PENTAIR CARBON CAPTURE SOLUTIONS

CHALLENGES WITH INTERFACES

CCS and CO$_2$ Management – from Capture to Offshore Storage Capture
Hosted by DTU offshore

HENRIK LYHNE
14TH JUNE, 2022
Agenda

About Pentair

Carbon Capture Solutions
– Status of Pentair Carbon Capture Technology
– CCS Integration with CHP Plants
– CO₂ Quality for CCUS

Reference Projects

Test Results
120 locations
In 25 countries
9,500 employees
8 business units
~$3B in revenue

Mission:
“Deliver Smart, Sustainable Solutions that empower customers to make the most of life’s essential resources!”
Our history in short

- Founded in Fredericia, Denmark
- First CO₂ plant installed: Coca Cola, Iran (CBU)
- Acquired by British Oxygen Company (BOC)
- Acquired by Norsk Hydro Danmark
- Sales and production in China established
- Sales and production in Brazil established
- Acquisition of Wittemann, USA
- Acquired by Pentair
- CO₂ ImpactBrew launched & patented

Long history and knowledge of CO₂ technology
Pentair’s contribution to decarbonization

**CO₂ & METHANE PURIFICATION FROM BIOGAS**
- 3 Stage & 2 Stage with CO₂
  - With Minimum Sip
- 2000+ CO₂ PLANTS

**CO₂ RECOVERY IN BREWERIES/SOFT DRINKS**
- CO₂ Plants for Breweries & Soft Drinks

**CO₂ CAPTURE FROM INDUSTRIAL PLANTS**
- 500 lb to 15 ton/hr CO₂ Industrial CO₂
  - Anaerobic Digestion Biogas Upgrading
- 350+ AMINE PLANTS

**GAS ANALYSIS IN BREWERIES/SD/BIOGAS**
- CO₂/O₂ in Breweries BioSENSE
- 20,000+ MEASUREMENT DEVICES

**Established provider in CO₂ Recovery and Biogas Solutions**
Status of Pentair Carbon Capture Technology
Advanced Amine Technology (AAT) - A Pentair Union Engineering Proprietary Technology

CO₂ Capture and Liquefaction – Process steps

Flue gas -100-500°C

Cooling and purification (particles & sulphur)

CO₂ capture by MEA

CO₂ Compression

Dehydrator & Activated carbon filtration

Liquefaction

H₂O, SOx

N₂, O₂, NOx, H₂O

H₂O

H₂O, IMPURTIES

CO₂, N₂, O₂, NO

Liquid CO₂ 16 bara -27°C
Advanced Amine Technology (AAT) is a Pentair Union Engineering Proprietary Technology

Advanced Amine Technology

- AAT is mainly developed for Flue Gas CO₂ extraction and can be used for biogas upgrading.
- Designed for many different flue gas sources (power plants: fossil fueled, biomass fired, WtE, Cement, Lime Kilns etc.).
- Permits large scale CO₂ capture from low pressure, high oxygen containing flue gases.
- Based on the current most proven and efficient amine technology available on the market.
- Approved for beverage grade and meets CCU/S final product quality requirements.

Pentair Union Engineering has more than 350 industrial scale amine plants in operation worldwide
Advanced Amine Technology (AAT), Advantages

- All skid-mounted, modular solution
- High CO₂ reaction rate
- Tolerate high oxygen content (15%)
- Non-corrosive
- Higher CO₂ loading; approx factor 4
  - Lower circulation rates
- Nox-Flash, Propriety technology
- Reclaimer, Propriety technology
- Lower energy demand for re-generation
- Lower total energy demand
- New patented MVR technology for steam saving

The only Industrial Scale proven technology on the market
115 tpd CO₂ is captured and utilized for on-site sodium bicarbonate production
Carbon Capture & Utilization Plant, Tata Chemicals, Northwich, UK

- 1st industrial scale CCU plant in the UK.
- Capturing 40,000 t of CO₂ from flue gases from on-site gas fired CHP plant, resulting in 11% carbon reduction.
- Captured CO₂ is liquefied, purified to highest standards and used for the manufacturing of high purity sodium bicarbonate.
- ‘Capture & Utilization’ presents true ‘circular economy’ opportunity and leads to one of the lowest carbon footprint sodium bicarbonate in the world.
- TCE CCU is mentioned for its valuable contribution towards net zero 2050 in UK government’s 10-point plan for the Green Industrial Revolution.

Largest carbon capture utilization plant built in the UK
Australia - Gas Fired Power Plant

- Installed in a very restrictive nature reserve.
- Conservation park at Torrens Island.
- Supplies beverage grade liquid CO$_2$ to the Merchant market.

More than 50,000 ton per year of CO$_2$ is captured and Liquified.
Spain - Biomass Fired Power Plant

• 150 tpd CO₂ capture capacity.
• Supply of both gaseous CO₂ for horticulture and liquid beverage grade CO₂.

More than 50,000 ton per year CO₂ will be captured soon
CCS INTEGRATION WITH CHP PLANTS
ARC CCS – CO$_2$ Capture Project

Partnership: EUDP Funding scheme under the Danish Energy Agency

Consortium:

- ARC: Waste to Energy plant
- DTU: Danish Technical University
- Ramboll: Engineering company
- Pentair: Technology provider

Pentair Union Engineering has supplied more than 350 Industrial Scale carbon capture plants worldwide.
ARC Copenhagen/Denmark: Net Zero Carbon Capture

Pentair and ARC cooperation, a 3-step process to full scale Carbon Capture

1. Pilot plant completed. Multiple test results have been evaluated and will continue.
2. Demonstration plant of 160 kg/h is under delivery and will be commissioned during 2023.
3. Full scale of 500,000 t/y is planned in 2025.
**CO₂-Capture at ARC, WtE Power Plant**

- 50 kg/h MEA extraction pilot plant installed.
- Prior to installation at ARC, it was used for testing on biogas.

- Why is Pentair involved:
  - Plant is prepared for testing of other solvents.
  - Integration of CC plant with Power Plant
  - Integration in District Heating systems
  - Support to DTU

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CO₂ Quality for CCUS
CO₂ quality for CCUS

- Northern Light – specs
- Horticulture
- Beverage Grade
  - Exceed the EIGA and ISBT standards
- Electronic grade
- Extensive references from all sources such as…

### CO₂ quality

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>CONCENTRATION PPM (MOL)</th>
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<tbody>
<tr>
<td>Water, H₂O</td>
<td>≤ 30</td>
</tr>
<tr>
<td>Oxygen, O₂</td>
<td>≤ 10</td>
</tr>
<tr>
<td>Sulphur oxides, SOx</td>
<td>≤ 10</td>
</tr>
<tr>
<td>Nitric oxide, Nitrogen dioxide, NOx</td>
<td>≤ 10</td>
</tr>
<tr>
<td>Hydrogen sulfide, H₂S</td>
<td>≤ 9</td>
</tr>
<tr>
<td>Carbon monoxide, CO</td>
<td>≤ 100</td>
</tr>
<tr>
<td>Amine</td>
<td>≤ 10</td>
</tr>
<tr>
<td>Ammonia, NH₃</td>
<td>≤ 10</td>
</tr>
<tr>
<td>Hydrogen, H₂</td>
<td>≤ 50</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>≤ 20</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>≤ 20</td>
</tr>
<tr>
<td>Mercury, Hg</td>
<td>≤ 0.03</td>
</tr>
<tr>
<td>Cadmium, Cd</td>
<td>≤ 0.03</td>
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<tr>
<td>Thallium, Tl</td>
<td>(sum)</td>
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### EIGA Specs. Food & Beverage grade

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<tr>
<th>Parameter</th>
<th>Rationale</th>
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<tr>
<td>Purify</td>
<td>Process</td>
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<tr>
<td>Moisture</td>
<td>Process</td>
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<tr>
<td>Acidity</td>
<td>Regulatory</td>
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<tr>
<td>Oxygen</td>
<td>Sensory</td>
</tr>
<tr>
<td>Nitrogen compounds</td>
<td>Process</td>
</tr>
<tr>
<td>Ammonia</td>
<td>Regulatory</td>
</tr>
<tr>
<td>Nitric oxide/nitrogen dioxide</td>
<td>Sensory</td>
</tr>
<tr>
<td>Non-volatile residue</td>
<td>Sensory</td>
</tr>
<tr>
<td>Non-volatile organic residue</td>
<td>Sensory</td>
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<tr>
<td>Phosphine</td>
<td>Regulatory</td>
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<tr>
<td>Total volatile</td>
<td>Sensory</td>
</tr>
<tr>
<td>Hydrocarbons (as methane)</td>
<td>Sensory</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>Sensory</td>
</tr>
<tr>
<td>Aromatic hydrocarbons</td>
<td>Process</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>Sensory</td>
</tr>
<tr>
<td>Total sulfur (as S)</td>
<td>Sensory</td>
</tr>
<tr>
<td>Carbonyl sulfide</td>
<td>Sensory</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>Sensory</td>
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<tr>
<td>Sulfur dioxide</td>
<td>Sensory</td>
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<td>Appearance in water</td>
<td>Sensory</td>
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<tr>
<td>Color</td>
<td>Sensory</td>
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<tr>
<td>Taste and odor</td>
<td>Sensory</td>
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Proven Technologies – Process Quality - Testing at ARC

- Stress testing of technologies
- Heat integration
- Testing of MEA solvent
- Testing of alternative solvents
- Specific Reboiler Duty
- Total cost of ownership
  - Open-source solvents vs Propriety solvents
  - Up-time vs unforeseen shut-downs
  - What if final product quality cannot be achieved?
  - What if process design flaws cannot be rectified?
- Why foaming?
  - With wrong design even anti-foaming agent has no impact

Pentair AAT advanced MEA plants is the only proven technology for short to mid-term CO₂ Extraction
THANK YOU FOR YOUR KIND ATTENTION