Primary funding is provided by
The SPE Foundation through member donations and a contribution from Offshore Europe

The Society is grateful to those companies that allow their professionals to serve as lecturers

Additional support provided by AIME
Recent Advances in Horizontal Well Water Shut-Off and Production Improvement

Keng Seng Chan
Petronas
Outline

- Improved Oil Recovery
- Simple Solution and Successful Case Histories
- Integrated Solution for Well Production Enhancement
- Use of Inflow Control Devices to enhance well performance
- Balancing Water Movement in Reservoir
- Conclusions and Recommendation
Improved Oil Production Strategy

- Maximize Reservoir Contact (MRC)
  - Horizontal Wells with or without Hydraulic Fractures
  - Multi-Laterals

- Improve Reservoir Oil Flow
  - Reduce Oil Viscosity (Steam, CO₂)
  - Reduce Interfacial Tension (Surfactant)

- Optimize Sweep and Conformance
  - Delay Water Breakthrough
  - Shut Off High Permeability Channels
  - Shut Off Excessive Water
  - Stimulate and Perforate for Enhancing Oil Inflow
The Trend of Oil and Gas Production*

Maximum Reservoir Contact  Extreme Reservoir Contact

The Enormous Need for Isolation and Control

Unlimited Number of Smart Laterals
Unlimited Number of Valves per Lateral
The Art of Multi-Laterals
(Example of Maximizing Reserve Contact)

- Productivity = 49 conventional and hydraulically fractured wells
- What if water enters your laterals?
Where the water enters your wellbore?

- Where the water comes from?
- How the water flows into your wells?
- Where the water enters your wellbore?
BRUNEI Bringing a Well Back to Life
by Akshay Sagar

A GROUND-BREAKING JOB enabled Total in Brunei to restore production on a dead well to 3,000 barrels of oil per day of natural production with only 1% water cut. The operation was completed safely via 10 tractor runs in a horizontal well without any downhole tool failures.

Two inflatable bridge plugs, the first ever to be set using MaxTRAC*, isolated a water producing zone, which was then successfully perforated. This intervention clearly demonstrated the value our combined technologies can bring to our clients. The new technologies deployed on this campaign were MaxTRAC, Wireline Perforation Shooting Tool (WPST*), Addressable Switch* and Secure Perforation*.

The success of the job was due to the professionalism of the Labuan team and the excellent job preparation. The detailed hazard analysis and job procedures demonstrated that we had good contingency plans in place to manage the risks, which gave the client confidence to proceed with the operation. The exceptional effort by the team to put together a specific maintenance container allowed the complete re-building of the tools in between the runs.

Horizontal Well
100% to 1% Water-Cut
3,000 BOPD Gain

Thanks to all who contributed to this success, including: Scott MacPhee, Ling Kea Hing, Sani Aliamat, Shanmugham Sambatham, Arsad Ladolo, Raja Sundaram, Mohd Yusaran Johary, Zalani Hj Taha, Faizal bin Hj Ismail, Greg Moore, Jong Vui Chin, and Juan Tai Eng.
Simple Solution
(If water entering from toe)

- Coiled Tubing with Cement or Gel

Horizontal Well
100% to 2% Water-Cut
2,500 BOPD Gain
Effect of Tunnel Length

Horizontal Tunnel Length, ft

Liquid Rate, BLPD

API 14.5

API 32
Fluid Slumping and Spreading in Horizontal Tunnel

- Highest injection point is 1907.2m MD
- Slumping span is about 9.6m

Graph showing:
- MD 1907.2m (TVD 1211.3m)
- 5.9m
- 5.2m
- 278.8m
- 3.5 degrees
- 10.2m span
- 8.5 inches
Case Example – Horizontal Well Drilling

- Drilling through high pressure water layer
- Poor or no wellbore layer isolation
- Water flows through the matrix and behind the pipe
- High pressure water blocked oil production from horizontal well
Treatment Procedure

- Clean inaccessible drain with a jetting tool
- Set a chemical temporary plug
- Set an acid-soluble cement plug
- Pressure test
- Perforate CT/TCP. Perform Injectivity Test
- Pump Polymer Cross-linked gel
- Pump a micro-fine cement
- Pressure test
- Cleanout plugs with a jetting tool
Treatment Procedure

- Clean inaccessible drain with a jetting tool
- Set a chemical temporary plug
- Set an acid-soluble cement plug
- Pressure test
- Perforate CT/TCP. Perform Injectivity Test
- Pump Polymer Cross-linked gel
- Pump a microfine cement
- Pressure test
- Cleanout plugs with a jetting tool
Results

- Water eliminated by 100%
- Full oil production restored
Integrated Solution for Horizontal Zonal Water Shut-Off and Production Optimization
ICD Types

- Nozzle Type ICD
- Orifice Type ICD
- Helical Channel ICD
- Tubular Type ICD
- AICD
ICD Minimizes Toe-Heel Effect (OTC-19172)

Heel’s high Influx!!

Screen Standalone

Toe’s Under-performed!!

ICD’s Completions

*Heel to Toe balanced Inflow Contribution*
ICD Improves Productivity (SPE 117213)

Not-equalized well
4 MBOD Oil 21% water cut

Equalized well
8 MBOD Oil 0% water cut
ICD Delays Water Breakthrough*

- Slotted Liner Completion
- No ICD
- Water Breakthrough 4.5 Years

- Slotted Liner Completion
- With ICD
- Water Breakthrough 9.2 Years

The Thin Oil Rim Reservoirs

- Multiple Gas Caps
- Huge Regional Aquifer
Thin Oil Rim Reservoirs
Force Balance to Control Bottom Water Movement

Produced Gas Injection
- Injection into Gas Cap
- Injection into Oil Rim
- GIGP Ratio

Water Injection
- Injection at GOC
- Injection at WOC
- Injection Rate

Water Production
- Selective Area
- Production under WOC
- Withdrawal Schedule
Force Balance in Oil Rim

- Horizontal well very low draw-down (< 25 Psi)
- Vertical well with varying draw-down (up to 650 Psi)
- Significant Gas Cap Expansion and high bottom water upward movement
- Horizontal well currently under water
- Vertical well can still produce with adjusted perforation interval
Well Oil Productivity Increase by Water Injection
A Tale of Two Wells

- 200 m lateral spacing for Well A05 & A10
- 5 m and 6 m above WOC respectively
Watch your Toes

SPE 122338, G. Kartoatmodjo et al, 2009 APOGCE
Horizontal Well Water Control

- Drill right. Watch your toe.
- Optimize the force balance in your reservoir, keep your wells in close contact with oil.
- Use of Inflow Control Devices to delay water breakthrough, minimize heel-toe effect, and improve productivity.
- Shut-Off excessive water entry
Your Feedback is Important

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