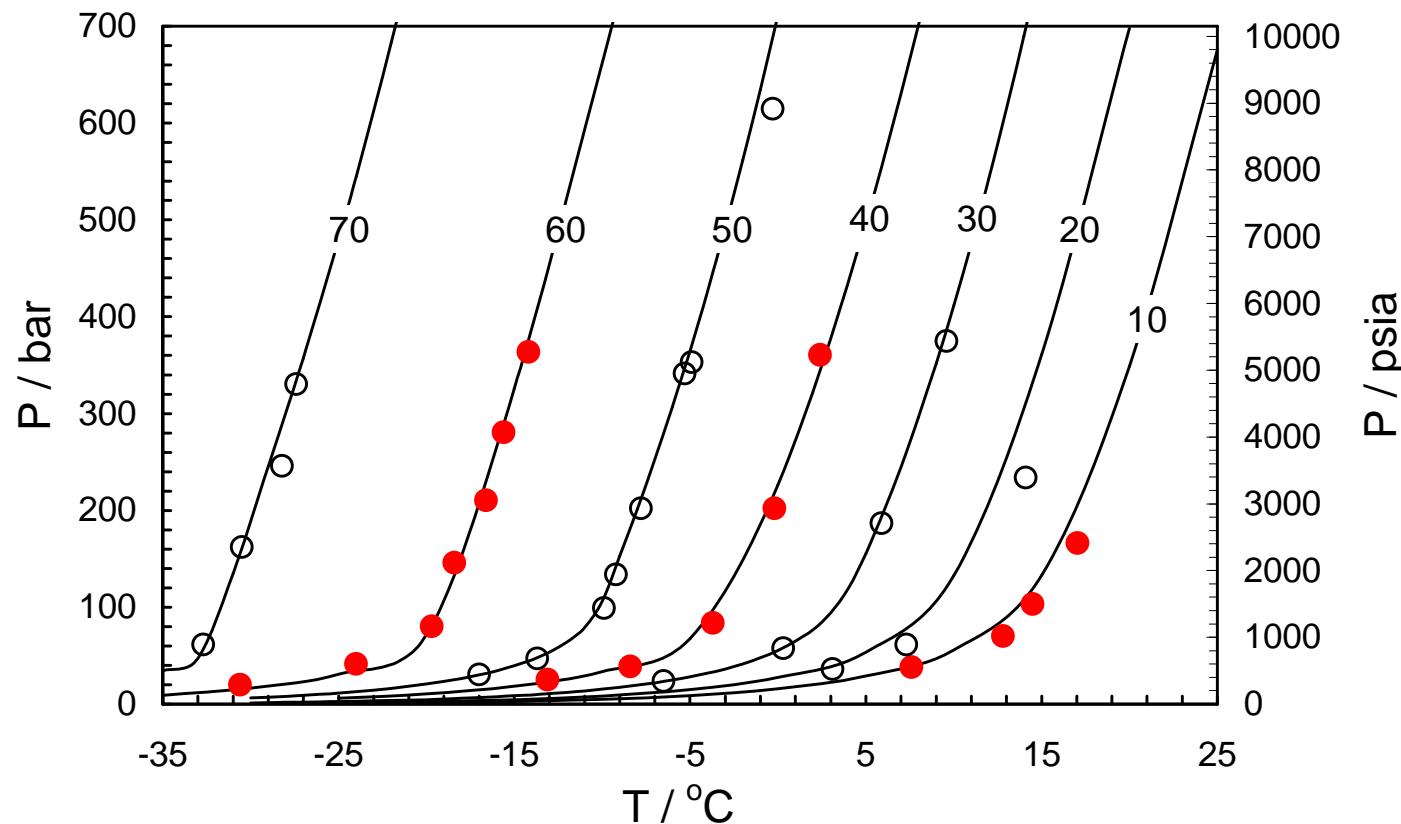


HSZ in The Presence of Organic Inhibitor

- Predicted hydrate dissociation conditions (structure II) for a North Sea natural gas in with the presence of **methanol** aqueous solutions.

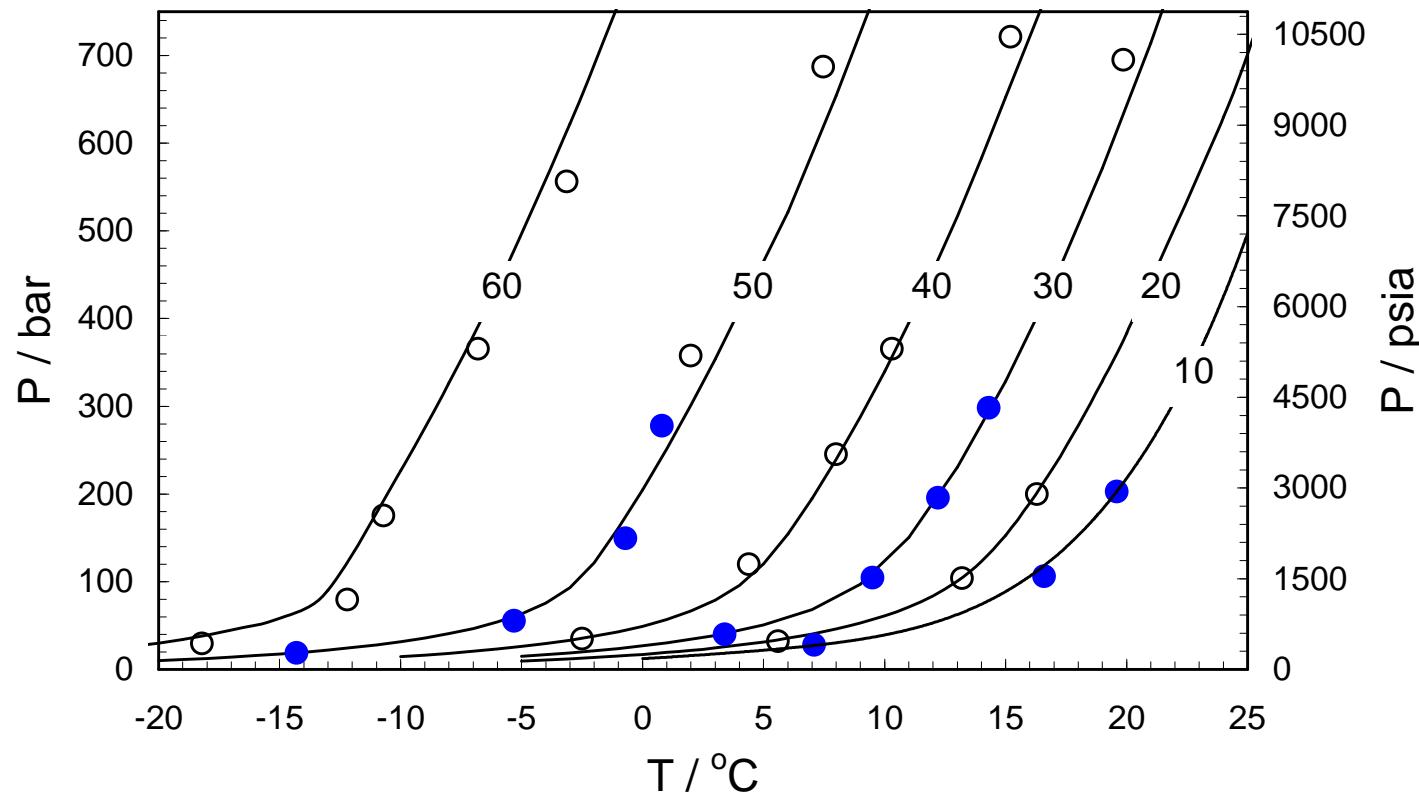


●: Haghghi et al., 2009.

○: data from HWU.

HSZ in The Presence of Organic Inhibitor

- Predicted hydrate dissociation conditions (structure II) for a North Sea natural gas in with the presence of MEG aqueous solutions.



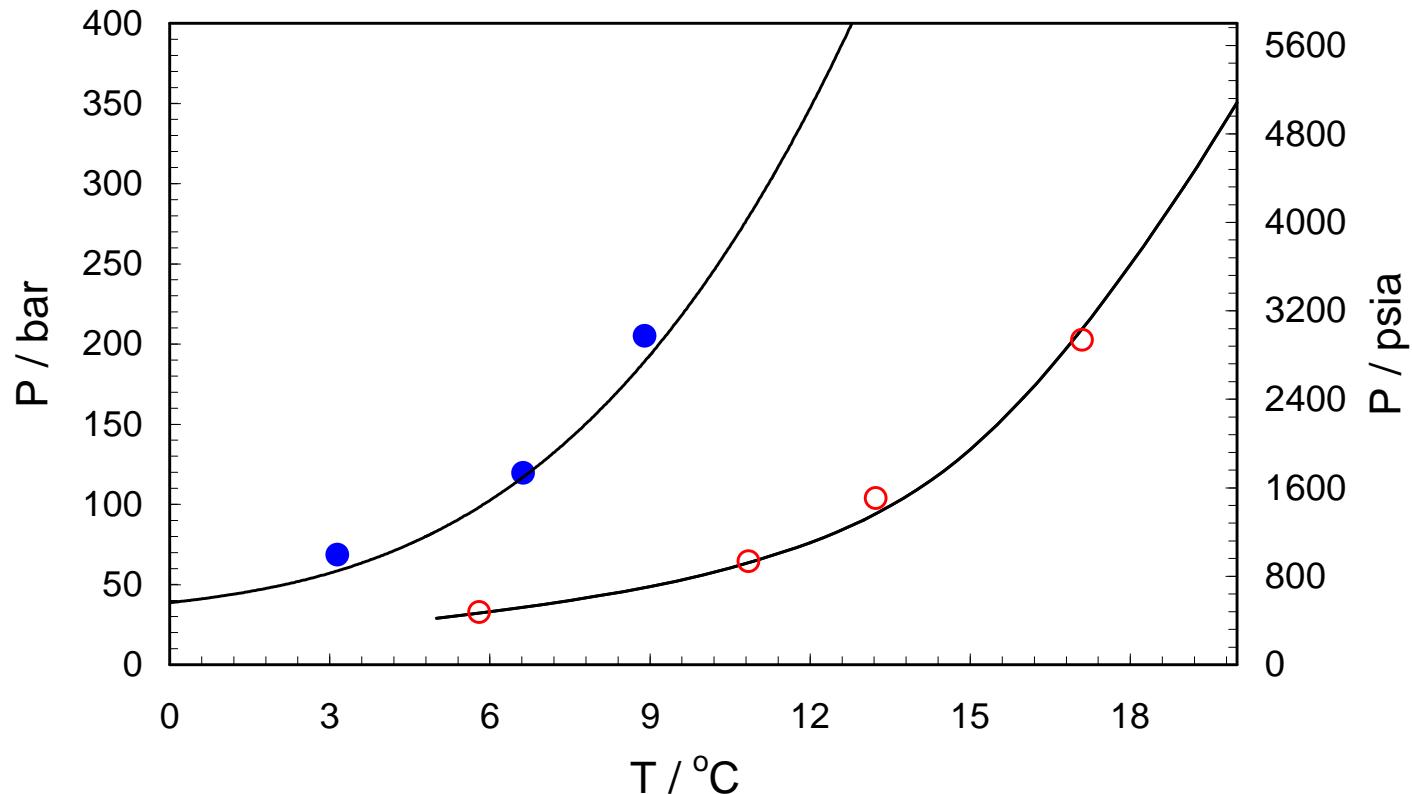
●: Haghghi et al., 2009.

○: data from HWU.

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HSZ in The Presence of Mixture of Inhibitors

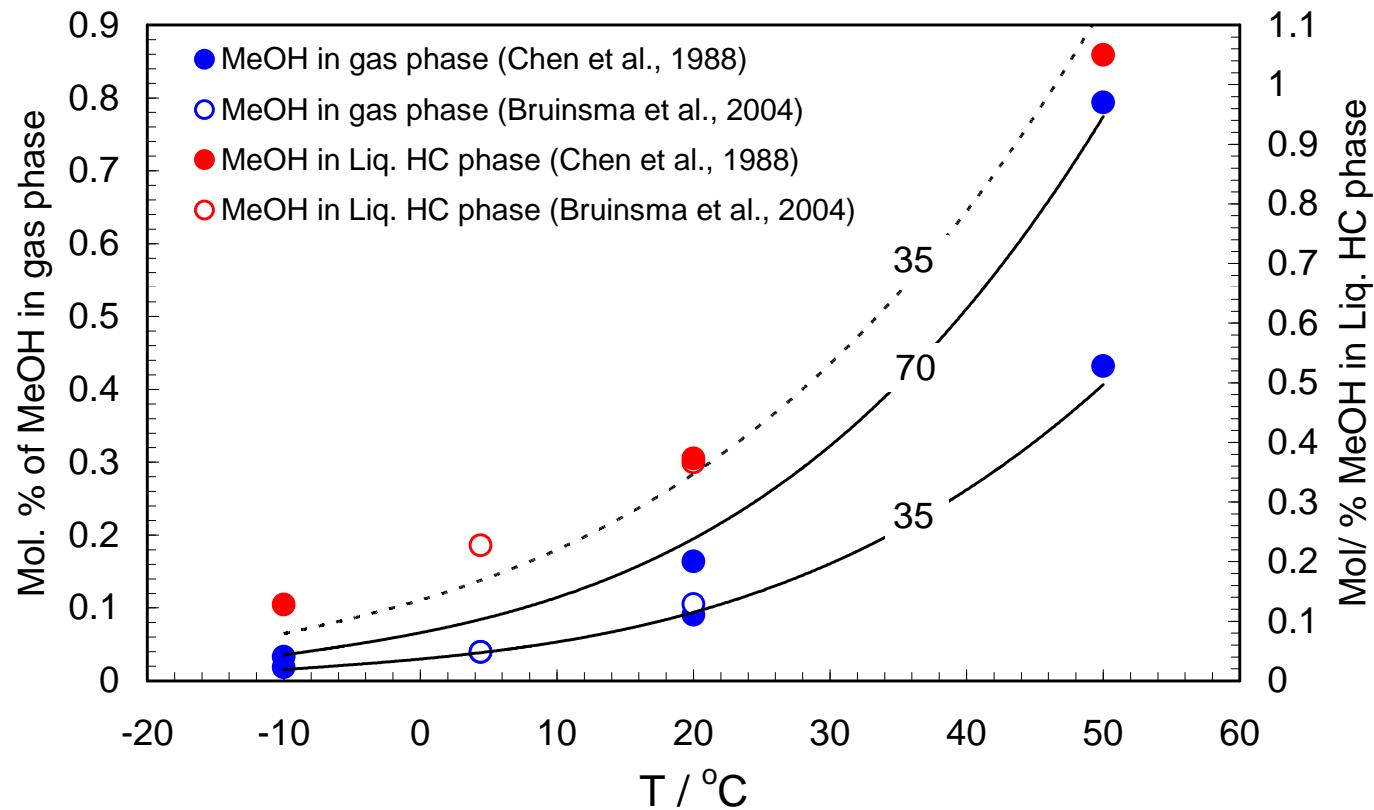
- Predicted natural hydrate dissociation conditions in the presence of 10 mass% of NaCl (●) and 30 mass% MEG and 5 mass% NaCl (○).



Experimental data from HWU.

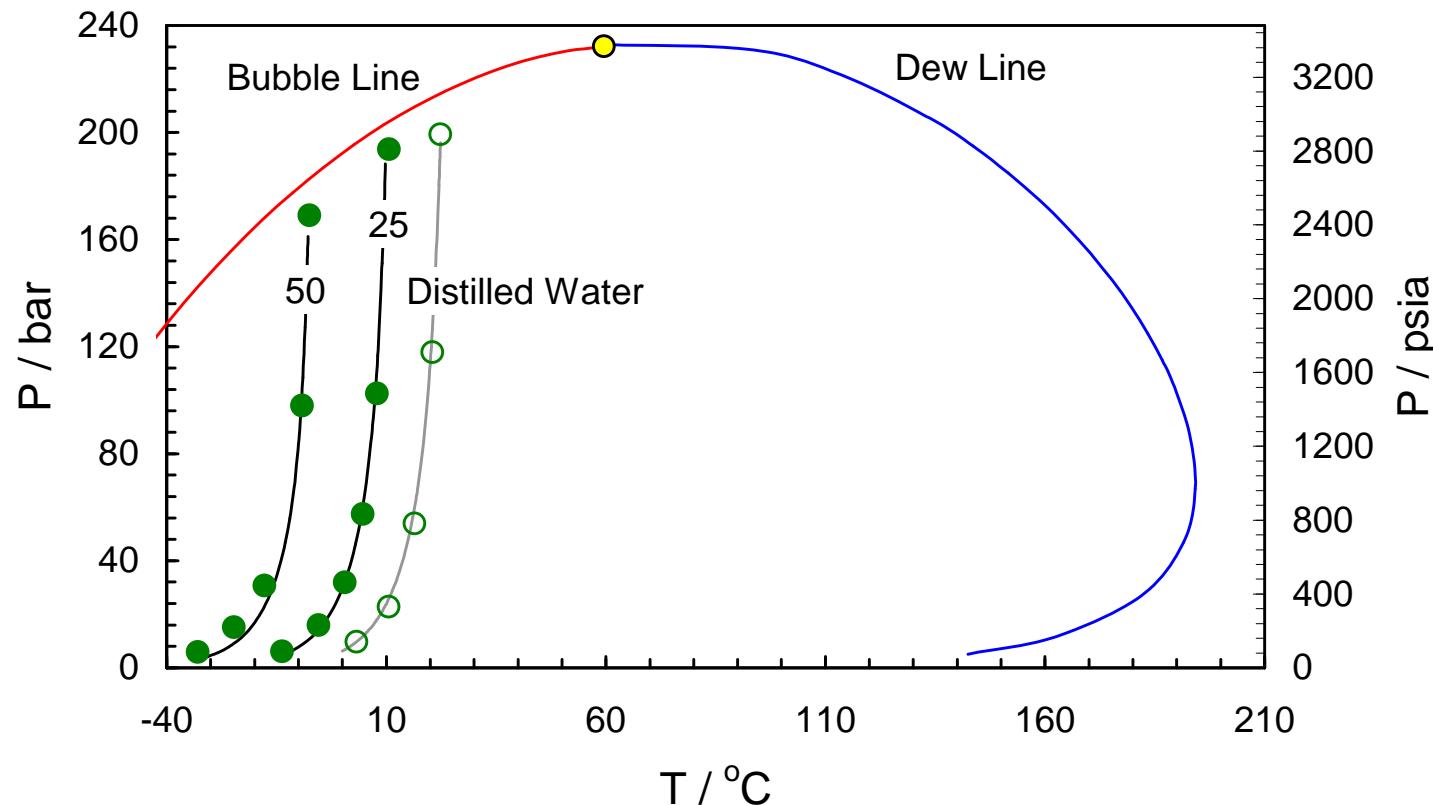
Inhibitor Distribution in Multiphase Systems

- Predicted methanol content in the gas and liquid hydrocarbon phases of a synthetic gas-condensate at 69 bar / 1000 psia bar in the presence of 35 and 70 mass% methanol aqueous solutions.



HSZ of Oil/Condensate in the Presence of Inhibitors

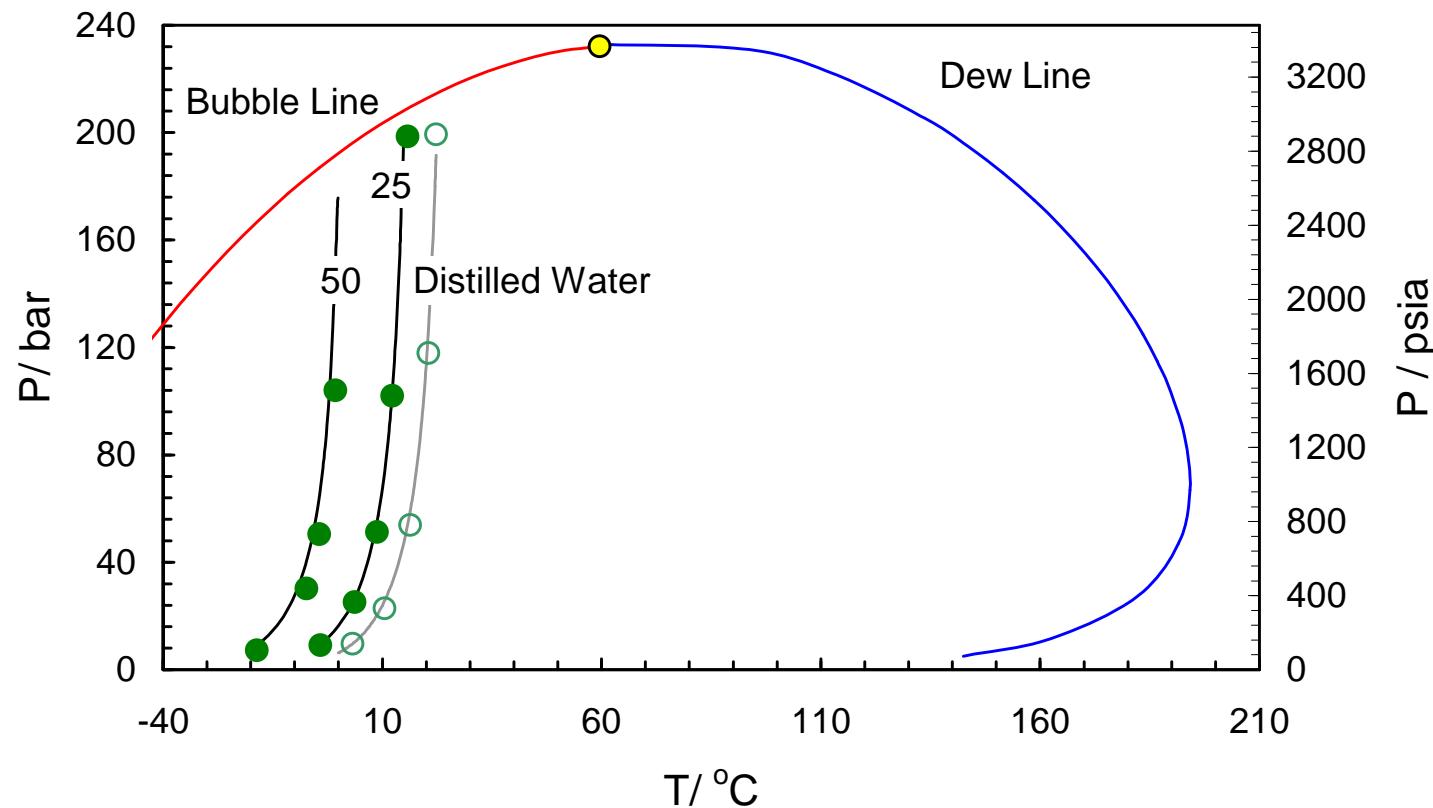
- predicted hydrate dissociation conditions and phase envelope for a gas condensate well-stream in presence of **methanol** aqueous solutions.



Experimental data from Ng et al., 1985.

HSZ of Oil/Condensate in the Presence of Inhibitors

- predicted hydrate dissociation conditions and phase envelope for a gas condensate well-stream in presence of MEG aqueous solutions.



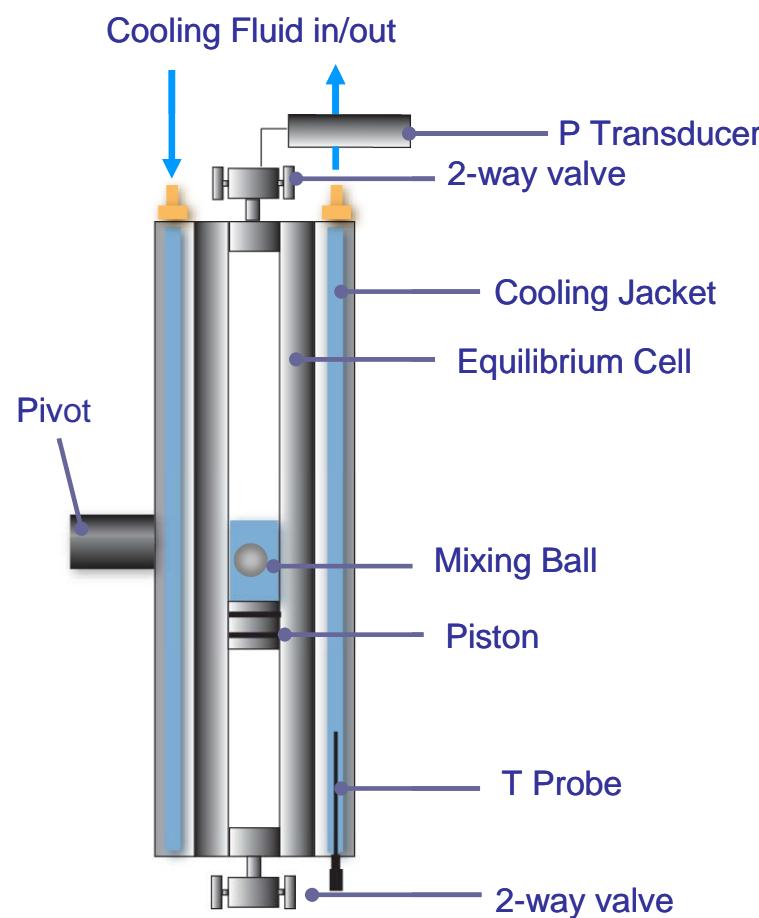
Experimental data from Ng et al., 1985.

Avoiding Hydrate Problems - Current practice

- Increasing the system temperature
 - *Insulation*
 - *Heating*
- Reducing the system pressure
- Injection of thermodynamic inhibitors
 - *Methanol, ethylene glycol, ethanol*
- Using Low Dosage Hydrate Inhibitors
 - *Kinetic Inhibitors (KHI)*
 - *Anti-Aggglomerants (AA)*
- **Water removal (dehydration)**
- Combinations of the above
- New Approach: Cold Flow

Water Content Measurements

- Experimental setup



Main Characteristics:

Titanium piston vessel

P_{\max} : 70 MPa

T_{\min} : 193 K

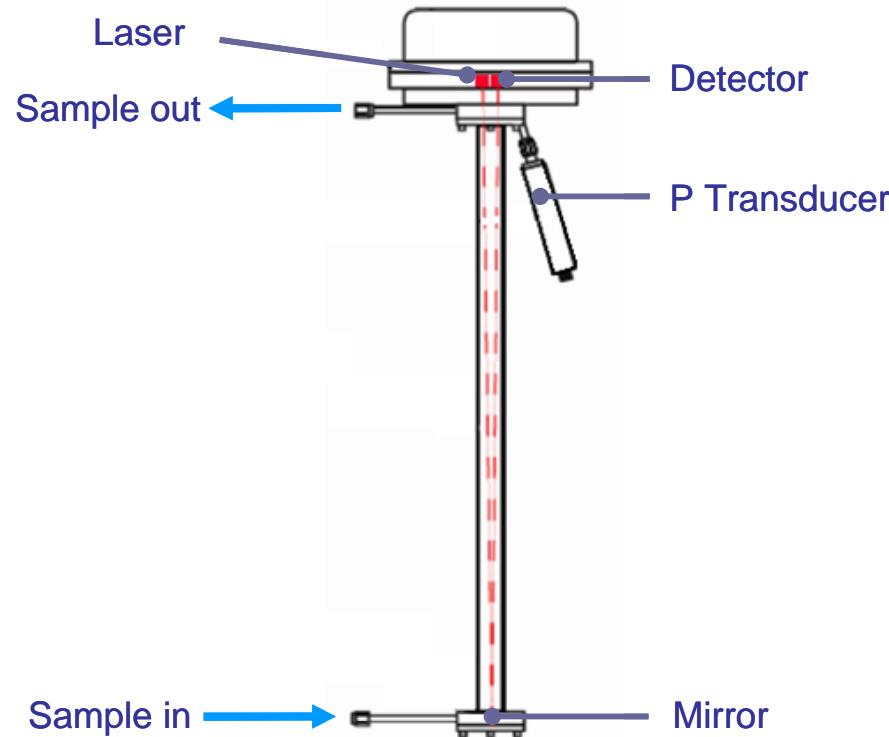
T_{\max} : 323 K

$T \pm 0.1K$

$P \pm 0.003 \text{ MPa}$

Water Content Measurements

- Schematic of the SpectraSensors™ SS2000 TDLAS set-up



Main Characteristics:

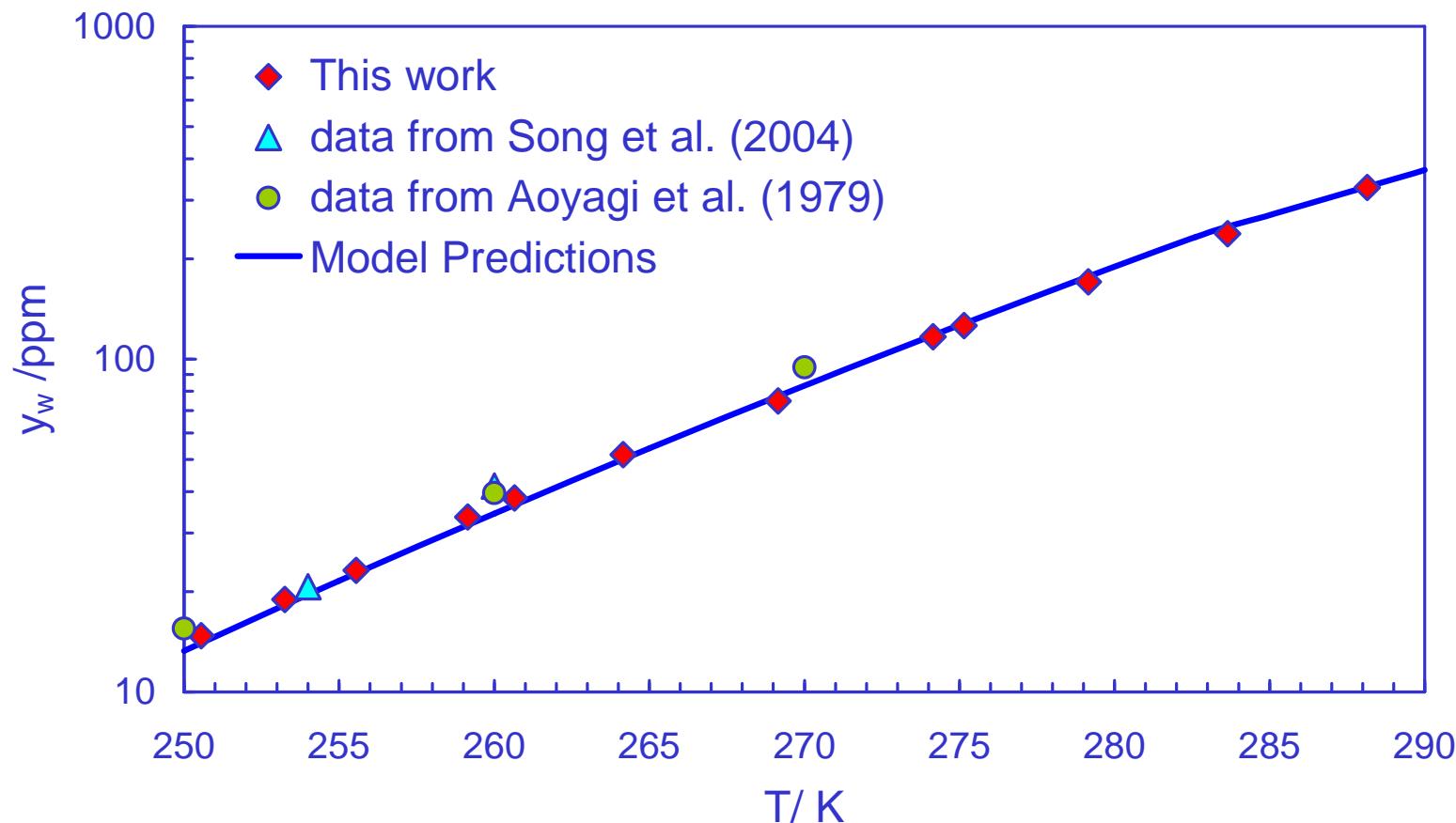
Beer law

$$\ln\left(\frac{I^o}{I}\right) = S \times L \times N$$

Standard error TDLAS set-up is the greater of 4 ppm or 2% of the reading.

Gas Hydrate in Low Water Content Gases

- Predicted water content (ppm mole) of methane in equilibrium with liquid water or hydrate at 68.9 bar.

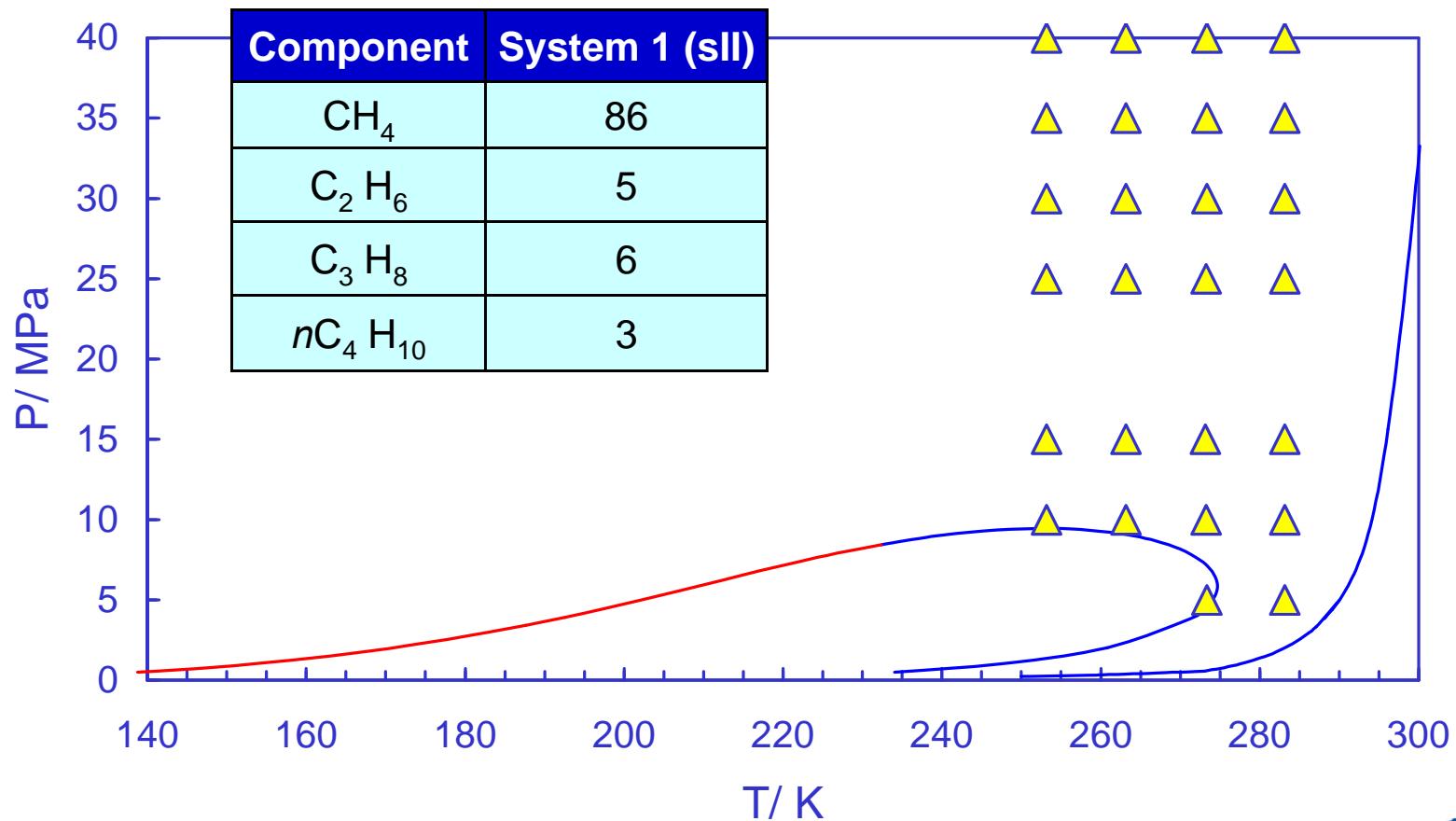


Experimental data from Chapoy et al., 2009.

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Gas Hydrate in Low Water Content Gases

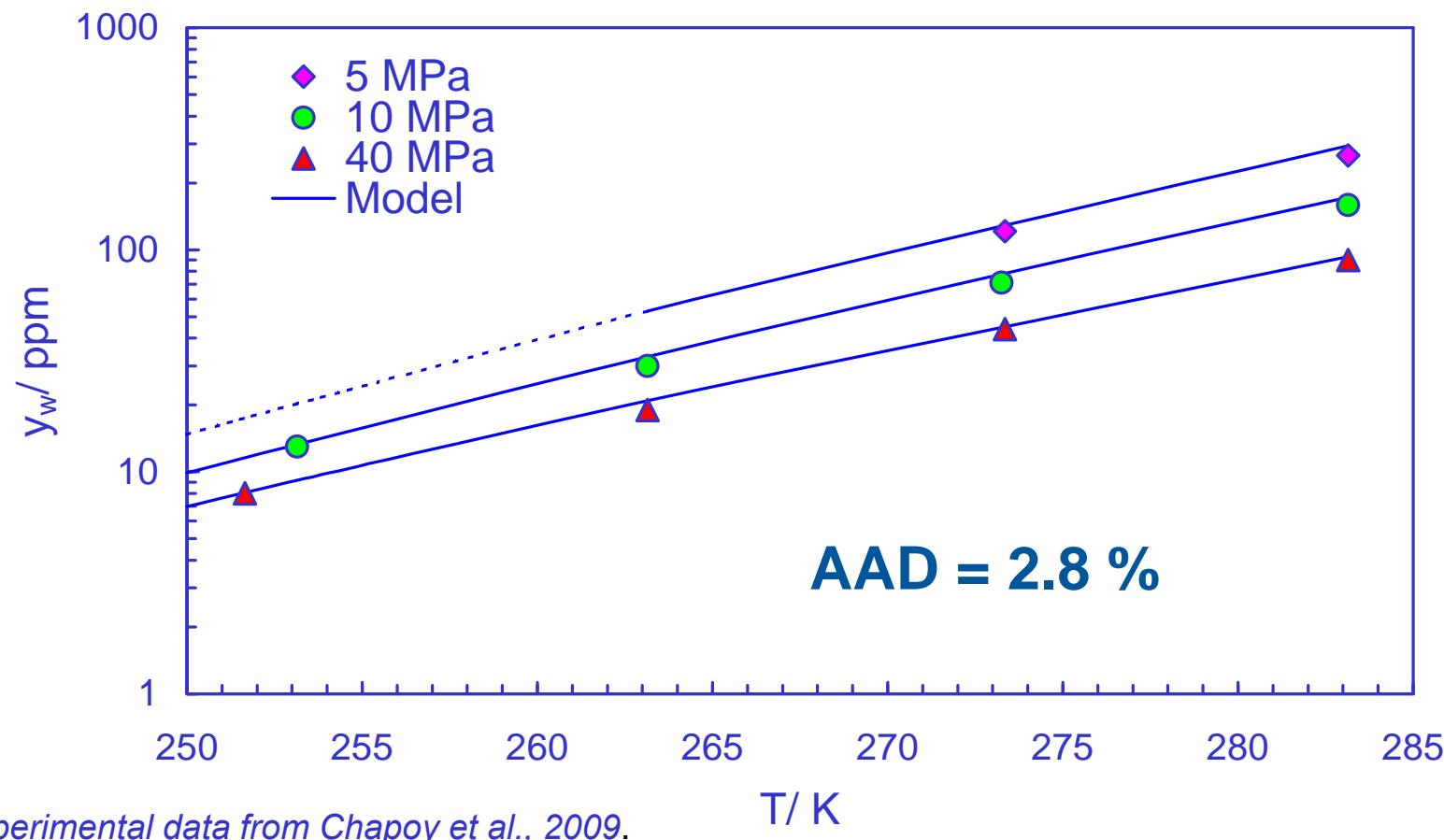
Experimental Conditions



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Gas Hydrate in Low Water Content Gases

- Experimental and predicted water content (ppm mole) of a synthetic gas in equilibrium with hydrate.



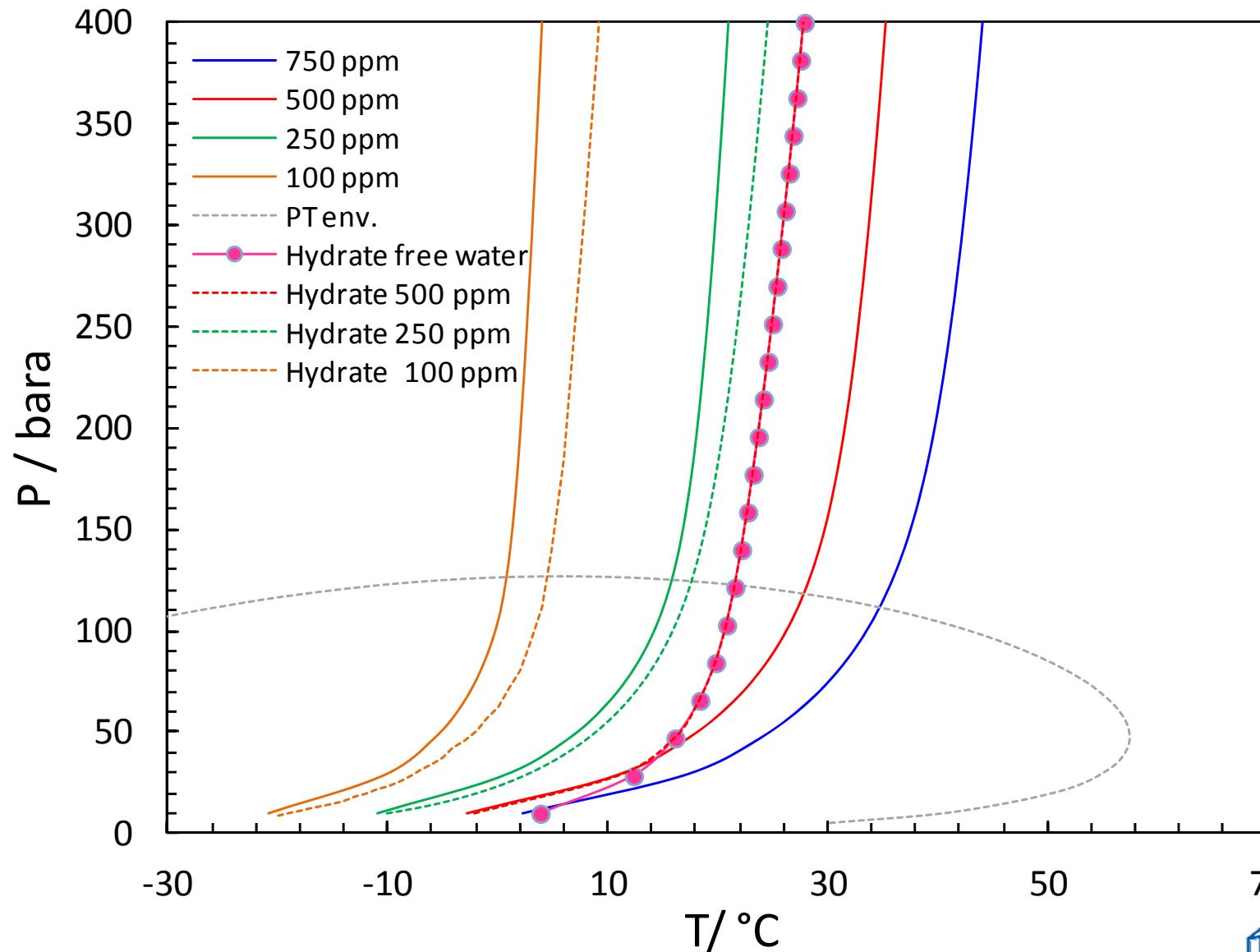
Gas Hydrate in Low Water Content Gases

Example: Real Case



| Component(s) | Mole Fraction |
|-----------------|---------------|
| Methane | 0.851359 |
| Ethane | 0.067004 |
| Propane | 0.044403 |
| i-Butane | 0.0063 |
| n-Butane | 0.010701 |
| i-Pentane | 0.0028 |
| CO ₂ | 0.007 |
| Nitrogen | 0.0017 |
| n-Pentane | 0.0022 |
| C6 | 0.001893 |
| C7 | 0.002143 |
| C8 | 0.00212 |
| C9 | 2.72E-04 |
| C10 | 8.50E-05 |
| C11+ | 2.00E-05 |

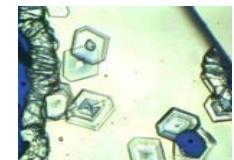
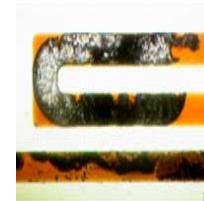
Gas Hydrate in Low Water Content Gases



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Conclusions - Perspectives

- The Cubic-Plus-Association (CPA) EoS has been applied to multiphase equilibria in mixtures containing water, **methanol**, **ethanol**, and **MEG** in the presence or absence of salts.
- Good agreement between model prediction in challenging hydrates calculations and experimental results:
 - gas hydrate in low water content gases
 - HSZ of oil/condensate in the presence of produced water and inhibitors
 - HSZ in the presence of high concentration of inhibitor(s) or salt(s)
 - prediction of hydrate inhibitor distribution in multiphase systems



Acknowledgements

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Thank you
for your
attention



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