EUROPEAN HEAT PUMP SUMMIT
POWERED BY CHILLVENTA

CONGRESS + EXPO
NUREMBERG, 22–23.10.2019

Industrial | Commercial | Residential
Heating & Cooling | Components & Equipment

hp-summit.de
Three concepts for high efficient, high economic ammonia heat pumps for industrial applications up to 95°C

Three principal circuit concepts (AddOn, Cascade and StandAlone) are discussed with the focus on standardization of the system design as well as on scalability and multiplication of the concept across the industries in Europa.
INTRODUCTION

- ENGIE KÄLTETECHNIK GMBH - Refrigeration Plant Engineering and Installation Company with head office in Lauterach / Austria, 250 employees

- PART OF THE ENGIE GROUP (electricity, natural gas and energy services, head office in Paris, 150 000 employees)

- Topic: „WASTE HEAT RECOVERY AND UTILIZATION“ gets more and more important in Industry. Background: Reduction of fossil fuels
INDUSTRIAL HEAT PUMPS WITH AMMONIA UP TO 95°C

WHY INDUSTRIAL HEAT PUMPS?

- Big amounts of heat, especially from refrigeration plants, are still wasted and could be transferred to useful process heat
- Legal restrictions increase in favor: F-gas reg., CO₂ red.,…
- Industrial high-temperature heat pumps could save enormous amounts of CO₂ emissions.

WHY AMMONIA AND WHY 95°C?

- The natural refrigerant Ammonia provides the highest efficiency and is used in most industrial refrigerant plants
- Temperatures up to 95 °C can be easily achieved with common compression technology and are crucial to gain useful heat for various industrial applications
- High capacity range from 0.5 to 10 MW
EXAMPLE: INDUSTRIAL REFRIGERATION PLANT

WHAT WE OFTEN FIND:

- Refrigerant Ammonia
- Screw or recip compressors
- Evaporative condensers
- Ammonia pump system or
- Thermosyphon brine cooler
1ST CONCEPT: STAND ALONE HEAT PUMP

Key figures:
- Simple / modular / "from the shelf"
- Every refrigerant is possible
- Quite bad efficiency

Industrial refrigeration plant
- \( t_c = +35^\circ \text{C} \)
- \( t_o = -40^\circ \text{C} \)
- pump separator for deep freezer,...

Water / water heat pump
- \(+32 / 27^\circ \text{C}\)
- cooling water
- additional water condenser

Food processing plant
- up to 95°C
- pasteurization, cleaning, drying,...
2ND CONCEPT: CASCADE HEAT PUMP

**Industrial refrigeration plant**
- \( t_c = +35^\circ C \)
- \( t_o = -40^\circ C \)

**Cascade heat pump**
- +35°C

**Food processing plant**
- Up to 95°C
- Pasteurization, cleaning, drying,...

**Key features:**
- Every refrigerant is possible
- “Tailor made” connection to refrigerant cycle
- Slightly better efficiency
3RD CONCEPT: ADD ON / BOOSTER HEAT PUMP

key features:
- Less parts / quite low investment costs
- “tailor made” / common refrigerant cycle
- Best efficiency

Industrial refrigeration plant

Add On / Booster heat pump

Food processing plant

pump separator for deep freezer,...

tc = +35°C

to = -40°C

up to 95°C

pasteurization, cleaning, drying,...
## COMPARISON OF EFFICIENCY AND COSTS

<table>
<thead>
<tr>
<th></th>
<th>Stand Alone</th>
<th>Cascade</th>
<th>Add On</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporation temp. [°C]</td>
<td>24</td>
<td>32</td>
<td>35</td>
</tr>
<tr>
<td>Condensing temp. [°C]</td>
<td>96</td>
<td>96</td>
<td>96</td>
</tr>
<tr>
<td><strong>COP heating</strong></td>
<td>3,71</td>
<td>4,26</td>
<td>4,45</td>
</tr>
<tr>
<td>OPEX var [k€]</td>
<td>1696</td>
<td>1479</td>
<td>1413</td>
</tr>
<tr>
<td>OPEX fix [k€]</td>
<td>416</td>
<td>388</td>
<td>380</td>
</tr>
<tr>
<td>CAPEX [k€]</td>
<td>550</td>
<td>650</td>
<td>600</td>
</tr>
<tr>
<td>LCOH [€/MWh]</td>
<td>59</td>
<td>57</td>
<td>54</td>
</tr>
</tbody>
</table>

→ LCOH of GAS ~ 60 €/MWh

### boundary conditions:
- plant size: 1 MW
- electricity price: 126 € per MWh / 80 € per kW_peak
- full load hours per year: 5000 h
- plant life time: 10 years / replacement factor = 1,5

### plant specifications:
- 2 stage recip system
- optimal hydraulic connected desuperheater, condenser, subcooler
<table>
<thead>
<tr>
<th>Risk</th>
<th>Possible Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor operation limits (pressure, temperature)</td>
<td>process control, multistage, low superheat</td>
</tr>
<tr>
<td>Function of middle pressure separator, desuperheater</td>
<td>Lab and field tests, pilot plant</td>
</tr>
<tr>
<td>HP desuperheater, condenser (material, strength)</td>
<td>Validation process at the supplier, pilot plant</td>
</tr>
<tr>
<td>Stability of refrigerant Ammonia (degradation, inert gas formation)</td>
<td>Lab tests with different water contents and materials at operation conditions (pressure / temperature)</td>
</tr>
<tr>
<td>Stability of the lubricant (temperature, coking)</td>
<td>Lab tests in combination with ammonia and different materials at operation conditions, field tests, oil quality monitoring</td>
</tr>
<tr>
<td>Lubrication system, oil management</td>
<td>Good separation of refrigerant from oil (boil out tank), validation of different oil pump systems</td>
</tr>
<tr>
<td>Condensing of refrigerant in compressor or suction lines, liquid hammer</td>
<td>Motor valves, oil conditioning (heating, cooling), compressor stand by heating</td>
</tr>
</tbody>
</table>
Interaction between stakeholders

EU cooperation project „triple high 95“

Projects
- end customer
- planer, consultant
- contractor
- refrigeration engineering company

Products
- research
- equipment manufacturer
- service
- contractor
### Sectors (cf. Figure 2)

<table>
<thead>
<tr>
<th>INDUSTRY</th>
<th>Sectors</th>
<th>Application</th>
<th>Temp. range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Food, drink &amp; Tabaco</td>
<td>Pasteurization, cleaning, heating,</td>
<td>95 °C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>drying</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Transport Equipment /</td>
<td>Alcohol distillation</td>
<td>80 – 95 °C</td>
</tr>
<tr>
<td></td>
<td>Machinery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Textile &amp; Leather</td>
<td>Food drying and preservation,</td>
<td>80 – 95 °C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>cleaning (CIP), heating</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Paper, Pulp and Printing</td>
<td>Room heating and moistening</td>
<td>80 – 95 °C</td>
</tr>
<tr>
<td>5</td>
<td>Iron &amp; Steel</td>
<td>Bleaching, colouring</td>
<td>60 – 90 °C</td>
</tr>
<tr>
<td>6</td>
<td>District heating</td>
<td>Heating, drying, varnishing</td>
<td>60 – 95 °C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Galvanizing, hardening</td>
<td>95 – 95 °C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heating and hot water</td>
<td>60 – 95 °C</td>
</tr>
</tbody>
</table>

**MARKET UP-TAKE**

- Markets & Business models
- Prototype Field pilots
- Generalisation, Standardisation, Scalability & Multiplication
- System optimisation & integration

**EIC … European innovation council**

**FTI … Fast track to innovation**
TRIPLE HIGH 95 - GOALS

- Natural Refrigerant - Ammonia
- Sales and Distribution Strategies
- Tailor-Made Business Models → Low Effort in Financing
- Stakeholder Engagement Across Europa and Cross Link to Refrigeration
- Generalised Concepts for Different Boundaries → Convincing Solutions
- Three Concepts → Add-On, Cascade, Stand-Alone
- Temperature Level → 95°
- Optimised Components & System → Highly Efficient
- Simple Design & Construction → Fast Tendering & Implementation
- Standardized Components → Lower Investment
- 1 Prototype & 3 Field Tests → Reliable Results
- Capacity → 0.5-10 MW
Thank you for your kind attention.