Intelligent Water-Alternating-Gas Process using Downhole Control Valve (WAG-CV): Concepts, Tools and Simulations

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Agenda

- The challenge: increasing oil recovery in Water Alternating Gas (WAG) EOR projects
- Proposed solution: Water Alternating Gas Control Valves (WAG-CV)
- Optimization process
- Simulation results
- Technical paper and patent
What drives the needs for EOR?

Mature Fields Snapshot

70% Amount of worldwide oil and gas production from mature fields

35% Average worldwide recovery factor for oil. Up to 70% in North Sea

1% Recovery factor increase needed for additional 2-year global oil and gas supply
The Challenge with Traditional WAG EOR Projects: Managing Heterogeneity and Increasing Recovery

- A traditional WAG flood involves injecting water for ~6 months followed by ~3-6 months of injecting gas
- 10 percent more oil recovery is expected from a traditional WAG than a water flood alone
- However, traditional WAGs face challenges:
  - Reservoir heterogeneity can result in inefficient sweep, reducing oil recovery
  - Injection rates are difficult to control along a lateral injector
- The proposed patented WAG-CV system addresses these challenges by enabling injection of water and gas selectively in different segments of a well
- This presentation shows the results of simulation in Nexus software to evaluate the potential benefits of WAG-CV in a “generic” horizontal injector and producer. The same principles apply to vertical or deviated injectors and producers
Proposed Solution: Water Alternating Gas Control Valves (WAG-CV)
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WAG-CV Proposed Optimization Process

**Water rate**

**Gas rate**

Gas and water are injected continually at wellhead

**Water is injected continually downhole**

**Gas is injected through zones**

- Downhole valve controls water rate per zones

**Multiple Optimization Technique**

At time step 1...

- Maximize oil and minimize water in each zone.
- Maximize oil and minimize water. Lower water cuts.

- Optimize Surface Gas Rate
- Optimize Surface Water Rate
- Optimize Valve Setting
- Determine gas injection time
- Determine water injection time
- Select Gas Zones On/off
Patented WAG-CV Completion Schematic
Saturations Based on Simulation

Water saturation

Gas saturation
Simulated Slug Injection Profile in Zone 1

Water Injection (STB/DAY) / Gas Injection (MSCF/DAY)
Simulated Slug Injection Profile in Zone 2

Water Injection (STB/DAY) / Gas Injection (MSCF/DAY)

Time (Days)
Simulated Slug Injection Profile in Zone 3

Water Injection (STB/DAY) / Gas Injection (MSCF/DAY)

Time (Days)
Simulated Slug Injection Profile in Zone 4

- Water Injection (STB/DAY)
- Gas Injection (MSCF/DAY)

Water Injection Graph:
- Y-axis: Water Injection (STB/DAY)
- X-axis: Time (Days)

Gas Injection Graph:
- Y-axis: Gas Injection (MSCF/DAY)
- X-axis: Time (Days)
Simulated Slug Injection Profile in Zone 5

- **Water Injection (STB/DAY)**
- **Gas Injection (MSCF/DAY)**

Water Injection (STB/DAY) / Gas Injection (MSCF/DAY) vs. Time (Days)
Simulated Relationship of Gas Versus Water Injection

Water/Gas Ratio

Time (Days)
Results: Oil Recovery Expectation Based on Simulation

- **Depletion drive**: 12%
- **Gas Injection**: 23%
- **Water Injection**: 30%
- **WAG**: 37%
- **WAG-CV**: 42%
Technical Paper and Patent

- Gustavo Carvajal, Michael Konopczynski, Alejandro Chacon and Steven Knabe Method, System and Optimization Technique to Improve Oil Reservoir Recovery in the Water-Alternating-Gas Injection Process by Using Downhole Control Valves (WAG-CV).