent
- Surfactant
Recovery Methods
Tight Oil

Primary Recovery

Depletion Drive
Solution Gas Drive
Primary Recovery: Depletion Drive & Solution Gas Drive

- Reservoir
- Oil + CH₄ + NGL
- Solution Gas Drive
- Depletion Drive
- Critical Point
- Dew Point Line
- Bubble Point Line
- % Liquid
- Temperature
- Pressure
Consequences of Solution Gas Drive

- Associated gas in tight oil reservoirs is being produced copiously, leading to a glut of ethane and other natural gas liquids in the U.S.

- The 90-95% of the oil that is left behind is gas-depleted ("dead").

- Enhanced oil recovery technologies may help us produce dead tight oil some day – but without the associated gas.
The Glut of Cheap Ethane has Encouraged a Dramatic Expansion of US Ethylene Cracker Capacity

Existing (pre-2014) and Planned (2014-2018) thousand barrels per day

- conversions
- restarts and expansions (planned 2014-2018)
- new ethylene crackers

Existing plants (pre-2014)

Ethane feed

Ethylene crackers

EIA Today in Energy, 29 January 2015
http://www.eia.gov/todayinenergy/detail.cfm?id=19771#
Decline Curves and the Red Queen Race

**Conventional**
- Initial Production = 1000 bbl/d
- 10 year cumulative = 2.7 mmbbl

**Bakken**
- Initial Production = 1000 bbl/d
- 10 year cumulative = 0.9 mmbbl

IHS is more optimistic than Wood Mackenzie or EIA for 24-120 months.

Bakken Decline Curve after IHS Bakken Play Workbook, August 2013
scaled to IP = 1000 bbl/d
The Red Queen Race

“It takes all the running you can do, to keep in the same place.” – Lewis Carroll

The Red Queen, pronouncing sentence on inefficient drillers.

Bakken Decline Curve after IHS Bakken Play Workbook, August 2013
scaled to IP = 1000 bbl/d
Saudi Arabia boosts crude production to the highest in three decades in March, with a surge equal to half the daily output of the Bakken formation in North Dakota. In the space of 31 days, Saudi Arabia managed a production boost that took drillers in North Dakota’s Bakken almost 3 years to achieve.
Robert L. Kleinberg, Ph.D.
Unconventional Resources
Schlumberger-Doll Research
One Hampshire Street
Cambridge, MA  02139

617-768-2277
kleinberg@slb.com
http://www.linkedin.com/pub/robert-kleinberg/19/177/131