Heat recovery in milk powder drying by using a liquid sorption process

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Introduction: drying and heat pumps

• Approximately 15% of industrial energy use is for drying and dewatering.
• Latent heat recovery from drying air relatively straightforward when using compression heat pumps, e.g. at Smurfit Kappa Roermond Paper.
• Stickiness provides significant challenge for heat recovery: condensation of moisture from air often not an option, how to recover this heat instead?
• Also high air temperatures (180+ °C) provide challenge for conventional compression heat pump.
Spray drying & stickyness

condenser

> $T_{\text{g}}$

evaporator

sticky
Conventional spray dryer

- Liquid
- Hot, dry air

- Spray dryer

- Powder
- Humid, warm air

Sorption assisted spray dryer

- Concentrated
- Steam

- Absorber
- Regenerator

- Diluted
- Heat
Liquid sorption flow diagram

Basic Configuration

Target: 180 °C
8 gH₂O/kg_dry_air

10 bar steam is useful for heating:
- Cleaning fluids
- Boiler feed water
- An existing SD
- TVR evaporators
Absorber Model

- Equilibrium-based model
- Steady-state operation
- 5°C driving force for heat transfer from liquid to air
- Constant pressure: no pressure drops along the absorber
- The absorption of dry air is neglected
- Entrainment of liquid desiccant is neglected
Liquid Desiccant selection criteria

- Very low vapor pressure at relatively high temperature. 1 kPa at 185 °C.
- High absorption capacity (>5wt%).
- None or very low volatility at the operating conditions in the system.
- Good stability in cycling operations.
- Low corrosiveness or availability of construction materials.
- No toxicity and no flammability.
Results: Basic Configuration with H₃PO₄ Solutions

Energy recovery: 99%

SD capacity: 3000 [kg/h] powder
Results: Absorber performance
Results: Sorption cycle

![Graph showing sorption cycle phases](image)

- Absorption
- Regeneration
Results: Config 2. Adiabatic absorber with H$_3$PO$_4$ solution

Energy recovery: 78%

SD capacity: 3000 [kg/h] powder
Results: Config 2. Adiabatic absorber with H$_3$PO$_4$ solution
Results: Config 3. Adiabatic absorber with $\text{H}_3\text{PO}_4$ solution and air-air HEX

Energy recovery: 58 %

SD capacity: 3000 [kg/h] powder
Results: Config 3. Adiabatic absorber with $\text{H}_3\text{PO}_4$ solution and air-air HEX
## Energy recovery and payback times

### Heat recovery system

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Absorber [k€]</th>
<th>SHX [k€]</th>
<th>Regenerator [k€]</th>
<th>AHX1 [k€]</th>
<th>Cost of unit [k€]</th>
<th>Cost of project [k€]</th>
<th>Annual Savings [k€/y]</th>
<th>Payback time [years]</th>
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<tbody>
<tr>
<td>Basic</td>
<td>1600</td>
<td>35</td>
<td>160</td>
<td>NA</td>
<td>3900</td>
<td>7100</td>
<td>743</td>
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<td>Adiabatic abs. air mixer</td>
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<td>31</td>
<td>135</td>
<td>NA</td>
<td>1800</td>
<td>3200</td>
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<td>140</td>
<td>44</td>
<td>2400</td>
<td>4400</td>
<td>434</td>
<td>10.0</td>
</tr>
</tbody>
</table>

### EELS system with $\text{H}_3\text{PO}_4$: basic configuration

- ER [%] 99

### EELS system with $\text{H}_3\text{PO}_4$: adiabatic absorber with mixture exhaust and ambient air

- ER [%] 78

### EELS system with $\text{H}_3\text{PO}_4$: adiabatic absorber with air-air HEx for 100% fresh air

- ER [%] 58
Conclusions

- Liquid sorption system cycle can be achieved using phosphoric acid.

- Energy savings potential (defined as amount of heat that can be recovered for use elsewhere) is between 60 to 100% - larger than any existing option.

- Payback times estimated to be between 5 and 10 years.

- Payback time calculated for configurations optimized for energy savings. When optimized for pay back time, approximately 30% reduction in payback time achievable.

- Given the corrosiveness of the available liquid desiccant, it is recommended to continue searching for a suitable liquid desiccant for the EELS system based on the selection criteria defined. The chosen material factor (4.4 compared to carbon steel) might have to be reconsidered.
Challenges and future activities

✓ Can the model performance of absorber be achieved in real life? Currently constructing lab-scale unit to measure absorption of moisture from air under similar conditions.

✓ Which material can withstand regeneration of phosphoric acid at 400°C?

✓ Can alternative absorbents such as NaOH solution be used instead? Creation of novel cycles is in very early stage of development.

✓ After successful testing of absorber & finding suitable regenerator materials => development of bench-scale prototype.
Interested? More info presented at SusTEM conference, 28-30\textsuperscript{th} June 2017

Thermal Energy Challenge Network

The 4th Sustainable Thermal Energy Management International Conference (SusTEM 2017)

28\textsuperscript{th}–30\textsuperscript{th} June 2017, Alkmaar, Netherlands

[https://research.ncl.ac.uk/thermal_challenge_network/events/sustem2017inthenetherlands/](https://research.ncl.ac.uk/thermal_challenge_network/events/sustem2017inthenetherlands/)