PENTAIR Haffmans

BIOGAS UPGRADEING – best practice

PRESENTER: NIELS DEN HEIJER
DATE: APRIL 6, 2017
OUR CAPABILITIES SPAN THE GLOBE

19,000 EMPLOYEES
IN 40 COUNTRIES
ON SIX CONTINENTS
WE PARTNER WITH OUR CUSTOMERS

<table>
<thead>
<tr>
<th>WATER</th>
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</thead>
<tbody>
<tr>
<td><strong>Water Quality &amp; Availability</strong></td>
<td>Reduce, Recover, and Reuse Water, While Requiring Less Energy</td>
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<tr>
<td><strong>Food &amp; Beverage Processing</strong></td>
<td>Increase Yield and Decrease Cost, Waste, Energy Use, and Water Consumption – All While Maintaining Taste and Quality</td>
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<tr>
<th>ELECTRICAL</th>
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<tbody>
<tr>
<td><strong>Building Protection</strong></td>
<td>Protect Sensitive Equipment, Buildings, and Critical Processes and Help Keep People Safe</td>
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<tr>
<td><strong>Industrial Process &amp; Efficiency</strong></td>
<td>Improve Utilization, Lower Costs, and Minimize Downtime for Our Customers</td>
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To Build a Safer, More Sustainable World
**FOOD & BEVERAGE SITES**

<table>
<thead>
<tr>
<th>PENTAIR FLOW &amp; FILTRATION</th>
<th>PENTAIR SÜDMO, Riesbürg, Germany</th>
<th>PENTAIR HAFFMANS Venlo, the Netherlands</th>
<th>UNION ENGINEERING Fredericia, Denmark</th>
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<tr>
<td>Enschede, the Netherlands</td>
<td>Hamilton, New Zealand</td>
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- Production of the **Beer Membrane Filter (BMF)** + cellar solutions
- Production of valves, fittings and integrated valve systems
- Provides sustainable processing solutions to maximize production time and operational flexibility, from design through to the final commissioning of your process system.
- Production of quality control and process equipment for the brewing and beverage industries
- Production of CO$_2$ recovery and biogas upgrading solutions for the brewing / beverage, bio-ethanol and biogas industry
- Pentair acquired Union Engineering in early 2017
- Union Engineering’s CO$_2$ technologies and service capabilities reinforce and expand Pentair’s offerings within the Industrial Gas, Food & Beverage and Biogas Upgrading sectors.

- Solutions for process, wastewater treatment
- Production of membranes and membrane modules using proprietary production equipment
## INDUSTRIES WE WORK WITH

<table>
<thead>
<tr>
<th>Components</th>
<th>Systems</th>
<th>Services</th>
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<tbody>
<tr>
<td>BREWING</td>
<td>![Checkmark]</td>
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<td>DAIRY &amp; FOOD</td>
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<td>WINE &amp; CIDER</td>
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<tr>
<td>BIOGAS, CO₂, BIOETHANOL</td>
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BIOGAS UPGRADE
HAFFMANS
BIOMETHANE & GREEN CO$_2$
OVERVIEW – FROM FEEDSTOCK TO VALUE

WASTE STREAMS ➔ WASTE WATER ➔ MANURE ➔ ENERGY CROPS ➔ LANDFILL

ANAEROBIC DIGESTION

PRE-TREATMENT (COOLING, HEATING, H₂S REMOVAL)

HAFFMANS BIOGAS UPGRADING – PRODUCT PORTFOLIO

STANDARD Membrane Solution Without CO₂-Liquefaction <0,5% METHANE LOSS

ADVANCED Membrane Solution Without CO₂-Liquefaction 0% METHANE LOSS

ADVANCED plus Membrane Solution Including CO₂-Liquefaction 0% METHANE LOSS

BIO-METHANE ➔ GRID INJECTION

BIO-METHANE ➔ CNG

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FOODGRADE CO₂

LNG FUTURE SOLUTION

LNG FUTURE SOLUTION

LNG FUTURE SOLUTION

CHP

PRODUCT

PRODUCT

ELECTRICITY

LOCAL HEAT

FEEDSTOCK

VALUE

CURRENT PENTAIR-HAFFMANS PORTFOLIO

195 Wh/Nm³ BIOGAS

280 Wh/Nm³ BIOGAS

360 Wh/Nm³ BIOGAS

PENTAIR

5th BBS Summit Shanghai

March 16, 2017

Uwe Kikillus
BIOGAS UPGRADE - MEMBRANE GAS SEPARATION

Permeate - Low pressure CO₂ rich gas

Compressed raw Biogas

Retentate - High pressure Biomethane

Fast Permeation Rate Slow

H₂O  He  H₂  NH₃  CO₂  H₂S  O₂  Ar  CO  N₂  CH₄  C₂H₄  C₂H₈
BIOGAS UPGRADING - STANDARD

Biogas AD

Flare

Low Pressure Stage
- Fan Blower
- Scrubber Chiller Heater
- Activ Carbon (H₂S/VOC)
- Low Pressure Conditioning

High Pressure Stage
- Compression
- High Pressure Conditioning

Membrane Stage 1 & 2
- 1st Stage
- 2nd Stage
- Temperature Conditioning

Revenue Stream
- Quality Control
- BioMethane

Membrane Stage 3
- 3rd Stage

Methane Recovery

Biogas AD
- 45% v/v CO₂
- 50% v/v CH₄

High Pressure Stage
- 30% v/v CO₂
- 70% v/v CH₄

Membrane Stage 3
- 94% v/v CO₂
- 6% v/v CH₄

99.5% v/v CO₂
- 0.5% v/v CH₄

Flare / Digester

PENTAIR CO₂ Summit Innsbruck – March 7, 2017 – Uwe Kikillus
BIOGAS UPGRADING - ADVANCED

Biogas AD

Flare

Low Pressure Stage
- Fan Blower
- Scrubber
- Chiller
- Heater
- Activ Carbon
- (H₂S/VOC)
- Low Pressure Conditioning

High Pressure Stage
- Compression
- High Pressure Conditioning

Membrane Stage 1 & 2
- 1st Stage
- Temperature Conditioning
- 2nd Stage

Revenue Stream
- Quality Control
- BioMethane

BIOGAS PART
Membrane Separation

CO₂ PART
Cryogenic Separation

45% v/v CO₂
50% v/v CH₄

30% v/v CO₂
70% v/v CH₄

94% v/v CO₂
6% v/v CH₄

Methane Recovery

Green CO₂ to free air / Local gas consumption

Flare / Digester

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ADDITIONAL REVENUE WITH CO$_2$-BOLT-ON

Biogas AD

EXISTING BIOGAS UPGRADING PLANT

Methane Recovery ~2% of Biogas flow

CO$_2$-Bolt-On

- CO$_2$ purity acc EIGA Specs
- 440 Wh/Nm$^3$ Raw CO$_2$
BIOMETHANE APPLICATIONS

- USE the CH₄ as fuel
- Bio-CNG (LNG) for:
  - Trucks
  - Buses
  - Cars

- USE the CH₄ for pipeline injection
- Biomethane for:
  - Transportation
  - Electricity
  - Heat
CO₂ is used in different forms: gaseous, liquid, solid or super critical applications.

- **Agri-production**: Accelerate plant growth in greenhouses.
- **Beverages**: Carbonation and beverage dispensing.
- **Food industries**: Food preservation, freezing, chilling, packaging, extraction.
- **Refrigerated transport**: Maintain the cold chain for fresh and frozen products.
- **Chemistry**: Reactive agent.
- **Industrial cleaning**: Solvent free cleaning for surfaces.
- **Welding**: Arc stabilisation in MAG welding.
- **Agricultural & Food**: 85%
- **Other industries**: 15%

Many other applications: fire extinguishers, natural refrigerant, stunning of animals.
4. Extra Product : CO₂
- QUALITY of CO₂
Revised EIGA DOC 70 released in February 2017

Biogas from anaerobic digestion listed as carbon dioxide source
- Biogas from energy crop is handled similar to yeast-based fermentation (ethanol)
- Biogas from bio-waste digestion or co-digestion requires greater care in the evaluation
- [Biogas from landfills (landfill gas) with unlimited number of waste types requires extensive risk assessment]

Risk assessment process for AD plants for liquid CO₂ for food & beverages
- The food safety risk analysis (HACCP) includes the digester biogas process
- Final product carbon dioxide is always compliant with the Appendix A
- Complete on-line or complete batch analysis of carbon dioxide before supply to customer
- A food safety management system (e.g. ISO 22000) is strongly recommended for the carbon dioxide plant
- Compliance of the AD plant (and feedstock) with the EU regulations for animal by-products
**Food Safety Risk Assessment with Industrial Gas Company**

- Stricter quality criteria than for industrial \( \text{CO}_2 \)
- FSRA completed before EIGA DOC 70 revision
- Since July 2015 hundreds of samples have been analysed according to the EIGA standard
- Inline analysis or complete batch analysis of carbon dioxide before supply to customer
- Initial deviations caused by:
  - \( \text{H}_2\text{S} \)
  - Moisture
  - Hydrocarbons (propane)

**UK Experience**

- Substrates:
  - Mainly energy crops and unprocessed vegetable matter
  - High quality -> low risk
- \( \text{CO}_2 \) goes via industrial gas companies to food, beverage and industrial applications
- \( \text{CO}_2 \) complies with food-grade requirements

**NL Experience**

- Substrates:
  - Mainly bio-waste, vegetable & food waste
  - Higher level of impurities -> process control
  - One reference with energy crops
- \( \text{CO}_2 \) goes via industrial gas companies and OCAP pipeline mainly to greenhouses
- \( \text{CO}_2 \) complies with food-grade requirements
- Test result: < 2 bacteria / dm\(^3\)
SAFEGUARDING THE CO₂ QUALITY

Cleaning steps of raw biogas before membrane biogas upgrading:

Optional biological H₂S removal (bulk removal of H₂S):
- Reduction of H₂S levels from 1500 ppm to 30-50 ppm levels

Gas washer
Removal of ammonia/water solubles

Activated Carbon
Removal down to max. 1 ppm of all contaminations :
  - H₂S
  - VOC, MEK (methyl ethyl ketones), terpenes

Cleaning steps of raw CO₂ during liquefaction:

Compression to 18 bar (g)
-> Temperature increase to > 110 C -> sterilization of CO₂

Regenerative activated carbon
Removal of last ppm contaminations to ppb level

Liquefaction, strip column
Removal of all non-condensable gases: CH₄, N₂, H₂, O₂,
BIOGAS UPGRADING

TRACK RECORD & REFERENCES
REFERENCES: MANURE

Customer: 2 Cattle Farms in The Netherlands (Tirns & Biddinghuizen)
           1 Cattle Farm in France (Cucq)

Market: Manure & agricultural waste products

Capacity: 220-350 Nm³/h biogas

Output: 135-220 Nm³/h biomethane
ECOFUELS – 450 Nm³/h BIOGAS TO GRID & GREEN CO₂
ECOFUELS – 450 Nm³/h BIOGAS TO GRID & GREEN CO₂
ECOFUELS: BLOCK DIAGRAM BIOGAS PLANT

- **Solid**
- **Crusher**
- **Liquid**
- **CAT3-Liq.**
- **Pasteur.**

**System Components:**
- **PT1**
- **PT2**
- **PT3**
- **PT4**
- **PT5**

**Process Flow:**
- **Prim. Dig. 1** → **Biogas 1/2** → **Bio Filter** → **CHP**
- **Prim. Dig. 2** → **Sec. Dig.** → **Biogas 3**
- **Recirculate** → **Effluent** → **Centrifuge**

**Additional Systems:**
- **WWTP**
- **MBR**
- **Fertilizer**
- **Water**
- **Liquid CO₂**
- **CO₂ Tank**
- **CO₂ Liquefaction**
- **Membrane Upgrading**
- **Activ. Carbon (VOC)**
- **Activ. Carbon (H₂S)**
- **Water Scrubber**
- **Pipeline Injection**

**Outputs:**
- **Electricity**
- **Heat**
- **Food Plant**
- **Liquid CO₂**
- **CH₄**
BIOGAS UPGRADING
BIOGAS UPGRADING
BIOGAS UPGRADING – COMPACT ENCLOSED SKID
RELIABLE TECHNOLOGY PROVIDER

- Food Safety Risk Assessment (EIGA/ISBT) completed in cooperation with major gas company
- High CH₄ yield/ No CH₄ slip
- 24/7 Service desk / Own service team
- In-house design (incl. membranes) and production
- > 450 Haffmans CO₂ recovery plants world-wide
- > 1000 Union CO₂ plants world-wide
- > 1000 Process Installations in China
- 7+ years of service life experience with membranes
- Low membrane pressure and hence low energy Consumption

EIGA: European Industrial Gases Association – ISBT: International Society of Beverage Technologists
Thank you for your attention!

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