Condensate Blockage: Theory, Modelling, Identification & Solutions

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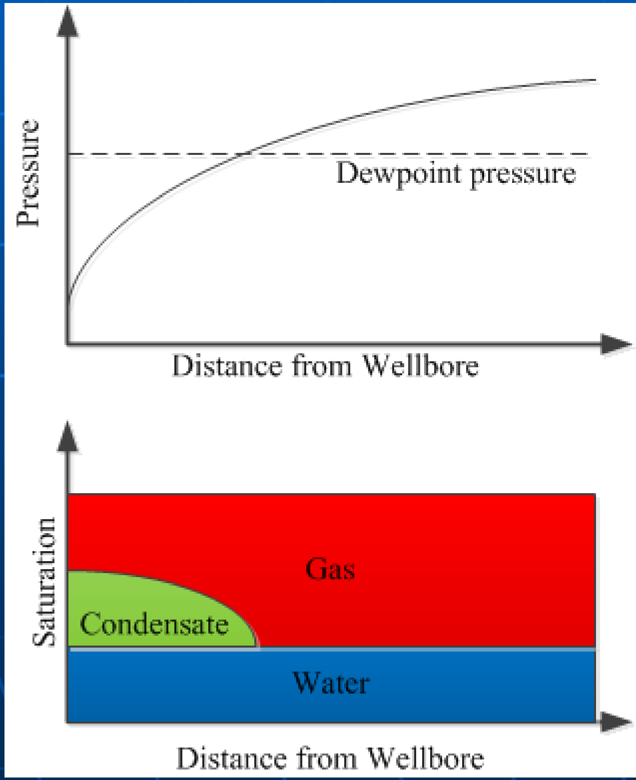
Retrograde Condensate Reservoirs

- Share of retrograde condensate reservoirs significantly increased recently
- Valuable liquid content
- Liquid dropout
- Low condensate recovery
- Condensate blockage

What is Condensate Blockage?

- When the flowing bottomhole pressure drops below the dewpoint pressure the condensate makes a retention in the near-wellbore region



Total Skin:

$$s_t = s + s_{2p}$$

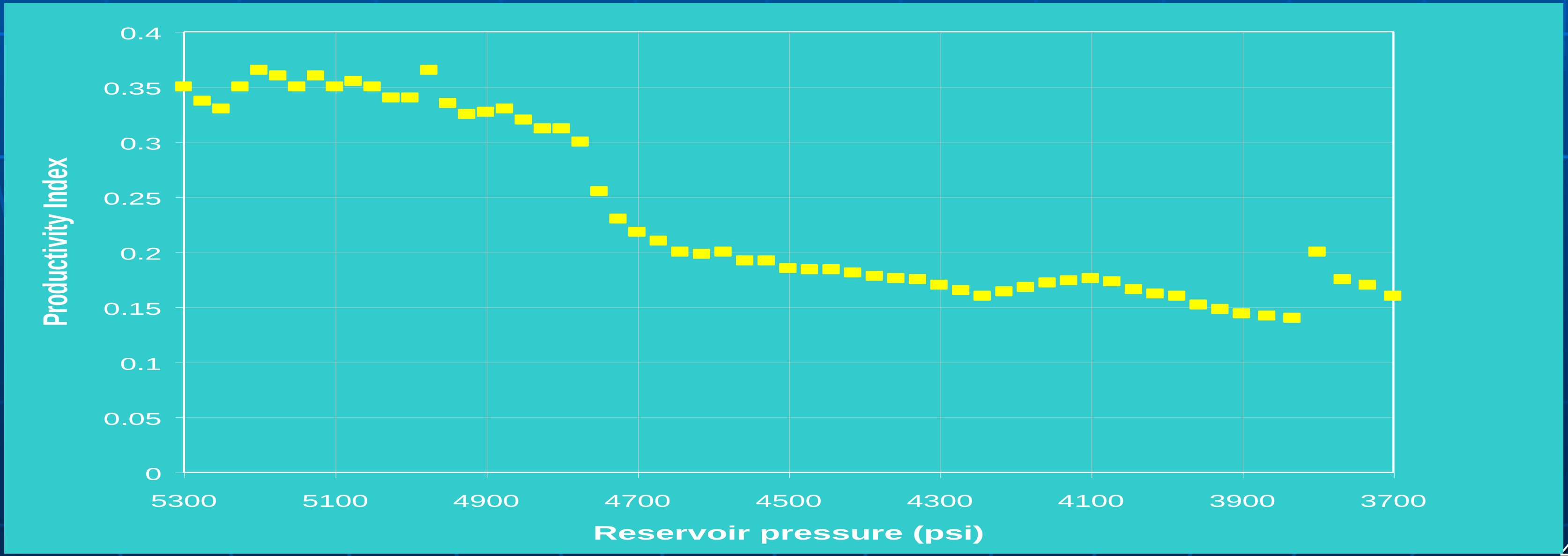
Skin effect caused by condensate drop-out:

$$s_{2p} = \frac{2.3025}{|m|} \int_{p_{wf,s}}^{p_{dew}} \left[\frac{k_{rg}(S_{wi})}{\mu_g \cdot Z_g} - \left(\frac{k_{ro}}{\mu_o \cdot Z_o} + \frac{k_{rg}}{\mu_g \cdot Z_g} \right) \right] dp$$

Importance

- Significantly deteriorates well productivity
- Significant if the pressure drop in the reservoir is comparable to the pressure drop in tubing and surface system

- Most famous case study (SPE 28749 – Arun Field, India, 1.1% LD & 10 mD):

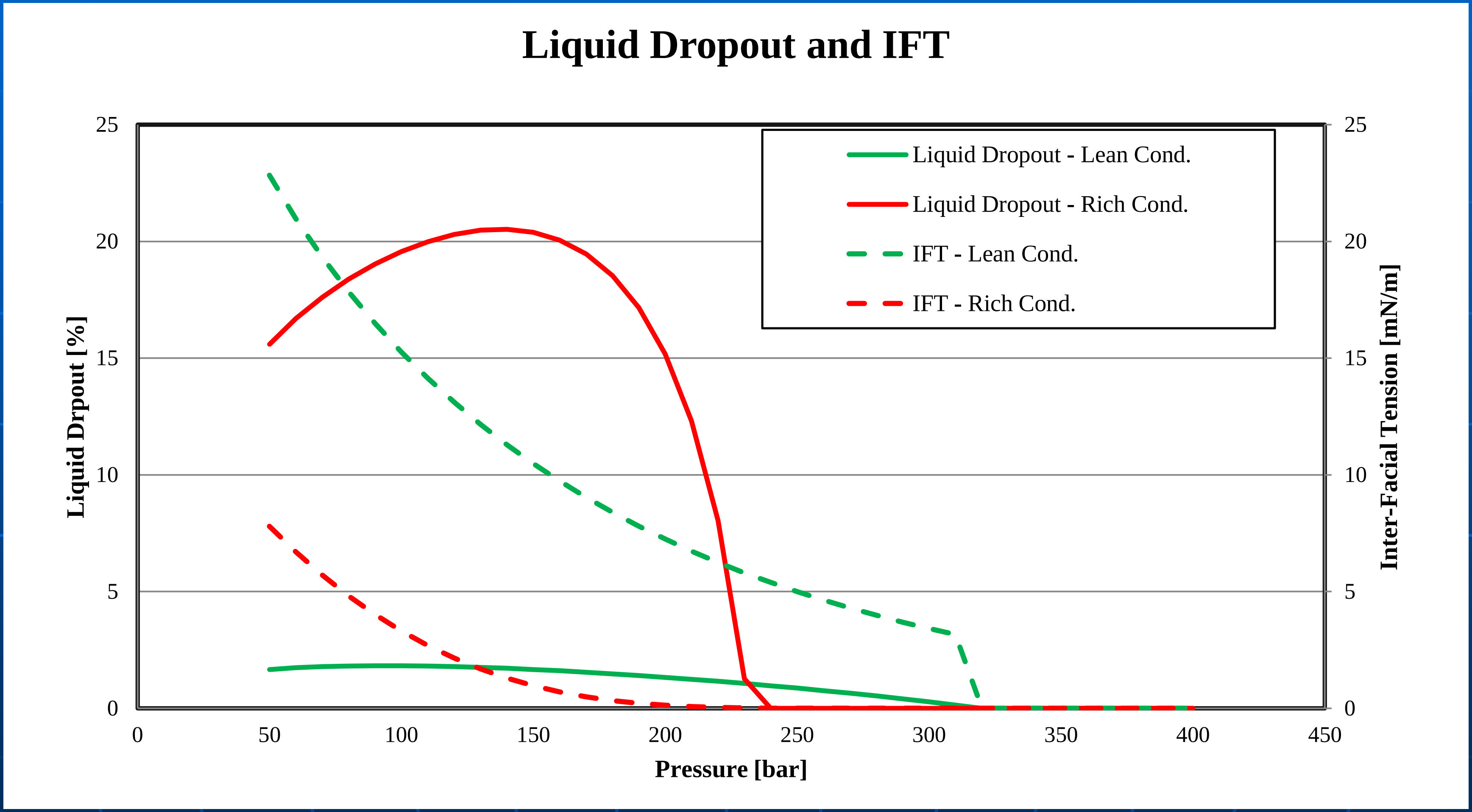


Modelling/Forecasting Condensate Banking

- Purpose:
  - Selecting best development concept for new reservoirs (green fields - optimization)
  - Detecting problem in old wells (brown fields)

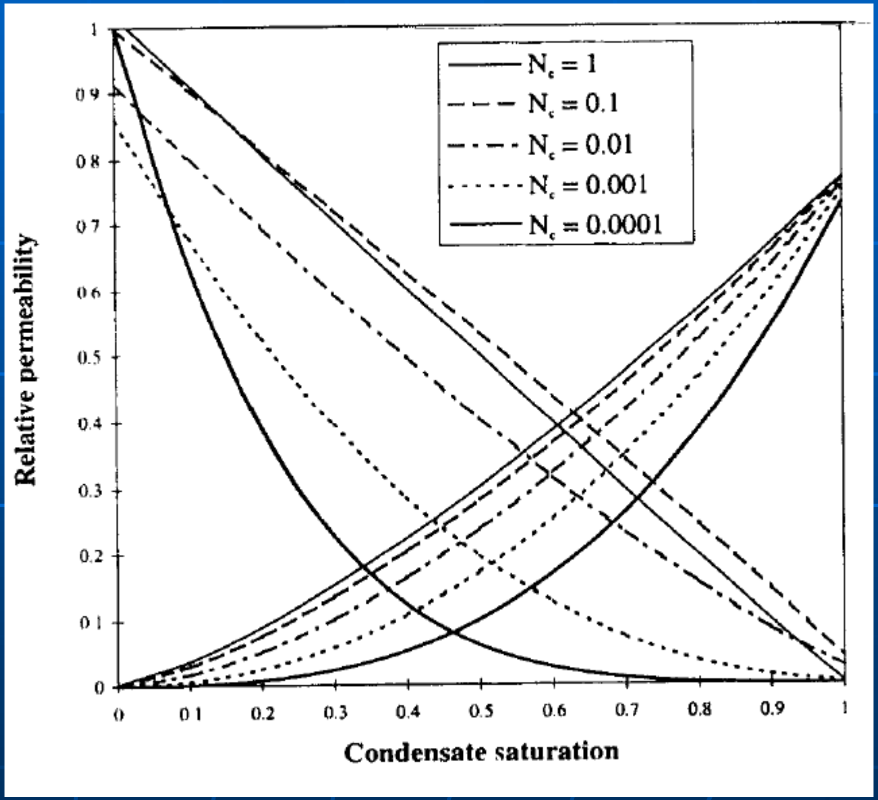
- Important Factors:
  - Proper PVT model/Fluid Properties
  - Non-Darcy Flow Effect
  - High Capillary Number Flow

Fluid Properties



Non-Darcy Effect and High Capillary Number Flow

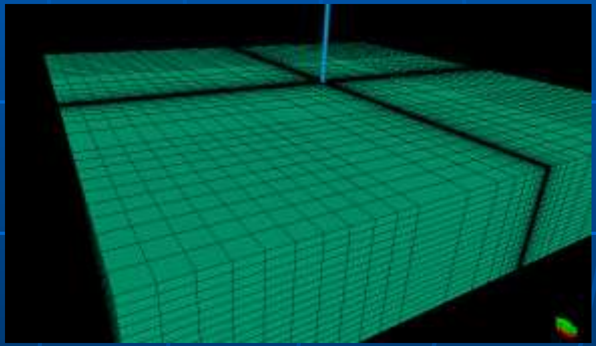
- Non-Darcy effect <- inertial flow (because of tortorous path)
- Capillary number dependent relative permeability curves (velocity stripping)
- $Nc = \frac{\mu_g \cdot v_{sg}}{IFT}$
- Usually these effects are disregarded



[Source: SPE 39976]

Numerical model

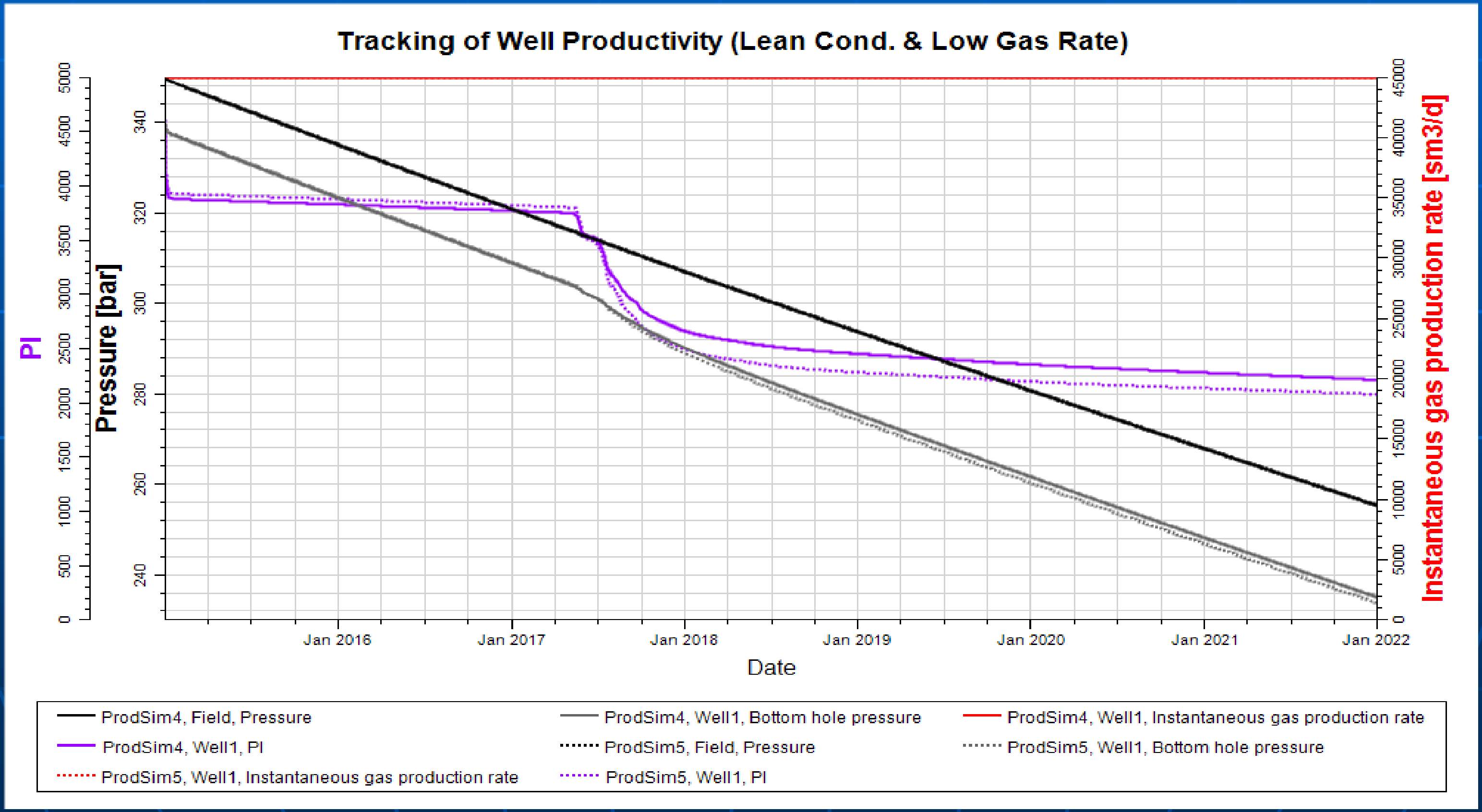
- Objective: to investigate the importance of velocity stripping
- Numerical model with 1 well (shoe box model)



- Investigation:
  - With a lean and a rich condensate
  - At a higher and a lower rate

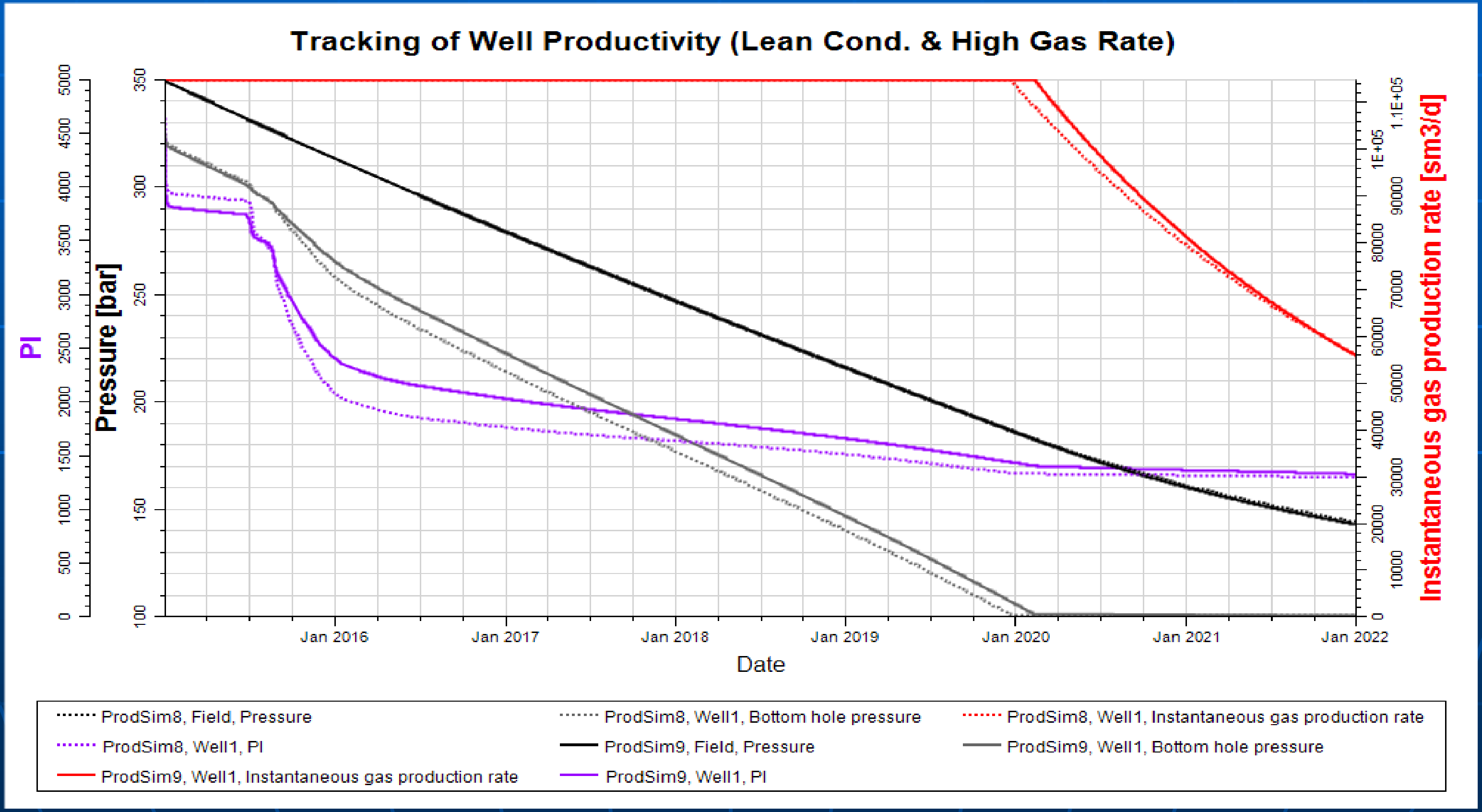
Well Productivity

Lean Condensate and Low Gas Rate (45 000 m^3/day)
Solide Line = <u>with</u> Non-Darcy and velocity stripping
Stripped Line = <u>without</u> Non-Darcy and velocity stripping

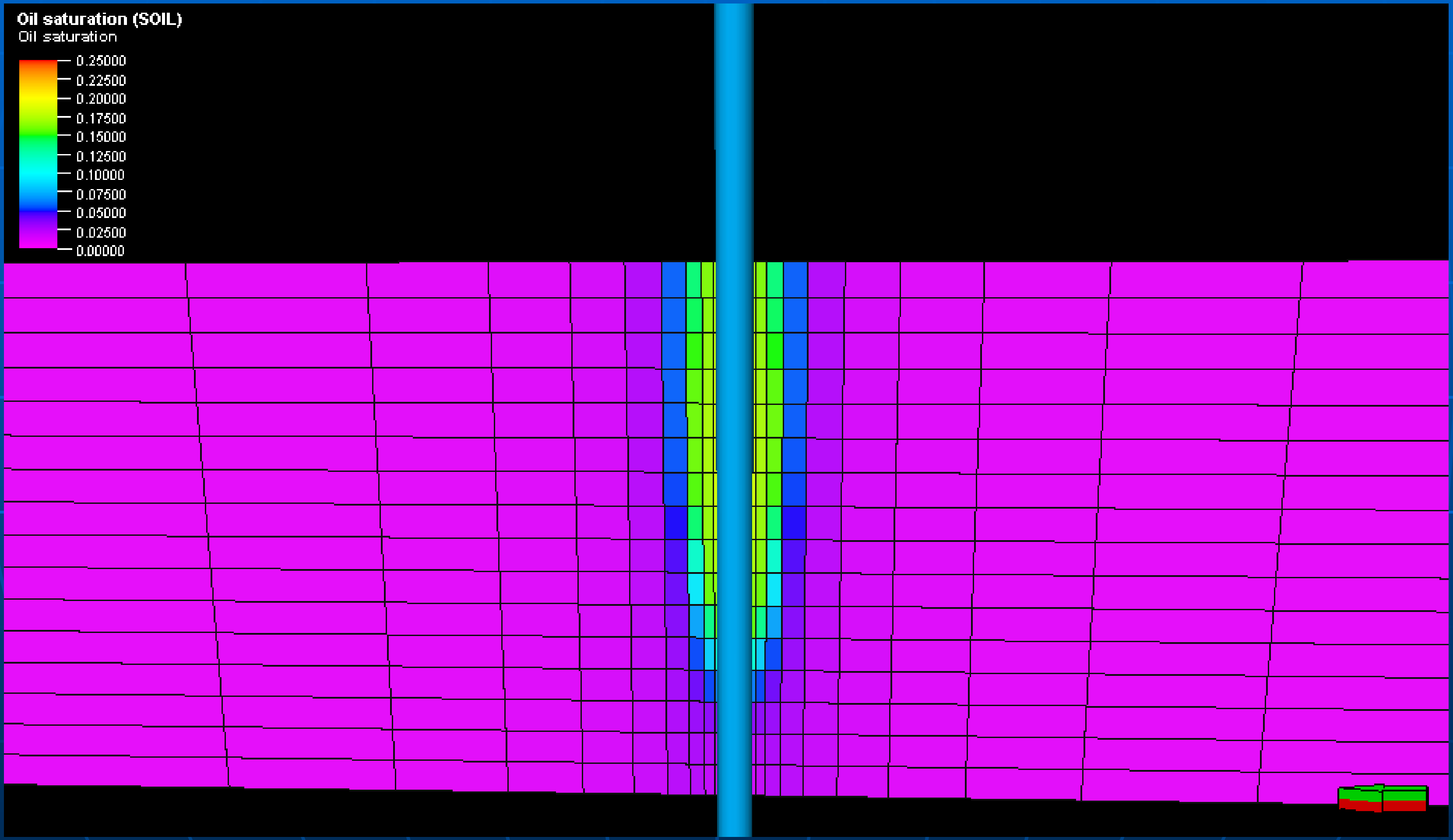


Well Productivity

Lean Condensate and Low Gas Rate (115 000 m^3/day)
Solide Line = <u>with</u> Non-Darcy and velocity stripping
Stripped Line = <u>without</u> Non-Darcy and velocity stripping



Condensate Saturation (Lean Gas Condensate)



Well Productivity

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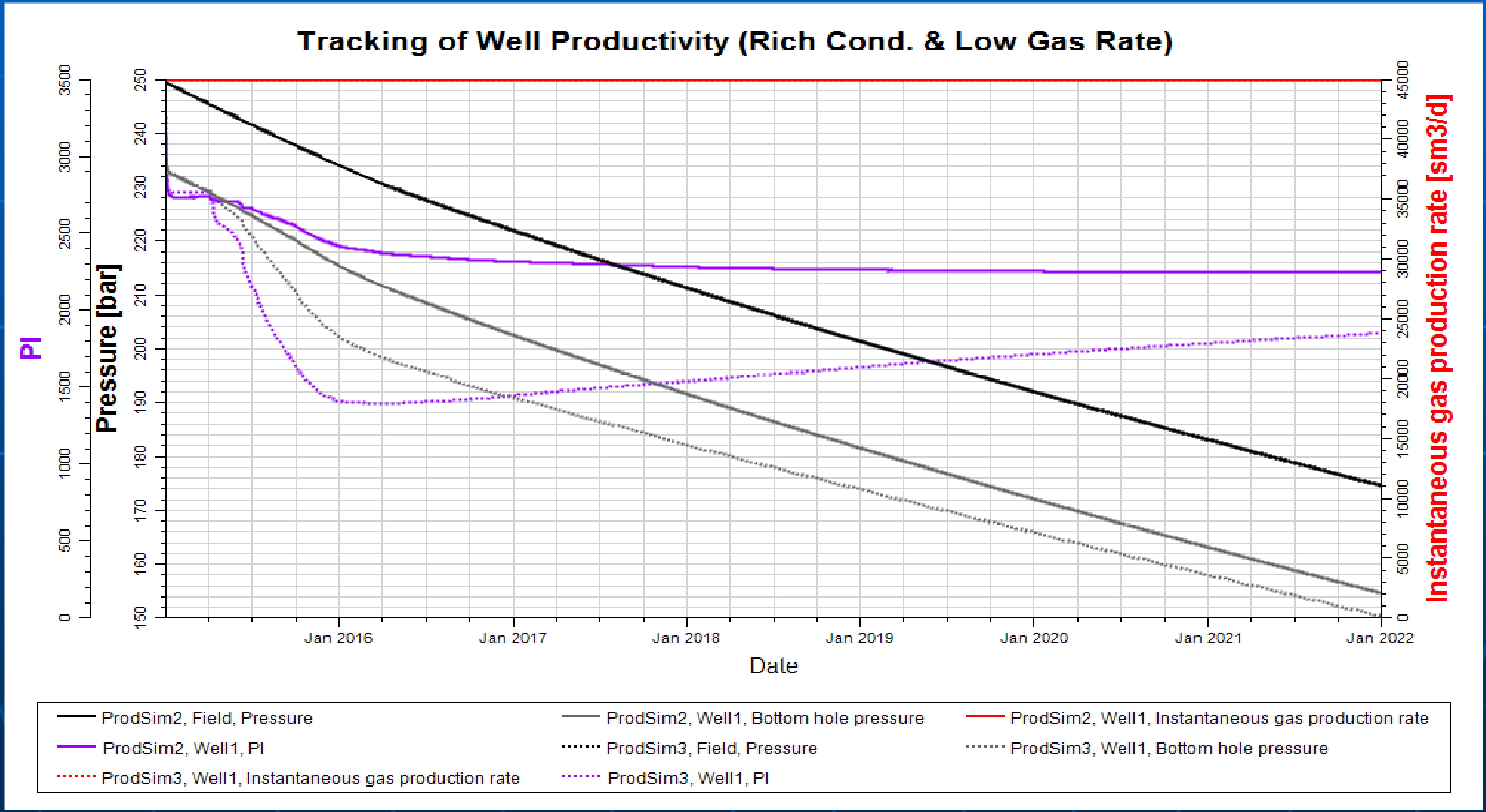

Well Productivity

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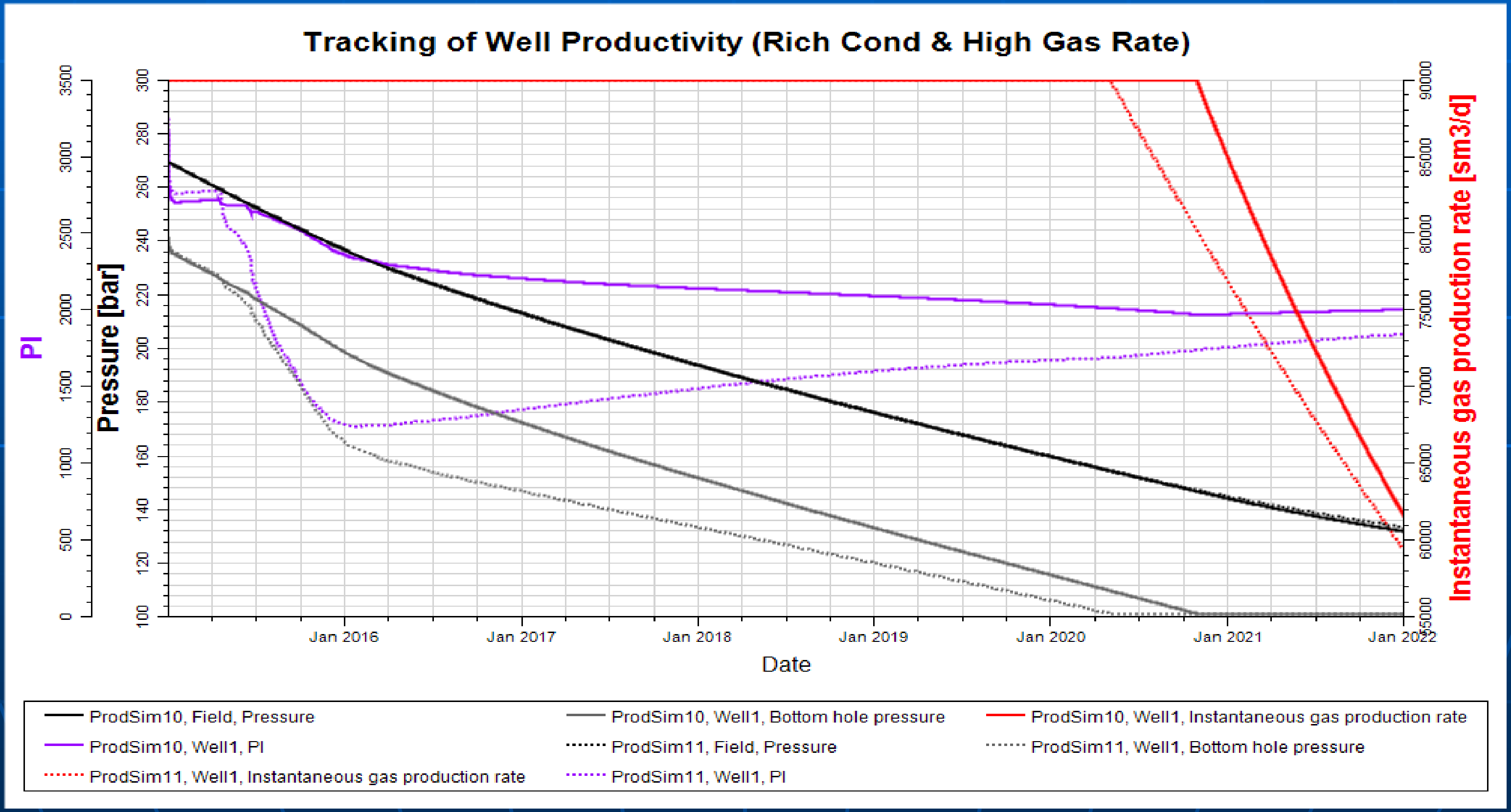
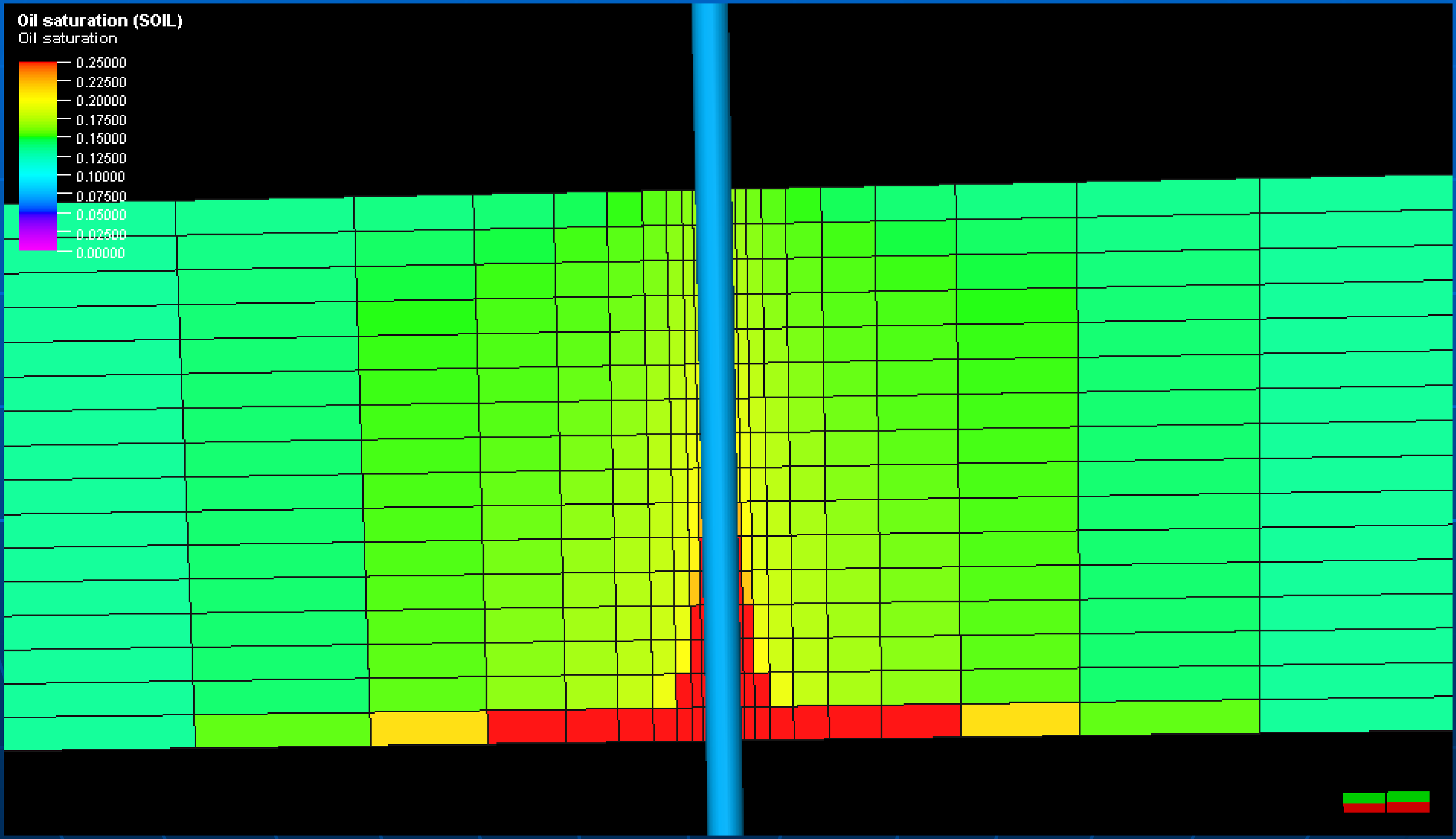


Condensate Saturation (Rich Gas Condensate)



Results of the Simulation

- The importance of velocity stripping is increasing as the inter-facial tension (IFT) decreasing and the production rate increasing
- Accordingly, as the condensate is getting richer and the production rate is increasing velocity stripping is getting more important
- As a result, velocity stripping and non-Darcy flow effect shouldn’t be neglected without pre-investigation

Identification of the Problem

- Low or moderate reservoir flow capacity (k*h)
- Significantly decreased well productivity
- Pressure drop in the reservoir is comperable to pressure drop in tubing

- Usually the problem is more serious in case of lean and depleted reservoirs because of high inter-facial tension

- Well test (rarely available)

Possible Solutions

- At developement phase:
  - Horizontal Well
  - Hydraulic Fracturing

- Later:
  - Hydraulic Fracturing (risky and expensive)
  - Lean Gas Injection
  - Propane Injection
  - Solvent/Alcohol Injections
  - Wettability Modification

Gas Injection

- Lean/Wet/Inert Gas and CO_2
  - Evaporate liquide phase
  - Investigated by the R&D department of MOL
  - Successfully applied in a hungarian gas condensate field

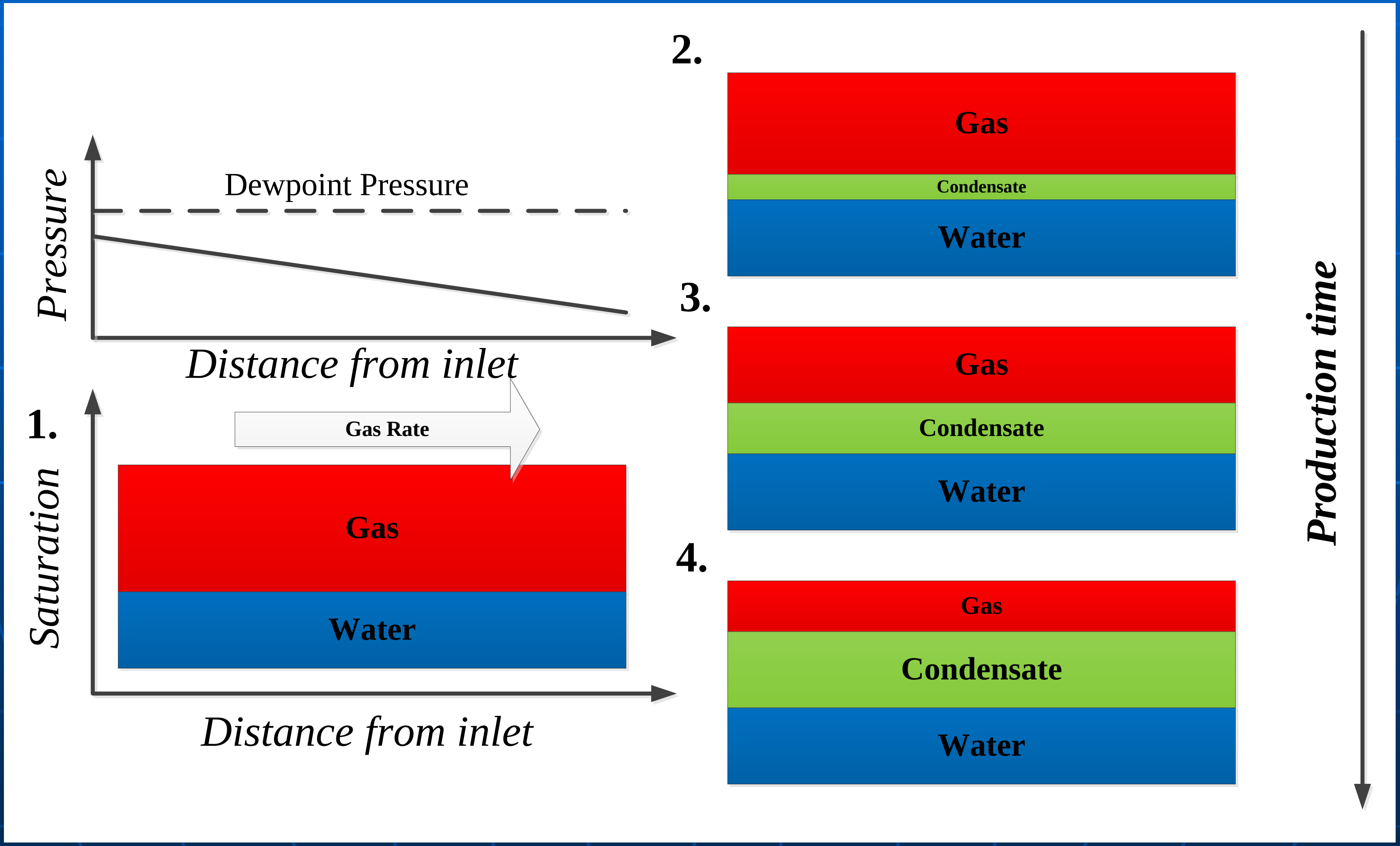
Solvent Injection

- Solvents: Propane, Methaol, iso-Propanol, dimethyl-Ether
- Solution for both condensate and water blockage
- Multicontact-miscible displacement
- Used for water blockage since 60’
- Used for condensate blockage since 2000

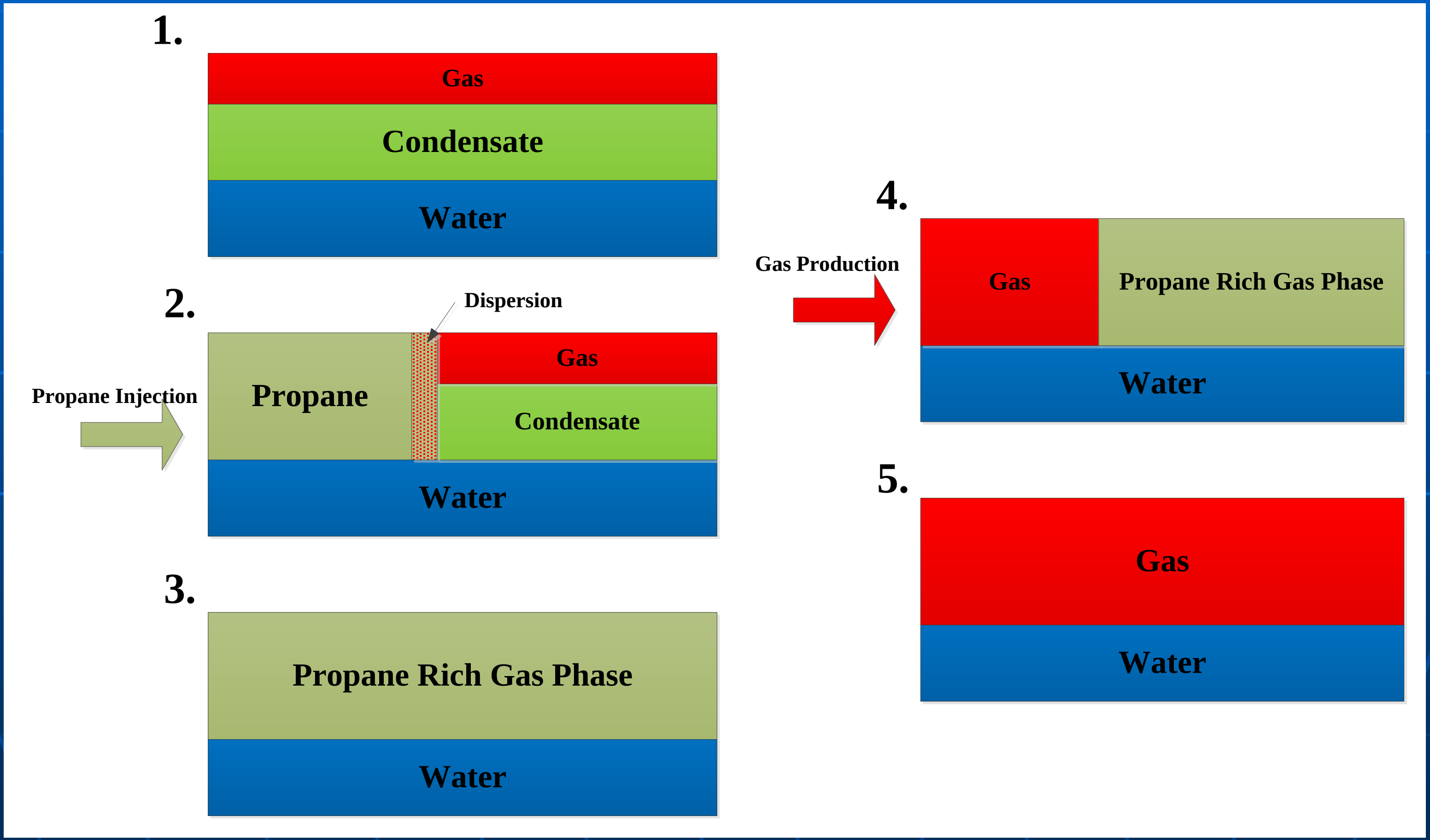
- Investigated by the R&D department of MOL
- Already applied in a Hungarian Field

- Laboratory measurements are required!!!

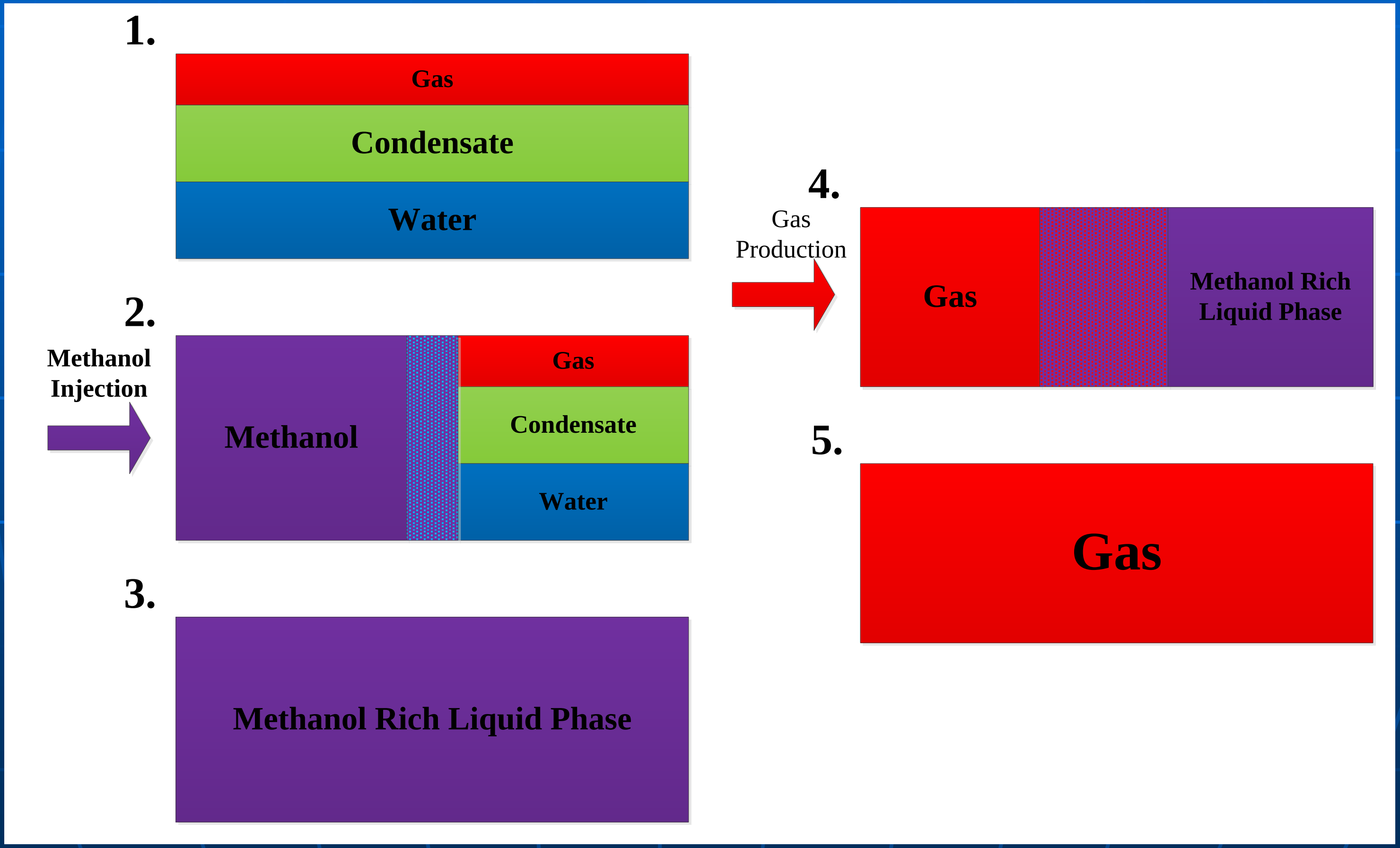
Accumulation of Condensate on Core Scale



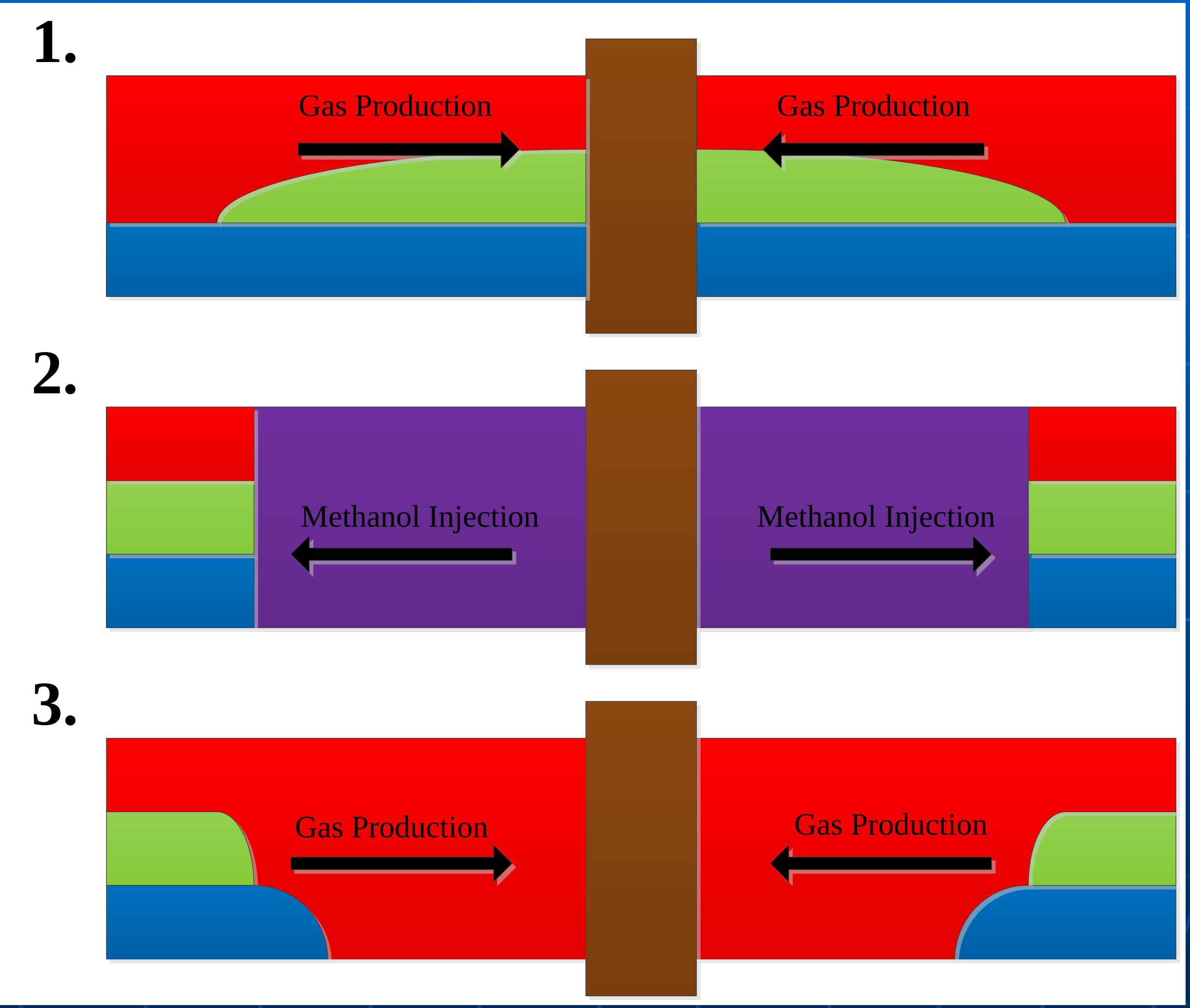
Propane Injection on Core Scale



Methanol Injection on Core Scale

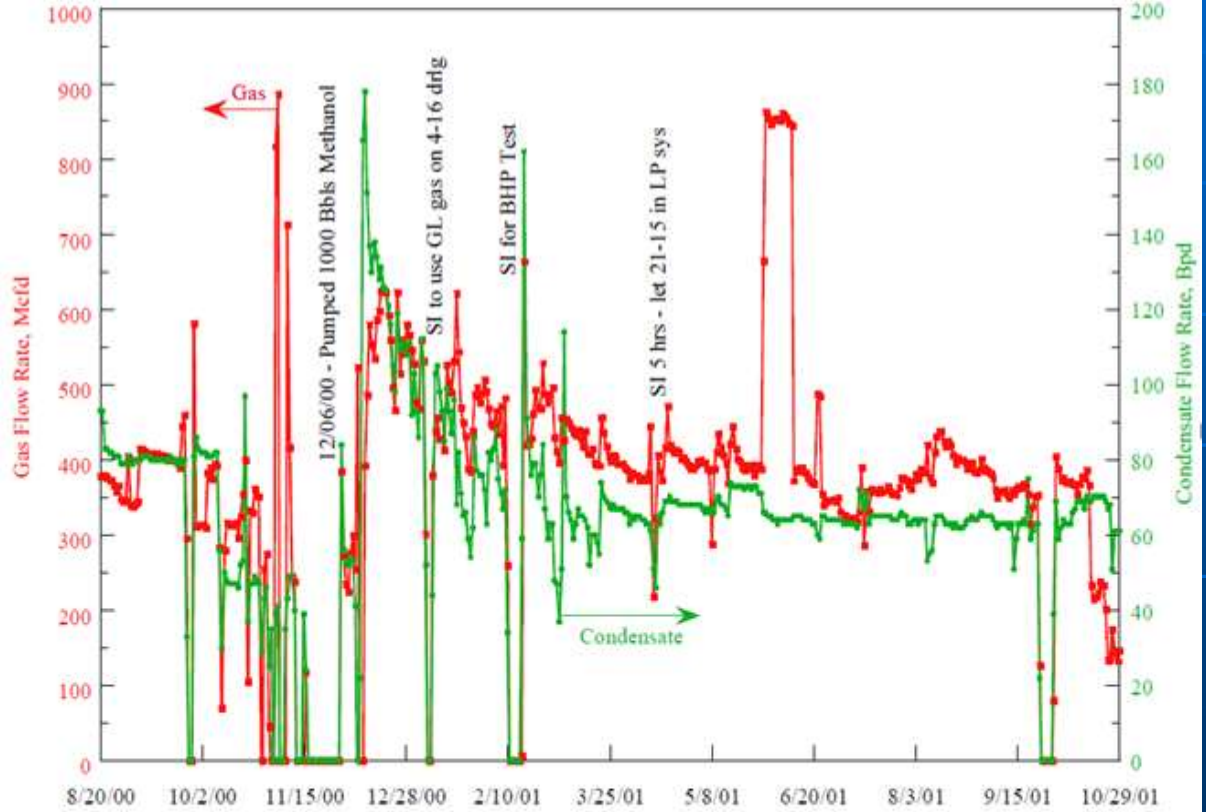


Methanol Injection on Well Scale



Results of Methanol Injection

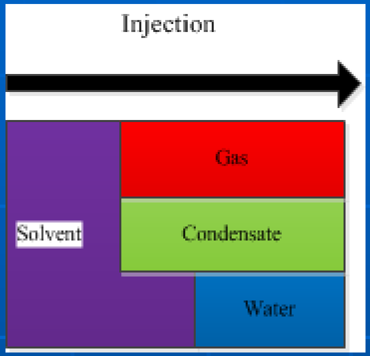
- 1000 bbl of methanol (169 m^3) was injected
- Gas and condensate production were doubled
- The positive effect was sustained for several month



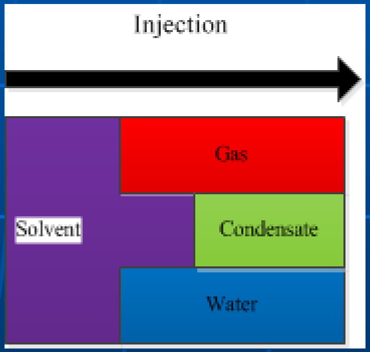
[Source : SPE 80901]

Most Important Features of the Different Solvents

- Methanol or Ethanol
  - Prefer to partition into water phase
  - Better at sweeping water



- Iso-Propanol
  - Prefer to partition into HC liquid phase
  - Better at sweeping HC liquid



- Dimethyl-Ether
  - Prefer to partition into HC liquid phase
  - Better at sweeping HC liquid
  - Higher vapor pressure makes the clean up period shorter

Wettability Modification

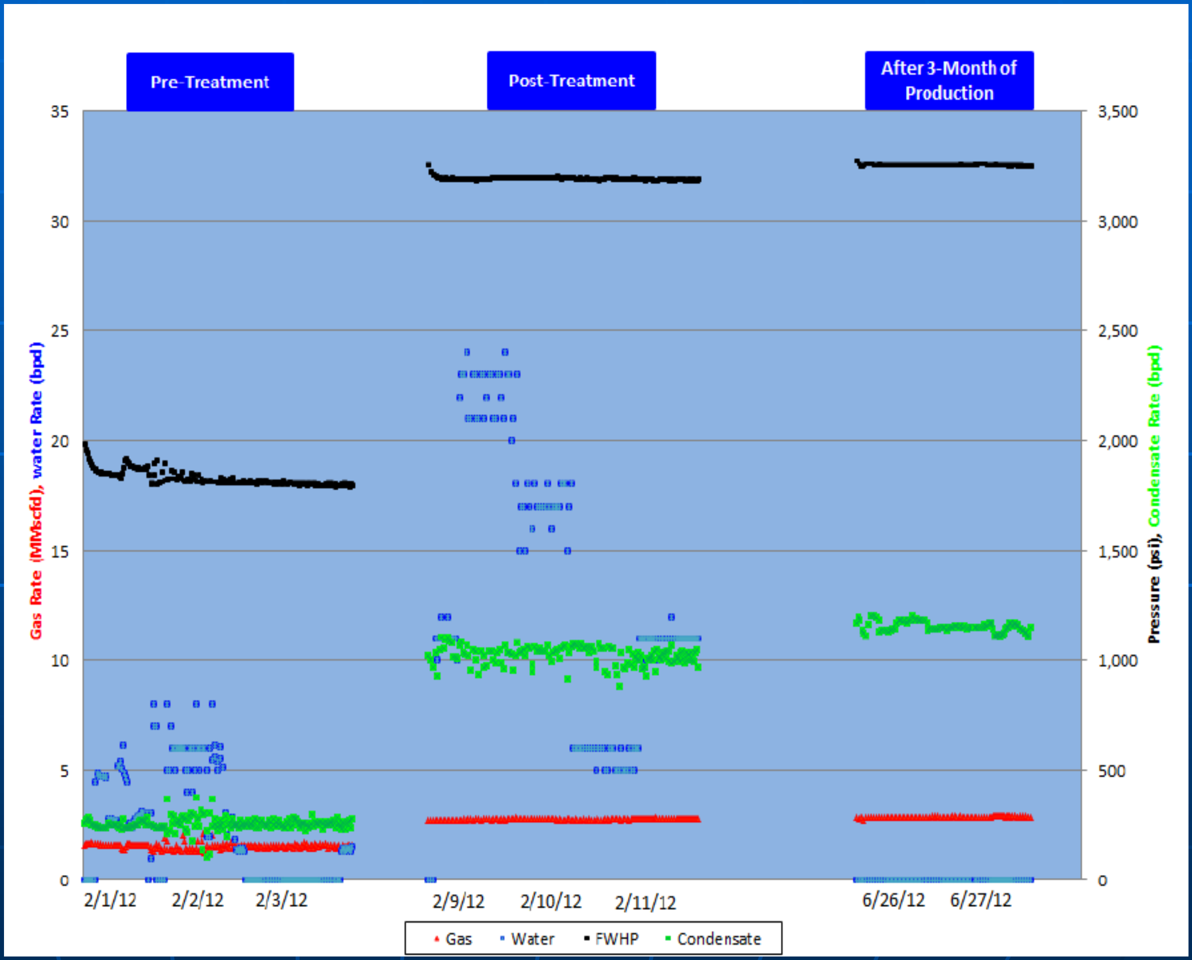
- Most novel method for the remediation of condensate blockage
- The fluorinated surfactant makes the reservoir rock intermediate gas wetting, thus less liquid can accumulate in the wellbore region(works for siliciclastic rocks only)
- Pumped down with solvent (like methanol)
- Cheap and long lasting solution for the problem

- Successful Field Application in Saudi Arabia(2013)

Results of Wettability Modification

- Gas Rate (83% increase)
- Condensate Rate (313% increase)
- CGR (127% increase)
- Wellhead Pressure (81% Increase)

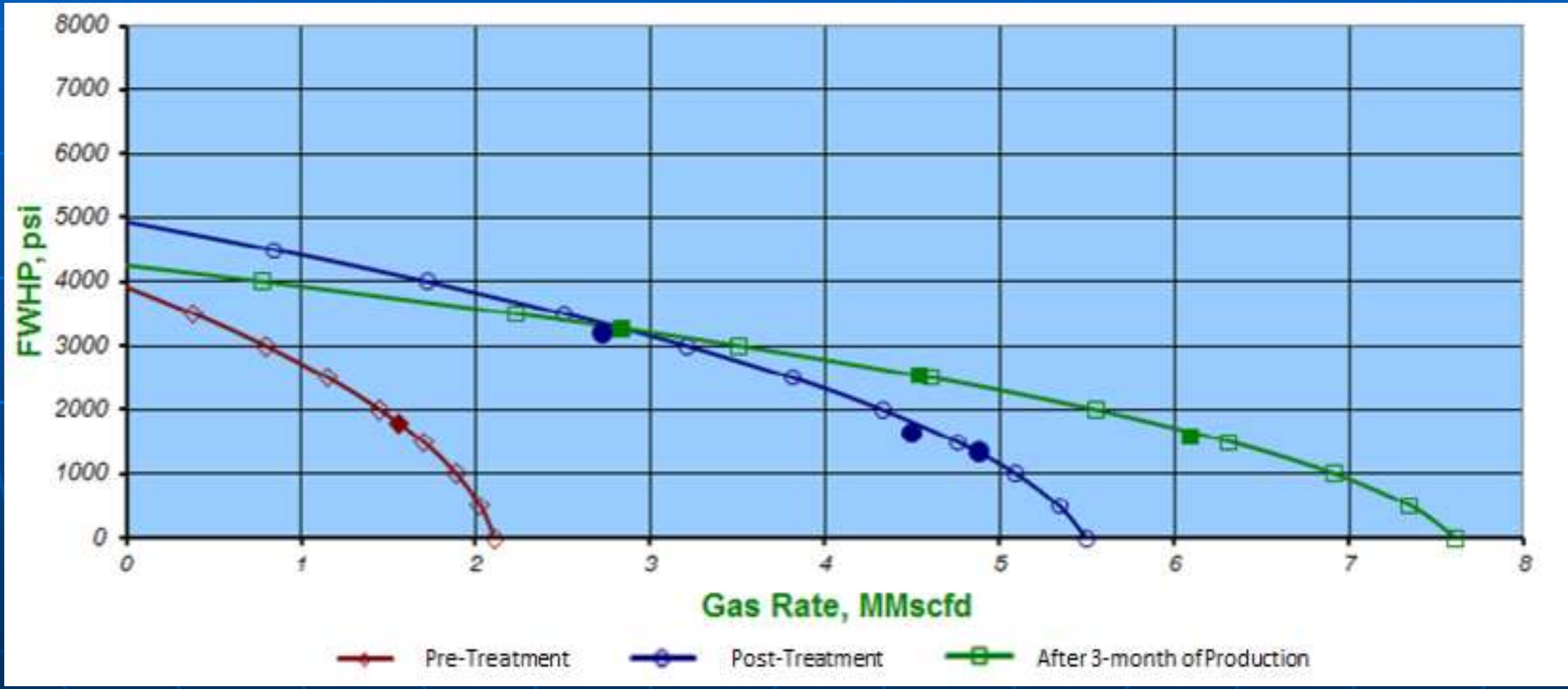
- <30 days pay off!



[Source: SPE 168086]

Results of Wettability Modification

The improvement is obvious in the measured inflow performance curves



[Source: SPE 168086]

Conclusions/Summary

- Condensate blockage is an important feature of retrograde condensate reservoirs
- Non-Darcy flow effect and velocity stripping phenomena are important in modelling condensate blockage and optimizing retrograde condensate reservoirs
- Gas injection, Solvent injection and wettability modification can remediate the problem
- Gas injection is the most simple and well-known method, although it is less effective
- Solvent injection and wettability modification are the most effective currently available treatments for condensate blockage