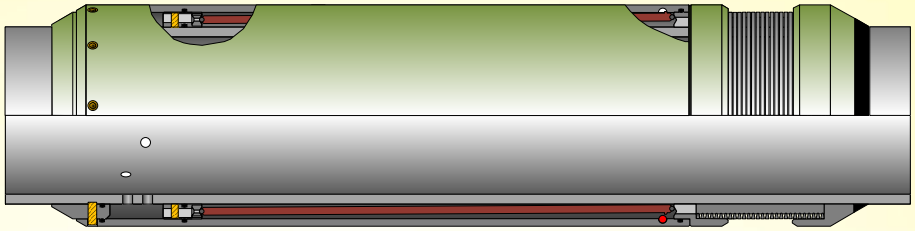

Robust Autonomous Flow Control Developments in Norway

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Inflow Control Tool Types

- There are two types of Inflow Control Tools
  - Flow reduction tools
  - Flow stop tools
- These can be installed separately or have a combined function. Examples follows
- Current understanding is that full flow stop is not optimal, a small flow is preferable

Outline of Presentation

- 1. Inflow control valves
  - 1.1 The ICD
  - 1.2 Autonomous Disc type valve
  - 1.3 Autonomous Constant flow valve
- 2. Autonomous water management technology
  - 2.1 Autonomous water stop
  - 2.2 Downhole reinjection
- Summary

1. Inflow Control Valves

1.1 The ICD (Inflow Control Device)

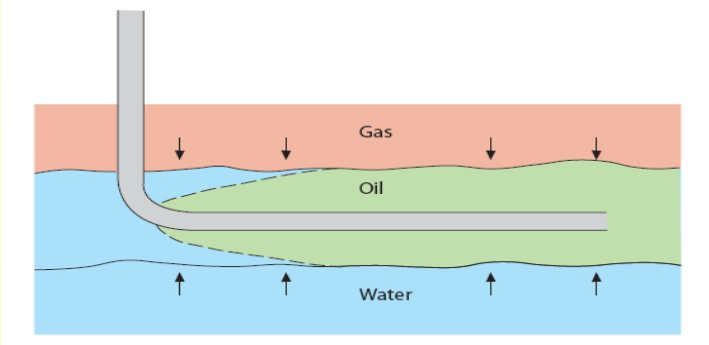
- Orifice, turbulent for low viscosity fluids
  - Sensitive to variations in density

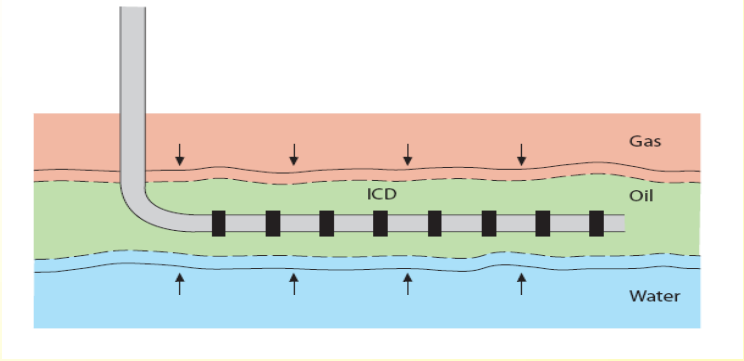
$$\Delta P \propto \rho Q^2$$

- Orifice, laminar flow for high-vis fluids
  - Sensitive to variations in viscosity

$$\Delta P \propto \mu Q$$

- Very successful in reducing coning in horizontal wells

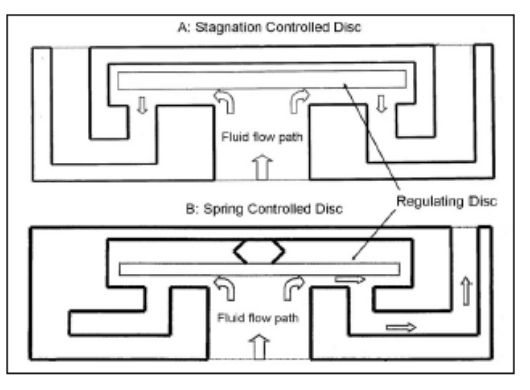


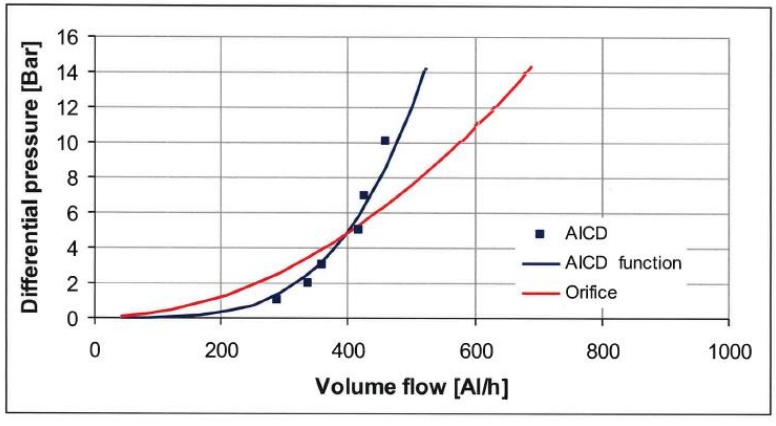


1.2 The Disc Valve

- The disc type valve
  - Similar to airplane wing
- Compared to ICD
  - Sharper response to flow
- Some advantages
  - More aggressive
  - Gravity independent tool
  - Simple
  - Efficient **gas** flow reducer
- Some concerns
  - Plugging, scaling
  - Good for water?

$$\Delta P \propto (\rho, \mu) Q^4$$



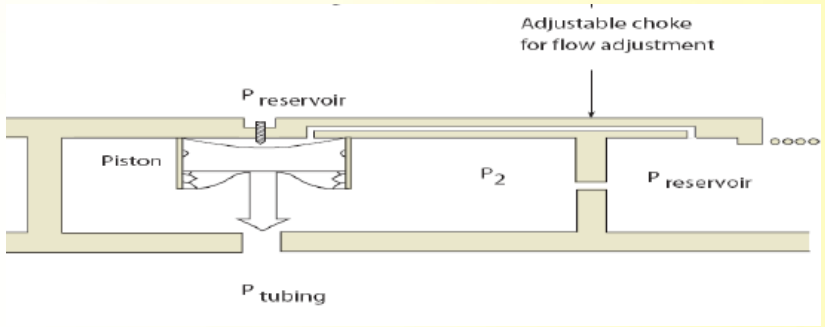


1.3 Autonomous Constant Flow Valve

- Autonomous Flow Device - AFD

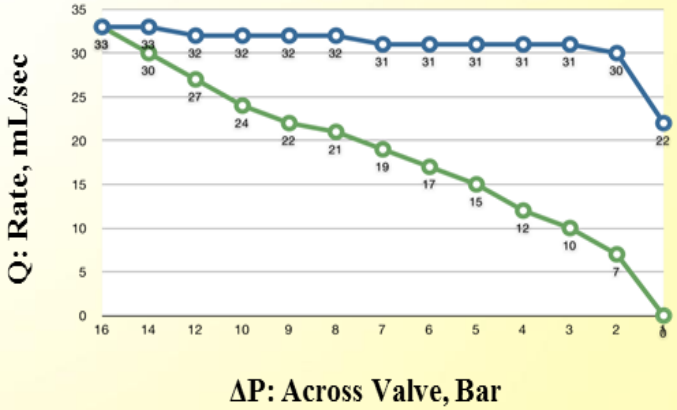
$$P_{reservoir} - P_{tubing} = \frac{KX}{A} + K_V \rho Q^2$$

$$Q = \sqrt{\frac{1}{K_V \rho}\left\{\left(P_{reservoir} - P_{tubing}\right) - \frac{KX}{A}\right\}}$$



- Flow constant regardless of pressures

- Properties of the constant flow valve:
  - WOC and GOC control
  - Higher production rates
  - Perfect for injectors



1.3 Autonomous Constant Flow Valve

- Comparison, faster production

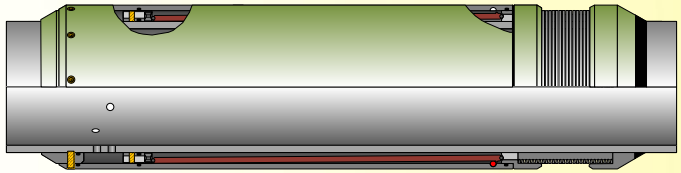
- Input data
  - Horizontal well
  - Reservoir length 3,600 m
  - 300 inflow control valves, one every 12.2 m
  - Initial flow rate 9900 bpd
  - Recoverable volume 10^8 barrels

Drainage analysis	ICD	AFD
Initial production rate	9900 bpd	9900 bpd
Final production rate	2120 bpd	9091 bpd
Time to drain reservoir	9 years	5.2 years

2. Autonomous water management

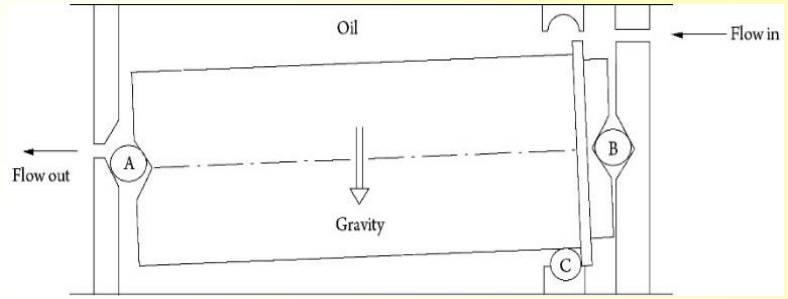
- Water production
  - 3 bbls water per bbl oil produced worldwide
  - Cost :4 – 5 $/bbl to handle
  - Reduces oil field recovery
- A new tool developed that can stop water*
  - Reversible, open if oil resume
  - Downhole water reinjection
  - Increase recovery

*Patented technology

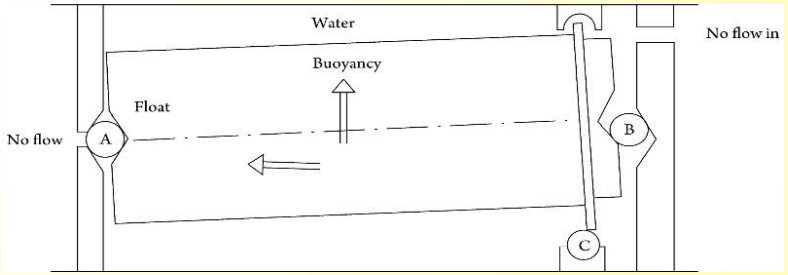


2. Autonomous water management

- 2.1 Autonomous water stop
  - Based on gravity
  - Float lifts with water
  - Symmetric, i.e. balls in recess
  - Run blindly into well

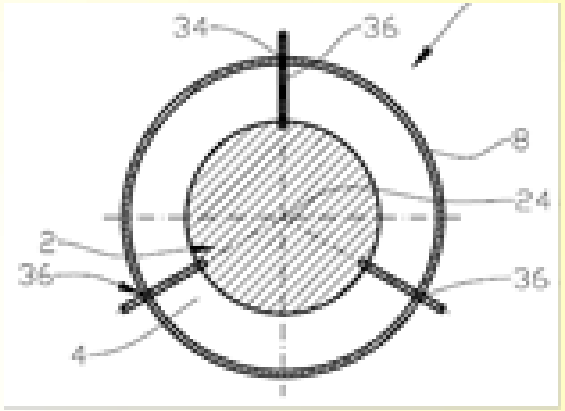


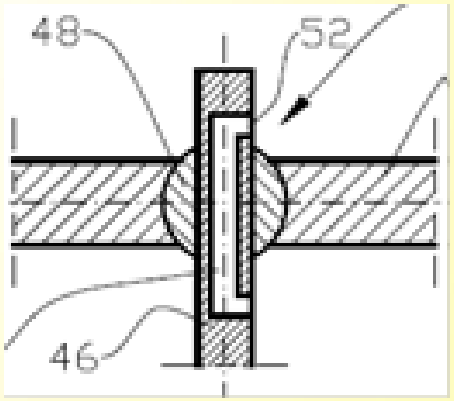
- With oil in tool (principle)
  - Float at bottom, orifice open
- Water in tool
  - Float rise, ball closes orifice
  - Produce water from zero to wanted flow



2.2 Autonomous water stop, cont.

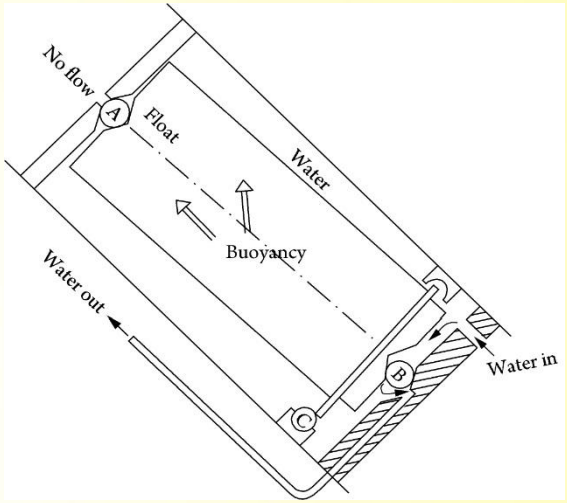
- Problem with ball type tools:
- When closed, well must be shut in to reopen
- Therefore, this tool is designed to be fully reversible; principle sliding rod



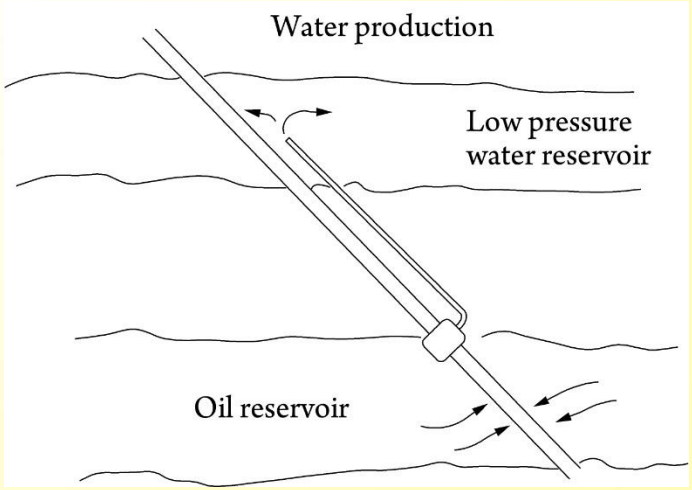


2.2 Autonomous water management

- Downhole water disposal
  - Two-way valve

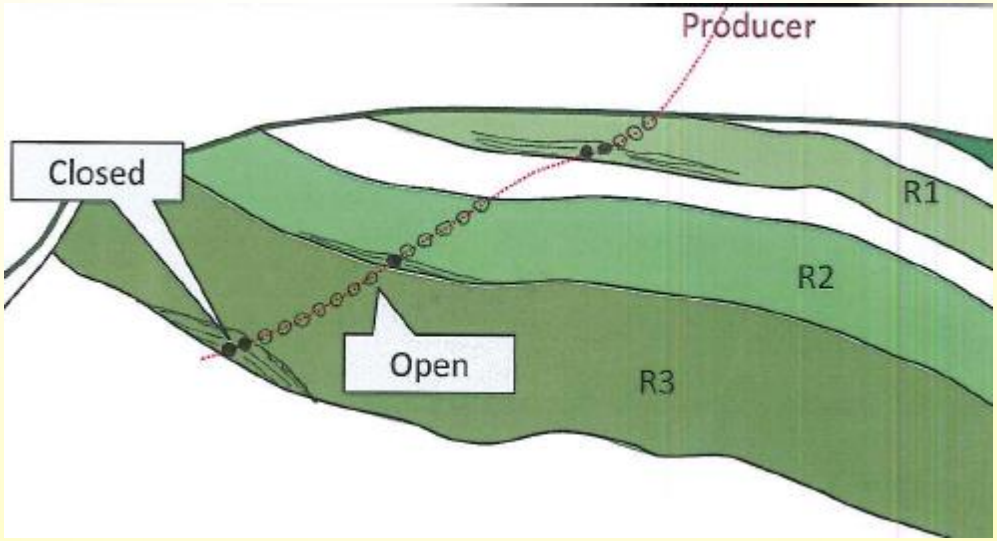


- Oil, upper valve open, bottom valve closed
- Water, upper valve closed, bottom valve open. Water is rerouted to another reservoir



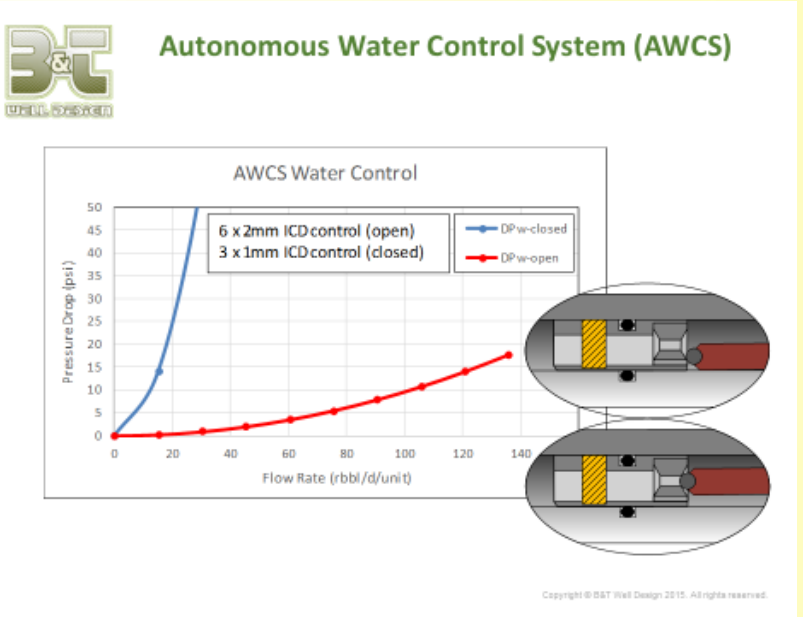
2.2 Autonomous water management

- Example application
  - 3 separate reservoirs
  - Water arrives unexpectedly
  - Reopening if oil returns
- Shut in all sections that produce water
- Produce untill all oil is gone
- Maximizes recovery



2.2 Autonomous water management

- Properties of autonomous water stop*
  - No tool orientation, runs blindly into the well
  - Works for all inclinations, vertical to horizontal
  - A simple mechanical device based on buoyancy
  - Can reinject produced water downhole
  - Is fully reversible
  - Optimal for commingling, maximizes recovery



*Patented technology

Summary

- Autonomous inflow technologies presented
  - Inflow control valves
    - ICD
    - Disc valves for gas stop
    - Constant flow valve for faster production
  - Autonomous water management technology
    - Simple tool, runs blindly into well
    - Fully reversible, opens if oil reenters tool
    - Two-way valve allows for downhole water disposal
    - Maximizes recovery