The Third MEA Campaign at the CO$_2$ Technology Centre Mongstad

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Located at the Mongstad industrial site:
Generic amine amine plant designed and constructed by Aker Solutions and Kværner.
Oil refinery (flue gas with ~13% CO$_2$) and gas fired power plant (flue gas with ~3.5% CO$_2$) available.

TCM Owners: Gassnova (Norwegian state), Statoil, Shell, Total:
New participant agreement with operations for 3 more years (Aug 2017 – Aug 2020).
catching our future
MEA-3 Approach and Targets

**Approach:**
1. follow (as much as possible) industrial approaches
2. existing guidelines for running CO\textsubscript{2} absorption amine plants

**Targets:**
MEA-3 aims to produce data and information that are relevant to realization of the full-scale CO\textsubscript{2} capture plants.
Business Significance of MEA Baselines: How They will be Used by Vendors?

- Measure
- Compare
- Diagnose
- Improve
- Optimize

Research Significance of MEA Baselines: How does it accelerate CCS?

- Development of plant control schemes
- CO₂ product composition for CO₂ storage and EOR
- Workplace monitoring
- Corrosion monitoring
- Emission monitoring & control techniques
- Flue gas composition and impurities
- Flue gas pretreatment
- Column flow distributions and mass transfer
- Detailed degradation mechanisms & inhibition
- Impact of dynamic operations
MEA Campaigns 2013-2017

**MEA-1 Highlights**
- Dec 2013 – Feb 2014
- Aker Solutions campaign
- Plant commissioning (in practice)
- CHP baseline established at capacity of 47,000 Sm3/hr and 4.1 GJ/t CO2
- Emission profiles and degradation mechanisms established

**MEA-2 Highlights**
- TCM campaign
- Commissioning of the instrumentation project
- CO₂ mass balance closure
- CHP baseline revisited and re-established at the full capacity of the amine plant and 3.6 GJ/t CO2

**MEA-3 Major Goals**
- Jun 2017 – ongoing
- TCM campaign
- **WP A**: Reduction in CO₂ avoided cost by parameter investigations
- **WP B**: Reduction in technology gaps
- **WP C1**: Reduced energy and operational costs by model predictive control (Climit Demo: DOCPCC)
- **WP C2**: Process parameters impact on aerosol emissions and RFCC baseline (Climit Demo: AeroSolve)
- **WP D**: Reduced energy penalty and flexible operation (Academic collaboration)
WP A: Reducing the Cost of Carbon Capture (not started)

WP B: Technology Gap Closure (ongoing)

WP C1: DOCPCC Climit Demo (operations completed)

WP C2: Aerosolve Climit Demo (ongoing)

WP D: Academic collaborations (operations completed)

Started June 12, MEA-3 will be operated at minimum length until October 31

Priority of MEA3: WP C1: DOCPCC
WP C2: Aerosolve

Collaboration Partners:

Statoil (Industry)
Shell (Industry)
Sasol (Industry)
Total (Industry)
Gassnova (Public)
US DOE NETL (Public)
SINTEF (Research)
TNO (Research)
NTNU (Academia)
Imperial College (Academia)
DTU (Academia)
University of Oslo (Academia)
Cybernetica (Industry)
The ROAD project
Engie (Industry)
Uniper (Industry)
Preliminary highlight results

WP B Technology Gap Closure:
Amine degradation is a major disadvantage of MEA as an absorbent for CO₂ removal
Injection of KHSO₃ oxygen inhibitor for reduced MEA degradation → lower MEA degradation during operations with high O₂ flue gas (gas turbine)

WP C2 Aerosolve Climit Demo:
Aerosols has caused inherent and unacceptable amine emissions during previous carbon capture work, at TCM and elsewhere.
Previous installation of a Brownian diffusion filter has now allowed for CO₂ removal from refinery flue gas
MEA degradation inhibitor

- Injection of KHSO$_3$ (potassium bisulfite)
- $\text{SO}_3^{2-} + \frac{1}{2} \text{O}_2 \rightarrow \text{SO}_4^{2-}$

<table>
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<tr>
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<th>NH$_3$ emissions</th>
<th>Heat stable salt (excl. SO$_4^{2-}$) and degradation products</th>
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<tbody>
<tr>
<td>Without inhibitor</td>
<td>$\sim$ 20 ppm</td>
<td>$\sim$ 1 (normalized)</td>
</tr>
<tr>
<td>With inhibitor</td>
<td>$\sim$ 2 – 3 ppm</td>
<td>$\sim$ 1/10 (relative to normalized)</td>
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</tbody>
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- Degradation from 1.5 kg MEA/ton CO$_2$ to about $X$ kg MEA/ton CO$_2$ (to be assessed)
- Injection philosophy;
  - $\text{SO}_3^{2-}$ solvent bulk concentration about 500 – 1000 ppm, reaction with $\text{O}_2$ in the film.
  - Use of NH$_3$ emissions for estimating $\text{SO}_3^{2-}$ dosage rates during operations (equivalent to oxygen absorption)
  - Potassium ions used as indicator for total amounts of inhibitor injected
  - Use of reclaimer to remove K$_2$SO$_4$ with caustic injection when approaching solubility limits
Aerosolve Climit Demo

- Refinery flue gas (RFCC) contains high amounts of sulfuric acid mist
  - Up to about 10 ppm SO$_3$ equivalent and some catalyst fines
  - Previous operations demonstrated unacceptable amine emissions of about 500 – 1000 ppm
    - Emission permit breaches, neighbor complaints, high loss of amines

- Much resources used to investigate the RFCC flue gas
  - ELPI+ and iso-kinetic measurements
  - 16 – 25 million particles per cm$^3$, primarily aqueous sulfuric acid mist particles
  - Conducted further investigations:
    - Use of 1000 Sm$^3$ / hr pilot Brownian Diffusion (BDU) filter
    - Mixing of RFCC flue gas into gas turbine (CHP) flue gas for determining relation between particle amounts and emissions

- Investment decisions for a full scale BDU filter installation taken by TCM owners
  - Stable pressure drop of about 25 mbar across filter, no indications of clogging
  - 0.5 millions particles / cm$^3$ downstream filter
  - Design 35.000 Sm$^3$/hr, total installation costs about 10 MNOK (1.2 MUSD)
Aerosolve Climit Demo
Thank you for your attention!!!

Acknowledgments to TCM DA owners