The New Sulzer Mellapak™CC™ and AYPlus™DC Structured Packings for Post-Combustion Capture

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IEAGHG 1st Post Combustion Capture Conference, 17 – 19 May, Abu Dhabi, UAE
Sulzer Services - CO₂ Capture

- CO₂ Absorption knowhow
- Support in Process modelling
- Support of Maldistribution analysis
- CFD modelling
- Pilot facilities
- Selection of right mass transfer technology
- Engineering of large size column internals
- Installation services

**Current focus on Process Intensification**

- Development of next generation mass transfer technology for post-combustion capture (Mellapak™CC™ and AYPlus™ DC structured packing)
- Optimizing the logistics, supply-chain, fabrication and installation
### References – CCS Post Combustion

Sulzer is working very closely with all major Process Licensors at the grassroot level

- **Pilot Plants**: 19
- **Demo Plants**: 1
- **Semi-Full-Scale plant**: 1

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<th>Country</th>
<th>Column geometry</th>
<th>Product</th>
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<td>Random packing</td>
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**Typical CO\(_2\) Absorber Design**

- **CO\(_2\) absorption**
  - Several sections (typical 2 to 3)
  - Packing height: 12 to 30 m

- **Emissions control**
  - Minimizing solvent emissions

- **Pump around section with cooler**
  - Water balance
  - Solvent absorption

- **Vapour distribution**
  - CFD analysis required
Why Sulzer Mellapak instead of Random Packing?

Mellapak Structured Packing offers better hydraulic & mass transfer characteristics compared to Random Packing (Rings) on a volume basis.

- **Improved mass transfer** due to increased specific area
  - less packing height
- **Less pressure drop** due to the defined geometrical structure
  - less operating costs
- **Less weight** due to the mechanically more stable structure
  - less investment costs

Pressure Drop – OPEX savings

- Electrical power for Flue Gas Blower to overcome pressure drop

- Assumptions for pressure drop calculation
  - Relative efficiencies of structured against random packing
    Mellapak 250.Y and 1” Rings have same efficiencies; 2” Ring 65% of 1” Ring
  - Superficial gas velocity: 1.6 m/s → F-factor=1.8 Pa$^{0.5}$
  - Specific liquid load: 30 m$^3$/m$^2$h

- Pressure Drop

<table>
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<tr>
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<th>1” Ring</th>
<th>2” Ring</th>
<th>Mellapak M250.Y</th>
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<tr>
<td>Packed height:</td>
<td>20</td>
<td>30</td>
<td>20 m</td>
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<tr>
<td>$\Delta p/\Delta z$</td>
<td>&gt; 3</td>
<td>1.9</td>
<td>1 mbar/m</td>
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<tr>
<td>$\Delta p_{\text{Absorber}}$</td>
<td>&gt; 60</td>
<td>57</td>
<td>20 mbar</td>
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</table>
Pressure Drop – OPEX savings in CO$_2$ Absorber

800 MW coal-fired power plant

- $G = 3'000'000$ m$^3$/h
- Fan efficiency = 0.75
- Operating time = 8'400 h/y
- $kWh_{el} = 5$ cents Euro

Electricity Cost for Flue Gas Fan

1” Ring: $\Delta p_{\text{Absorber}} > 60$ mbar $\Rightarrow$ $> 2'800'000.-$ € / year
2” Ring: $\Delta p_{\text{Absorber}} = 57$ mbar $\Rightarrow$ $2'660'000.-$ € / year
M250.Y: $\Delta p_{\text{Absorber}} = 20$ mbar $\Rightarrow$ $935'000.-$ € / year

Annual savings with M250.Y: $1'725'000.-$ € / year

Savings with M250.Y over life-span (30 y): $52'000'000$ €
Sulzer Mellapak™ CC™: Packing for CO₂ Capture

- Define the test system for CO₂ Capture
- Define the benchmark packing for optimization

Test System for Post Combustion CO₂ Capture
- Low partial pressure for CO₂ in flue gases with atmospheric pressure
- Physical solvents not applicable
- Chemical solvents undergoing a reversible reaction are feasible
- NaOH – CO₂ system was chosen as test system for optimization of Mellapak structured packing

- For most chemical solvents
  - mass transfer resistance: liquid-side controlled
  - reaction regime: fast-reaction regime
- System NaOH – CO₂ offers these features

The relative benefit gained from the new Sulzer MellapakCC packing compared with the conventional Mellapak packing will also be applicable to any system that belongs to the fast-reaction regime
Benchmark Structured Packing for Optimization

- Mellapak 250.Y is most commonly used structured packing
- Mellapak 250.Y is often used as benchmark
  - data available in public literature

» Benchmark packing for NaOH-CO₂: Mellapak 250.Y

- Sulzer MellapakCC structured packing
  - Specifically developed for post-combustion capture application
  - Desired Targets
    - lower pressure drop
    - better or similar separation efficiency
  - Specifics studied: micro structure, hole size, number of holes, angle of corrugation
Mass Transfer Performance of MellapakCC

Effective Interfacial Area (Separation Efficiency)

Test System: Air/NaOH-CO₂
F-factor: 1.5 Pa⁰.⁵

Liquid Load [m³/(m²h)]

- MellapakCC
- Mellapak 250.Y
- Mellapak 2X
Mellapak 250.Y - Benchmark

Pressure Drop Comparison
Mellapak CC vs. Mellapak 250.Y

System: Water-Air
Column ID: 1 m
Packing height: 3 m

- Mellapak 250.Y: 0 m³/m²h
- Mellapak 250.Y: 25 m³/m²h
- Mellapak 250.Y: 50 m³/m²h

\[ \Delta p/\Delta z \text{ [mbar/m]} \]

\[ F\text{-factor} [\text{Pa}^{0.5}] \]
MellapakCC vs Mellapak 250.Y

Pressure Drop Comparison
MellapakCC vs. Mellapak 250.Y

System: Water-Air
Column ID: 1 m
Packing height: 3 m

- MellapakCC: 0 m³/m²h
- Mellapak 250.Y: 0 m³/m²h
- Mellapak 250.Y: 25 m³/m²h
- Mellapak 250.Y: 50 m³/m²h

Graph showing the comparison of pressure drop across different flow rates for MellapakCC and Mellapak 250.Y.
MellapakCC vs Mellapak 250.Y

Pressure Drop Comparison
MellapakCC vs. Mellapak 250.Y

System: Water-Air
Column ID: 1 m
Packing height: 3 m

- MellapakCC: 0 m³/m²/h
- MellapakCC: 25 m³/m²/h
- Mellapak 250.Y: 0 m³/m²/h
- Mellapak 250.Y: 25 m³/m²/h
- Mellapak 250.Y: 50 m³/m²/h

\[ \Delta \frac{P}{\Delta z} \text{ [mbar/m]} \]

\[ F \text{-factor [Pa}^{0.5}\text{]} \]
MellapakCC vs. Mellapak 250.Y

Pressure Drop Comparison
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Mellapak 250.Y: 0 m³/m²h
Mellapak 250.Y: 25 m³/m²h
Mellapak 250.Y: 50 m³/m²h

60% lower
Pressure Drop Comparison
MellapakCC vs. Mellapak 2X

Test System: Air/Water
Column ID: 1 m
Packing Height: 3 m
Liquid Load: 25 m³/m²h

20% lower
Sulzer Mellapak™CC™: the Packing of Choice

- MellapakCC vs Mellapak 250.Y
  - same efficiency
  - and
  - up to 60% reduced pressure drop!

- MellapakCC vs Mellapak 2X
  - 20% higher efficiency!
  - and
  - up to 20% reduced pressure drop!
**OPEX Savings with MellapakCC**

**Example for a 800 MW coal-fired power plant: MellapakCC vs. M250.Y**

- **Assumptions**
  - Flue gas rate = 3’000’000 m³/h
  - Packing height = 20m
  - F-factor = 1.8 Pa^{0.5}
  - Avoided pressure drop with MellapakCC-3 = 10 to 12 mbar
  - Operating life-span for the power plant = 30 years

**Avoided OPEX over life span : € 16’000’000**
Solvent Emissions : Showstopper for CCS ??

- Recently, emission issues in post combustion CCS gained significant interest
  - Solvent emissions due to low vapor pressure
  - Nitrosamines formation (secondary amines)
  - Degradation products
  - Ammonia emissions
- This could be even a “show stopper”
- Environmental regulations in Europe target: **Ultra low emissions**
Standard Design Configuration (sub-ppm levels)

- “Pump around” above absorption section
  - Water condensation (balance)
  - Reduced solvent emissions (low ppm range)
  - Solvent concentration limited by equilibrium
- Excessive packing height does not result in reduced solvent emissions
- 2\textsuperscript{nd} pump around section reduces solvent emissions to sub-ppm level
Sulzer Zero Emissions Package - ‘ppb’ levels

New possible configuration

- “Once through” absorption section
  - Water make-up flow rate typically results in 50 to 200 lt/(m².h)
  - Problem: Poor wetting of packing surface reduces packing efficiency

Sulzer Zero Emissions Package

- AYPlus™DC developed for these challenging very low (aqueous) flow rates
- AYPlus™DC shows excellent wetting with aqueous media
- A liquid distributor for extremely low flow rates was also developed: Sulzer VEPK
AYPlus™ DC - Efficiency for Absorption Systems

Test system: DMF absorption with water

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<tr>
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<th>DMF</th>
<th>MEA</th>
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</thead>
<tbody>
<tr>
<td>Formula</td>
<td>C₃H₇NO</td>
<td>C₂H₇NO</td>
</tr>
<tr>
<td>MW</td>
<td>73.1</td>
<td>61</td>
</tr>
<tr>
<td>NBP [°C]</td>
<td>152</td>
<td>170</td>
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<tr>
<td>p° (T=40°C) [mbar]</td>
<td>13</td>
<td>1.6</td>
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</tbody>
</table>

F-factor: 1 to 3.5 Pa⁰.⁵

L/G / m: 2 to 40

AYPlus DC

Mellapak M250.Y
Liquid Distributor for AYPlus DC : VEPK
Liquid Distributor for AYPlus DC : VEPK

Sulzer Chemtech
Absorption of ..... 
- nitrosamines
- aldehydes
- other degradation products

.... has not been investigated!

Ammonia emissions cannot be reduced with such low water flow rates

AYPlus DC + VEPK Package allows to target “zero solvent emissions” for water soluble solvents with boiling point > 150°C
PROCESS INTENSIFICATION

- **Sulzer Mellapak™CC™ for Post-Combustion CO$_2$ Capture**
  - Significant reduction in pressure drop
  - Significant improvement in separation performance
  - Lower OPEX and CAPEX
  - **OPEX savings : € 16’000’000**

- **Sulzer AYPlus™ DC + VEPK Package for Emission Avoidance at Top of CO$_2$ Absorber**
  - Extraordinary wetting characteristics with aqueous media at extremely low liquid loads
  - Sulzer VEPK liquid distributor developed for extremely low liquid loads
  - AYPlus™ DC structured packing and VEPK liquid distributor together
    - drastically increases the separation performance
    - making it possible to realize 'close to zero' solvent emissions at the top of the CO$_2$ absorber
Your Partner in Capturing CO₂nvenient Truths

Thank You!