Thermodynamics in Gas Processing – Phase Envelope Predictions and Process Design

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1st Trondheim Gas Technology Conference, 21-22 October 2009

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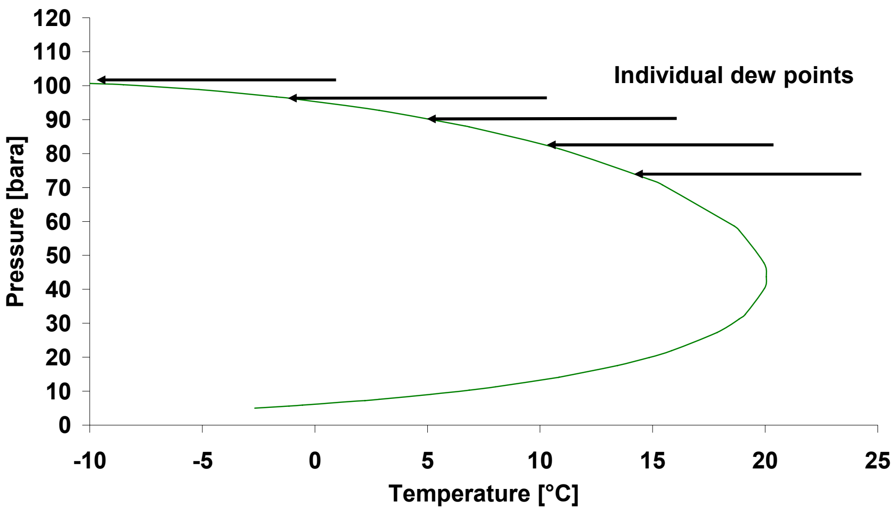
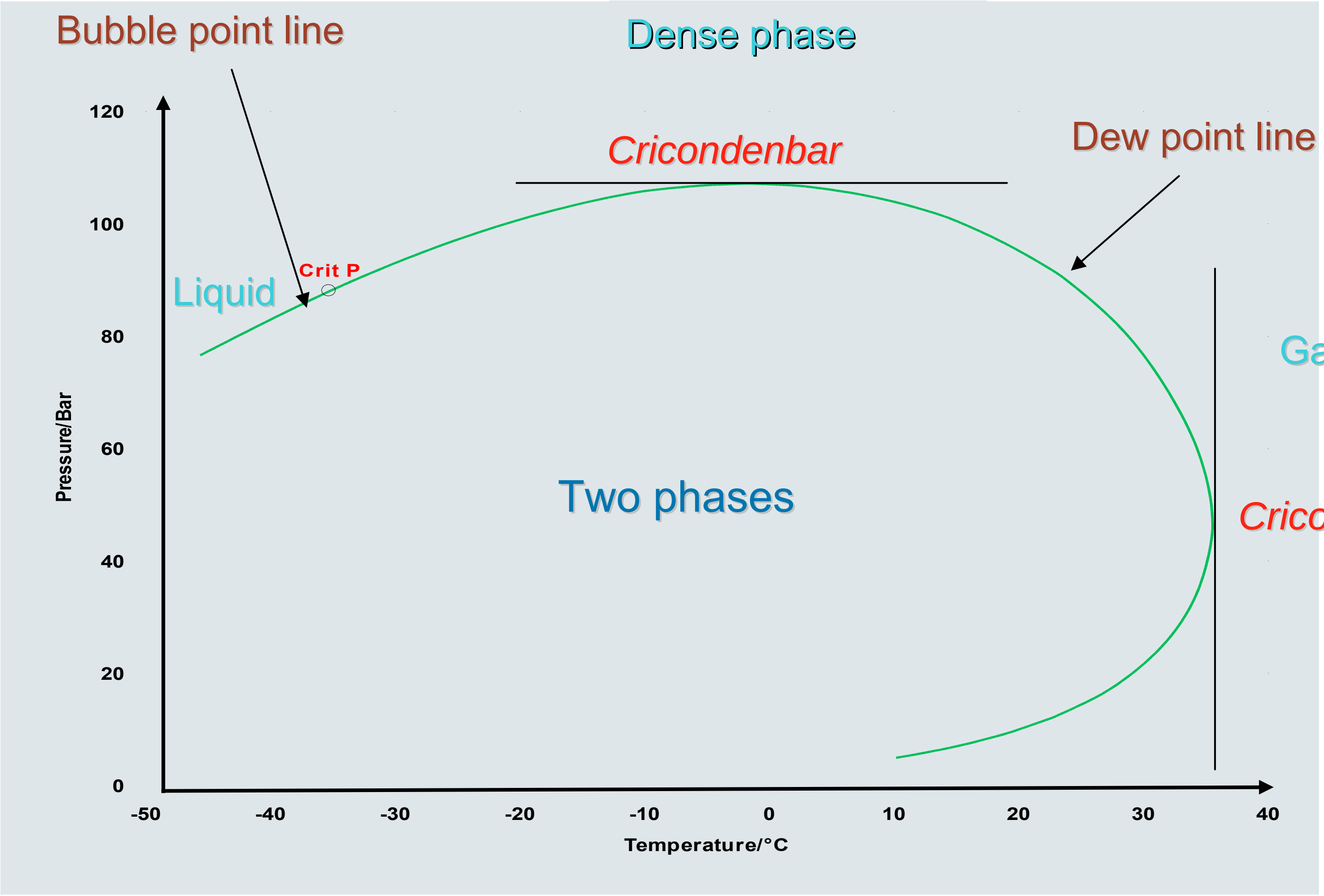
Presentation outline

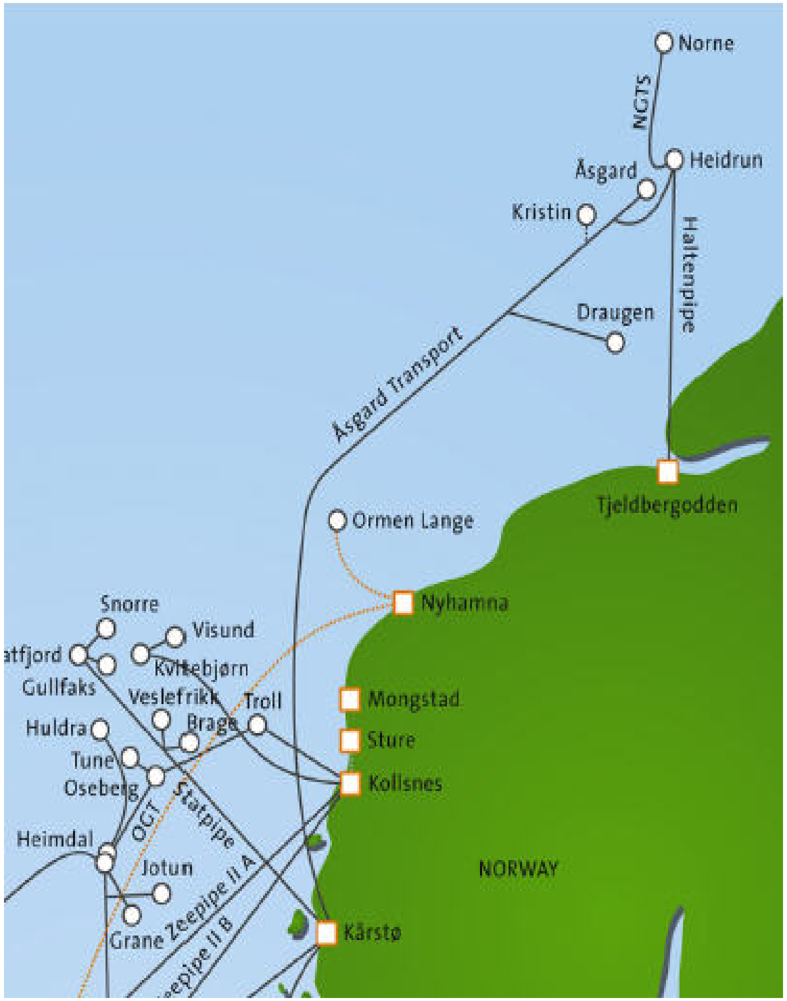
- Importance of correct phase envelope predictions
- Hydrocarbon dew points for real gases
  - Success factors
  - Predictions with thermodynamic models
- Phase envelope predictions: Impact on process design
- Conclusions



Phase envelope of a typical natural gas



Importance of correct phase envelope predictions



- In **offshore processing** the **cricondenbar** specification must be fulfilled to avoid condensation in the pipelines
- **Rich gas** transported to onshore terminals in **dense** phase in pipelines up to 830 km long
- In **onshore processing** the **cricondentherm** specification must be fulfilled to achieve desired gas quality for the **sales gas**

Correct phase envelope predictions

- Efficient operation/separation
- Optimise pipeline capacity
- Reduce design margins

Dew points for real gases: Success factors

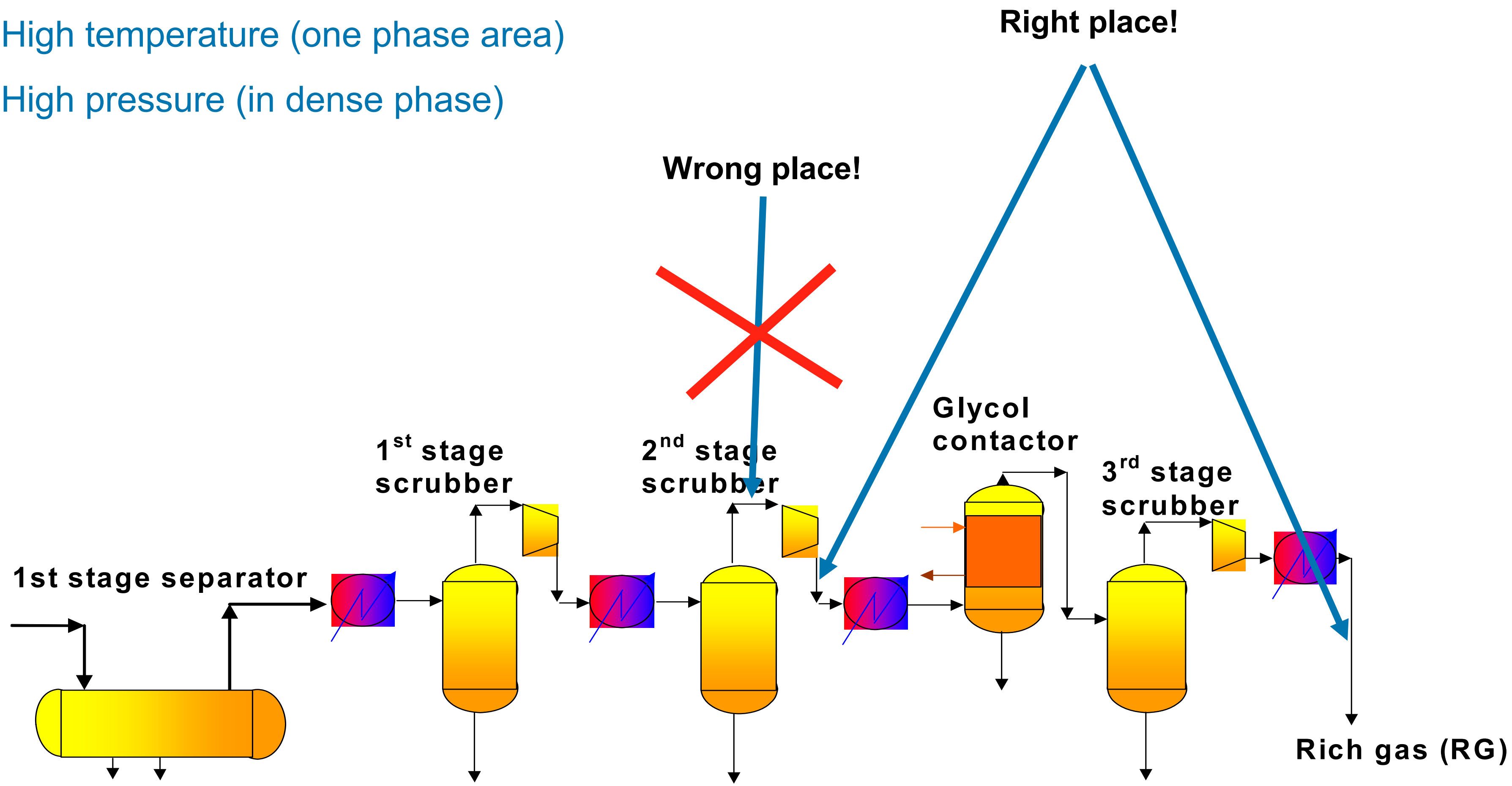
Success factors

- Gas sampling and conditioning
- Chromatographic gas analysis
- Characterisation of C7+ components
- Thermodynamic models

Success factors: Gas sampling and conditioning

Sampling at places where the gas is at:

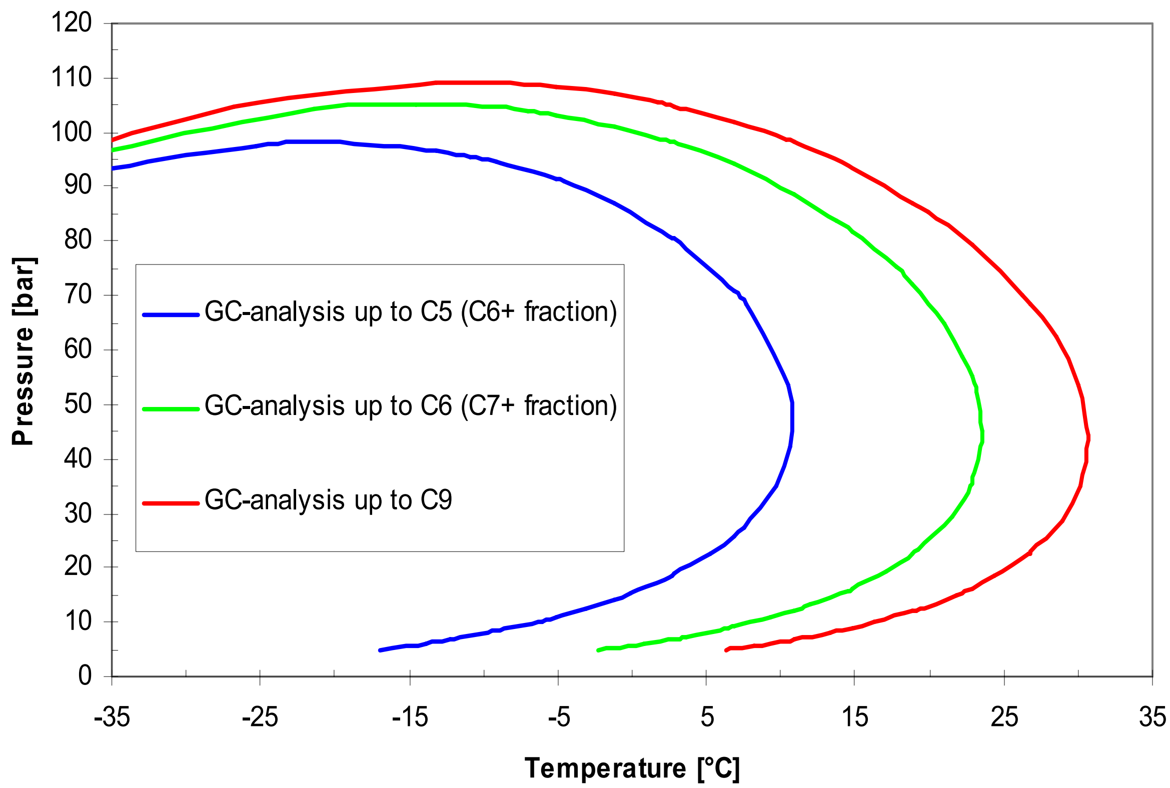
- High temperature (one phase area)
- High pressure (in dense phase)



Success factors: Chromatographic gas analysis

- How detailed should the gas analysis be?
- Enough with GC-analysis with a C6+, C7+ fraction?
- Does it really matter?

Example: Rich gas with C6+ fraction of 0.38 mol%



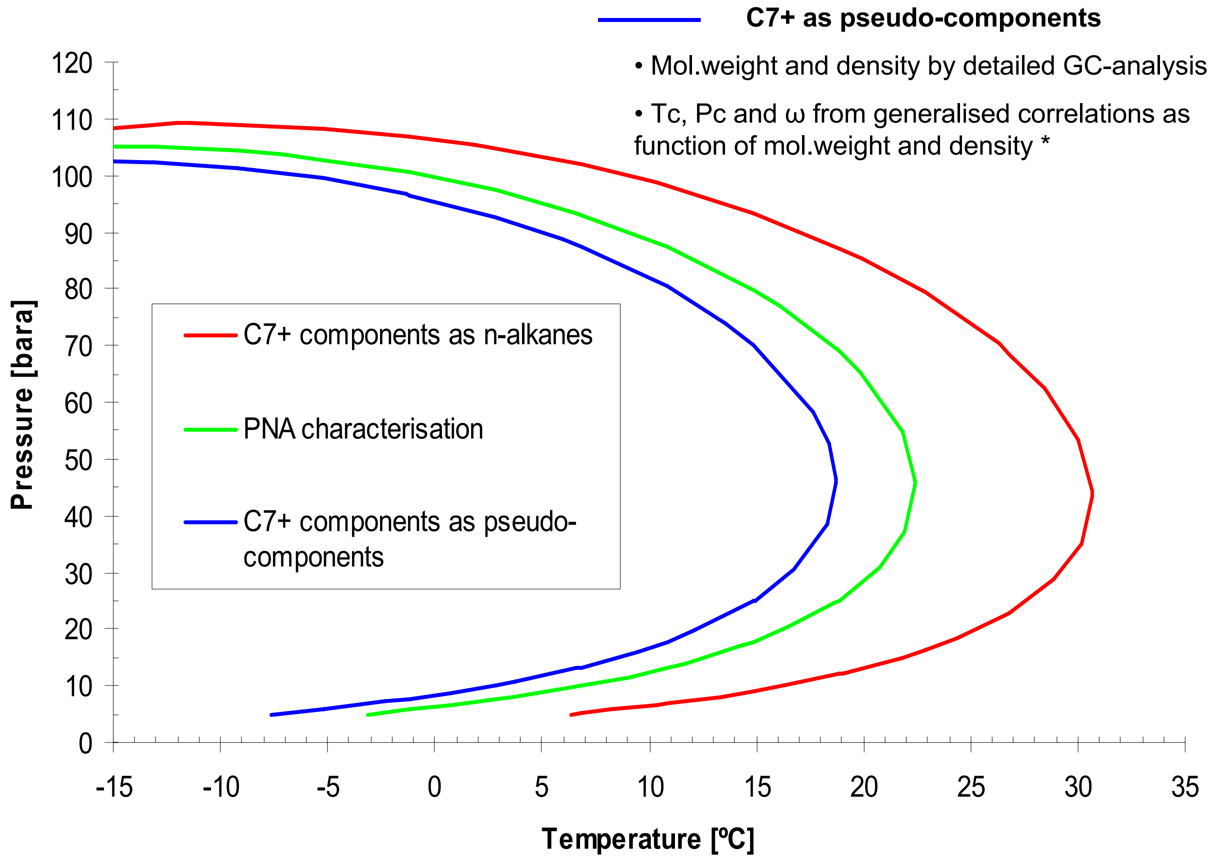
- **Deviations up to 20°C at the cricondentherm**
- **Deviations up to 10 bar at the cricondenbar**
- **The leaner the gas, the more effect the heavy ends have in the dew point**
- **Detection limit for lean gases 0.1 ppm for the heavy ends (ISO 23874)**

Success factors: Characterisation of C7+ components

- Is it enough to characterise C7+ components as n-alkanes?
- Is it important to distinguish between paraffinic (P), napthenic (N) and aromatic (A) components?
- Shall we characterise them as pseudo-components (C7*, C8*, etc)?
- How should we assign physical properties (mol. weight, density) and model parameters (Tc, Pc, ω) to the pseudo-components?
- Does it really matter?

- **Deviations up to 15°C at the cricondentherm**
- **Deviations up to 7-8 bar at the cricondenbar**

Effect of characterisation of C7+ components



* T_c, P_c from Riazi-Daubert (1987) and ω from Kesler-Lee (1976)

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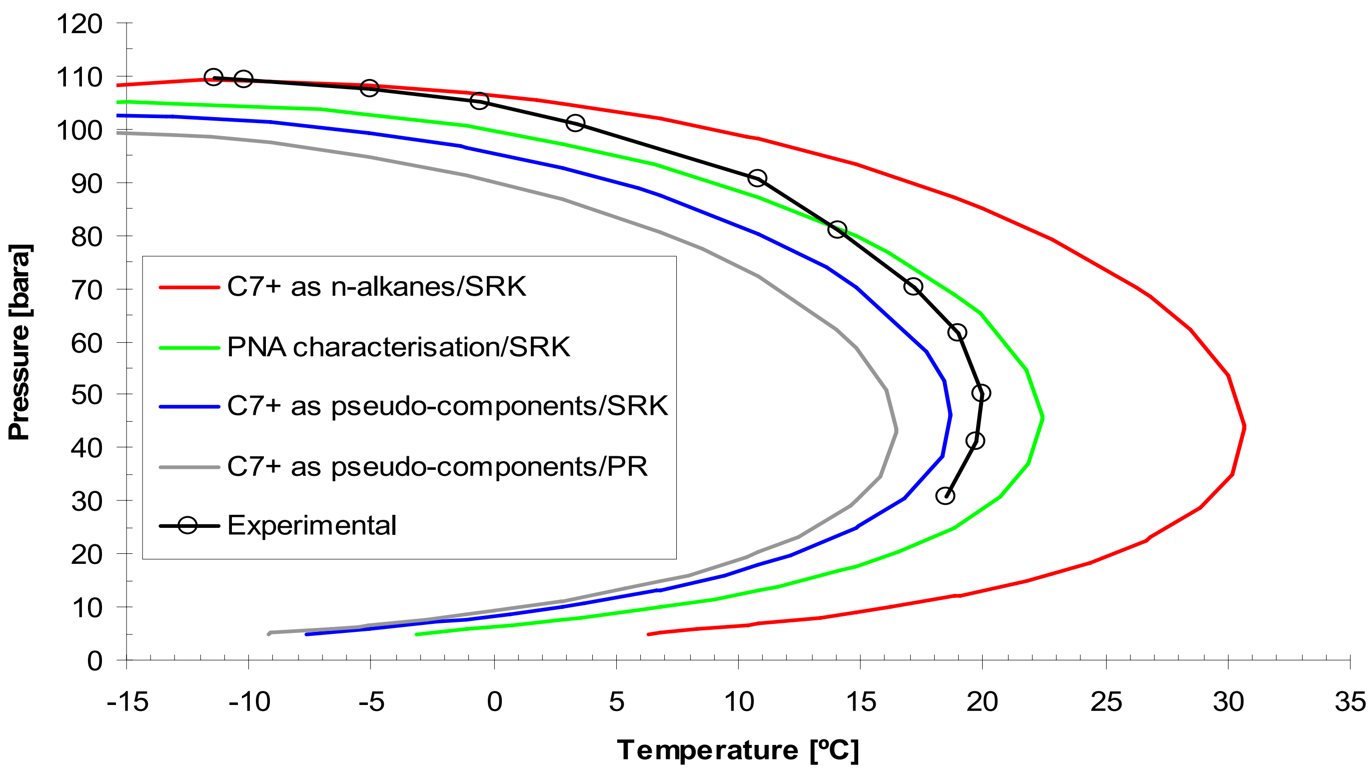
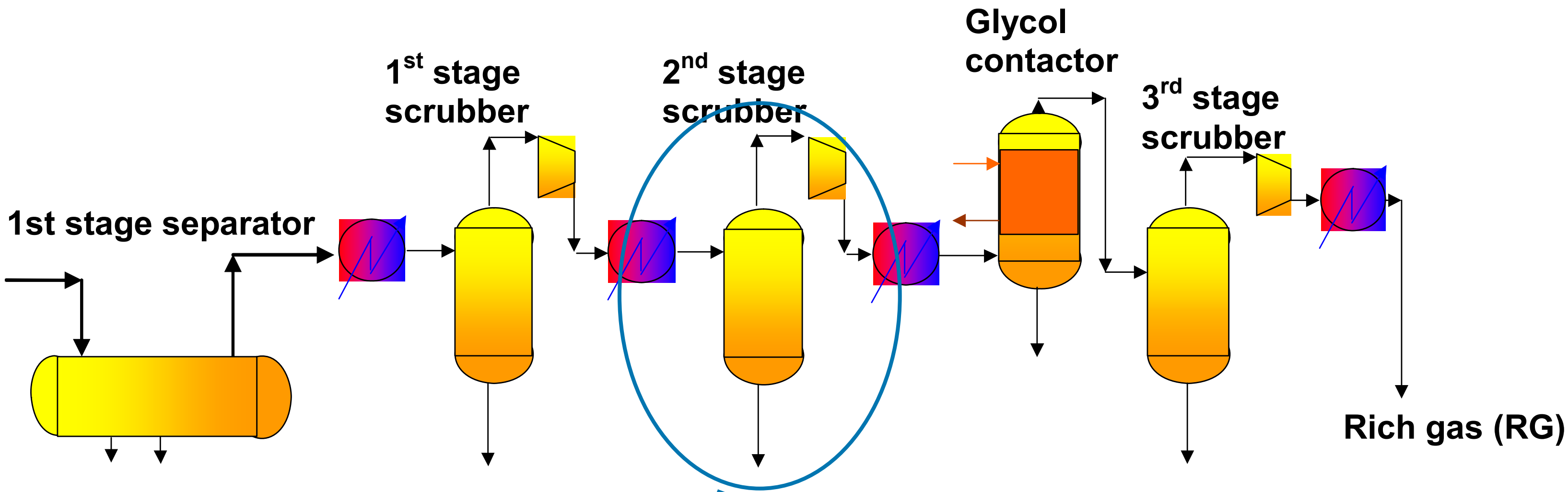
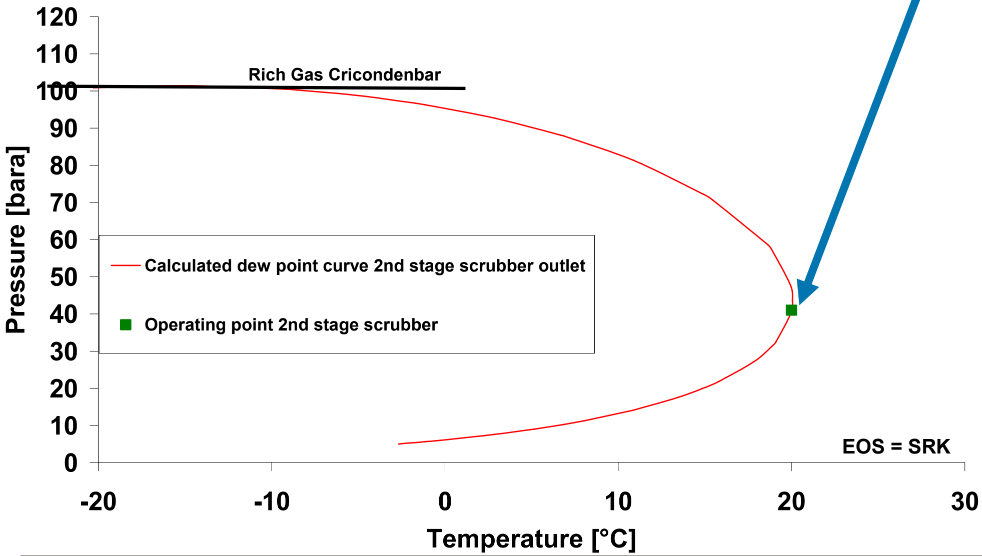
Dew points of real gases: Results for a rich gas



- Characterisation with PNA analysis gives better results than assuming C7+ as n-alkanes
- Characterisation with pseudo-components (utilising correct mol.weight and density and generalised correlations for Tc, Pc and ω) provides the correct shape of the phase envelope
- Cricondenbar underestimated. No model can predict both the cricondenbar and the cricondentherm
- Experimental dew point measurements still required to decide the correct phase envelope

Phase envelope predictions: Impact on process design





- The rich gas (RG) has to meet a specification of 105 barg spec
- The quality of the gas is decided at the 2nd stage scrubber (operating point: 40 barg, 20°C)
- The model predicts a cricondenbar of 100 barg
- Design margin of 5 bar to cricondenbar spec

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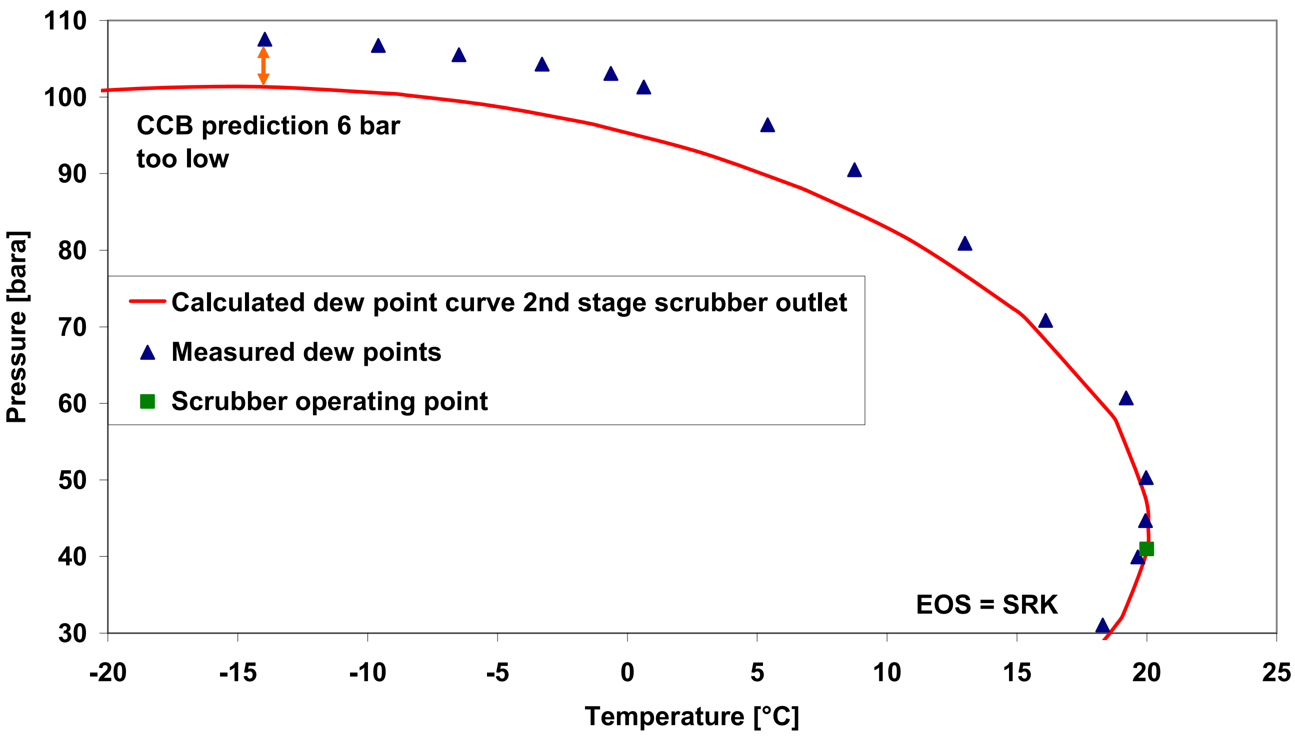
Phase envelope predictions: Impact on process design (cont.)



- Experimental measurements show give a cricondenbar of 106 barg. Gas is off spec!
- Design margin of 5 bar not sufficient. Higher design margin needed (10 bar)
- Improve accuracy of the model in order to reduce the design margin

Conclusions

- Focus on sample chain is decisive (sample taking, conditioning and GC-analysis)
- Characterisation of the heavy ends (C7+) is crucial
- The thermodynamic models are not capable to model sufficiently the whole phase envelope
- The models underpredict the cricondenbar
- Experimental dew point measurements are still needed to verify the model predictions
- Focus on thermodynamic models in order to achieve good process designs, reduce design margins and ensure product quality

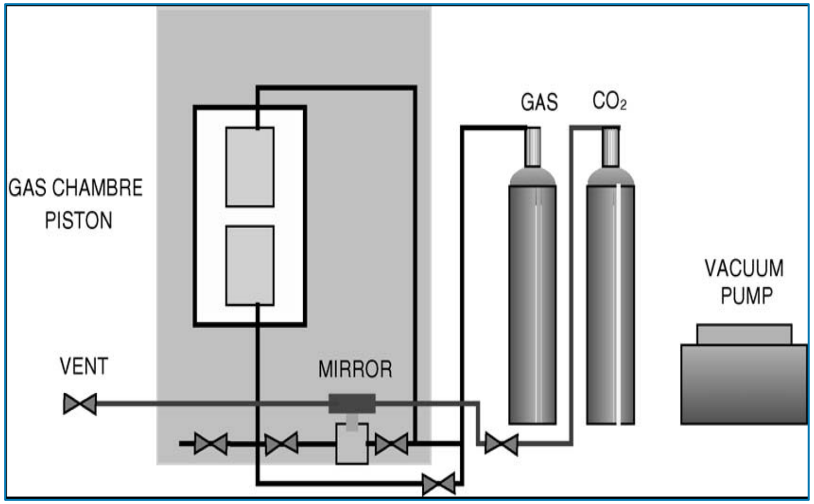
Source: www.statoilhydro.com

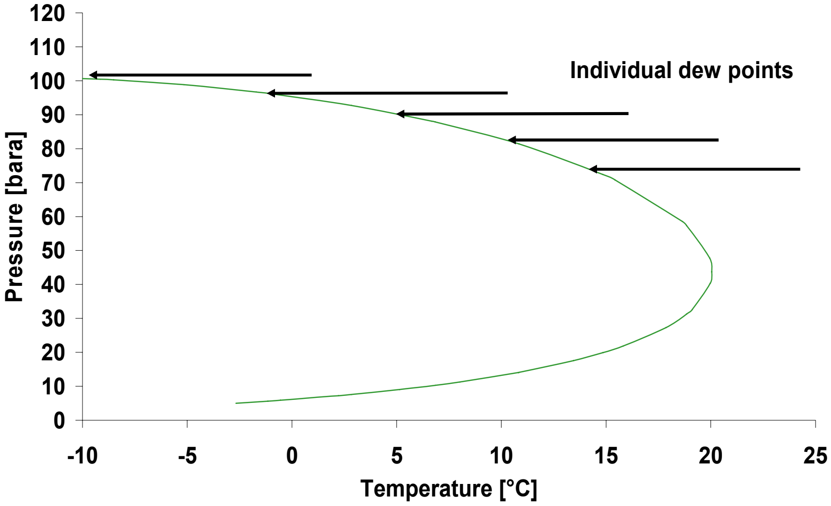
Thank you for your attention!

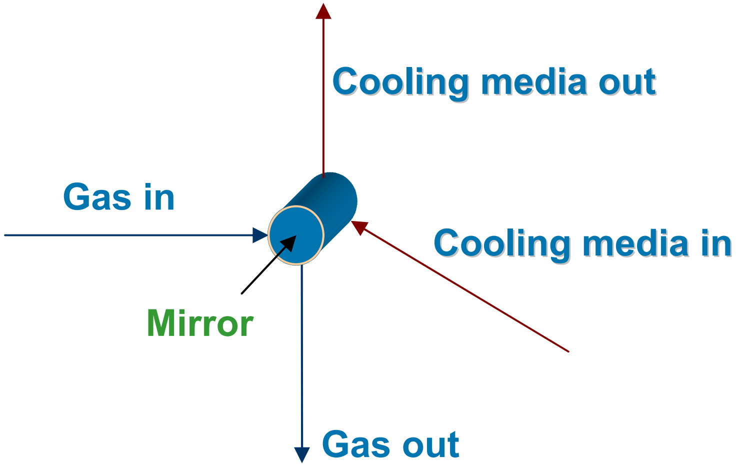
Back-up slides

Dew points for real gases: Experimental measurements

Chilled mirror optical apparatus from Chandler Engineering

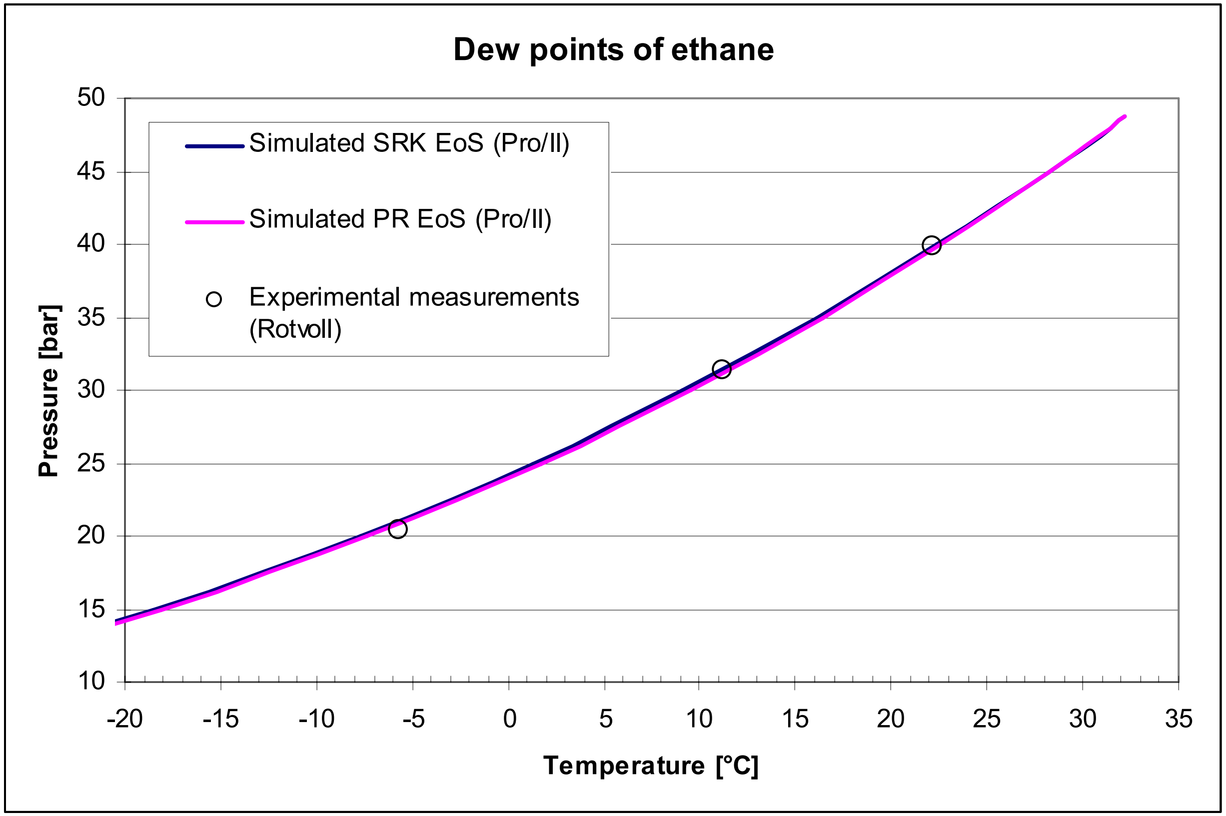




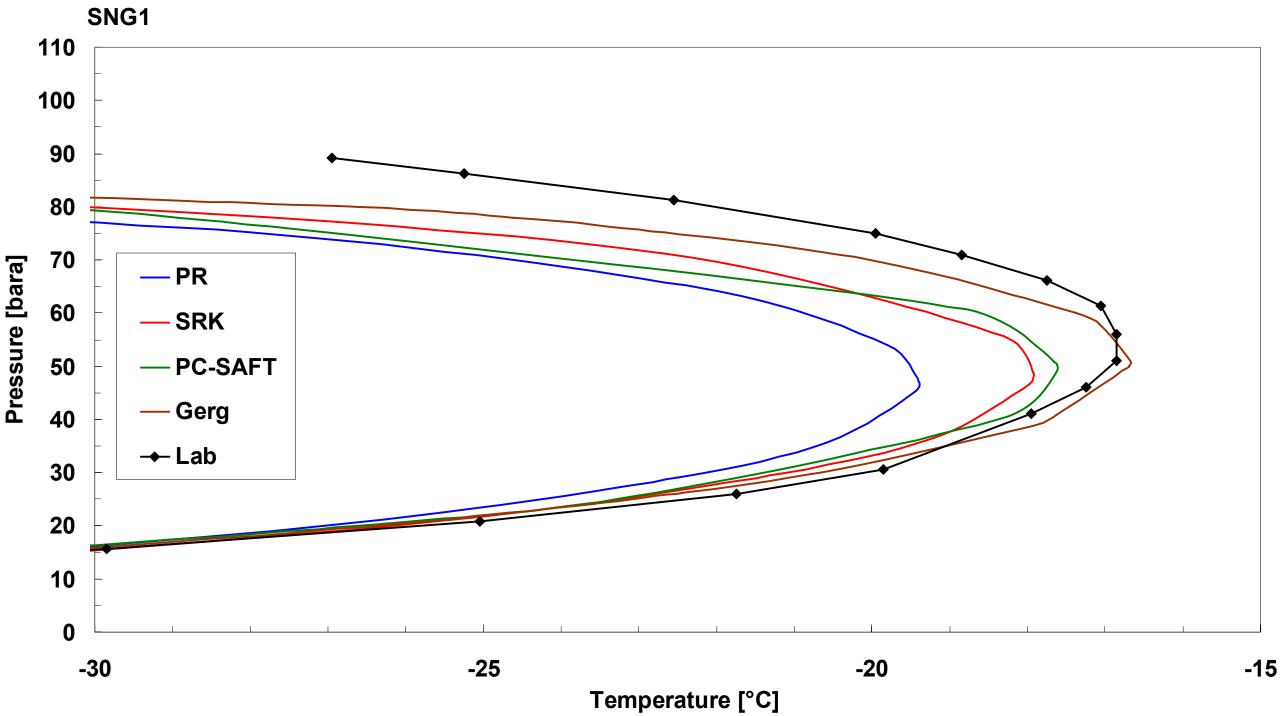


Dew point predictions: Pure components (ethane)

- Agreement between experimental dew points and predictions with SRK and PR EoS



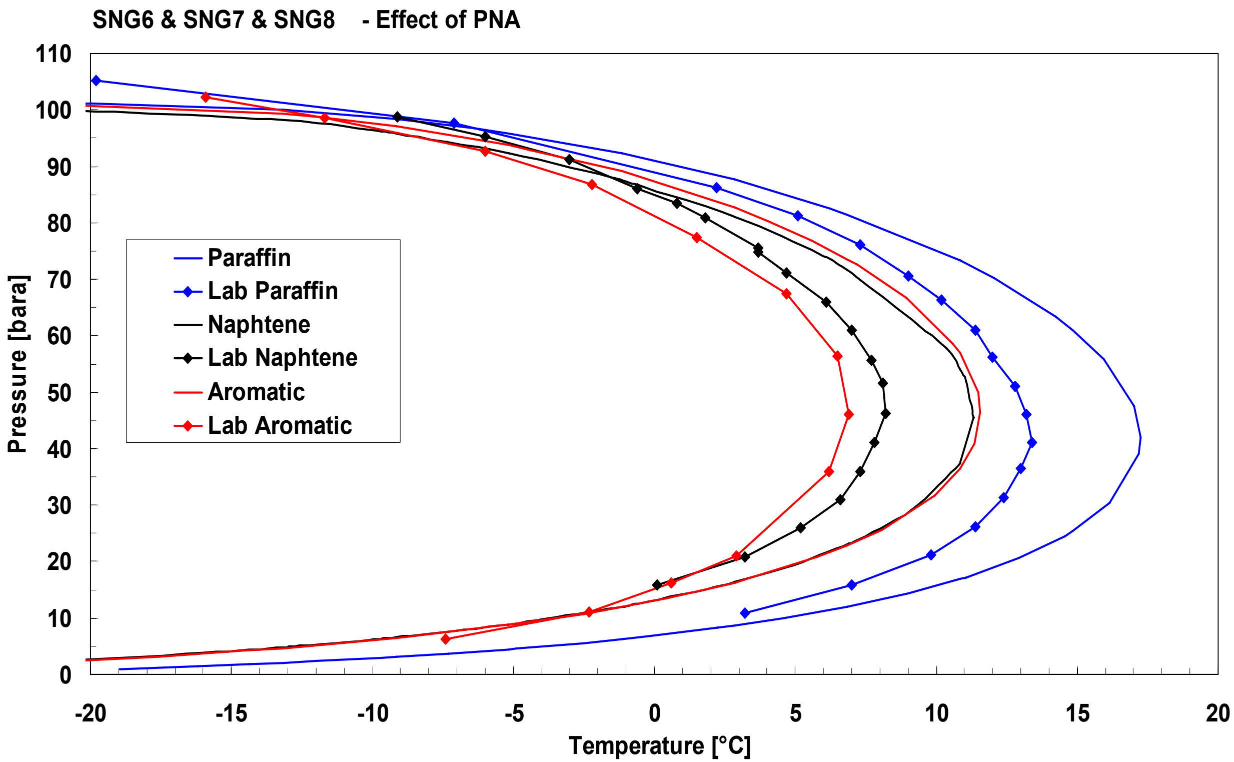
Dew point predictions: Simple synthetic gases (up to C5)



Component	SNG1
Methane	93.505
Ethane	2.972
Propane	1.008
i-Butane	1.050
n-Butane	1.465
n-Pentane	-

- Both cricondenbar and cricondentherm is under-predicted
- Deviations up to 5°C in cricondentherm and 15 bar in cricondenbar
- Good accordance at low pressure
- Shape of the experimental dew point line is different from predicted by the model

Synthetic gases with a selected C7 component



Component	SNG7	SNG8	SNG9
Methane	93.121	93.176	83.940
Ethane	3.048	3.064	10.016
Propane	0.994	1.014	4.109
i-Butane	1.032	1.027	0.601
n-Butane	1.510	1.521	1.031
i-Pentane	-	-	-
n-Pentane	-	-	-
n-Hexane	-	-	-
Benzene (A)	0.295	-	-
N-Heptane (P)	-	0.198	-
Cyclo-Hexane (N)	-	-	0.302

- **Cricondenbar still under-predicted, but cricondentherm over-predicted**
- **Aromatic and naphtene compounds give significant steeper dew point line than paraffins**
- **PNA characterization important for phase envelope prediction**

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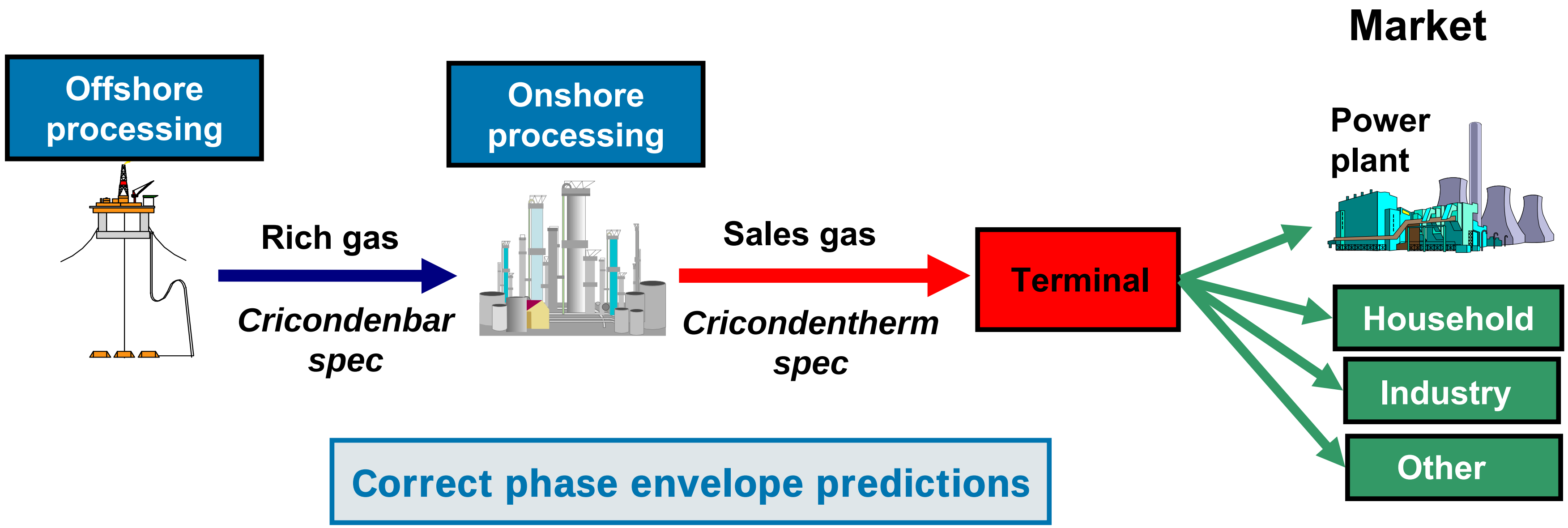
Importance of correct phase envelope predictions



- Efficient operation/separation
- Optimise pipeline capacity
- Reduce design margins