EUROPEAN HEAT PUMP SUMMIT
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CONGRESS + EXPO
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Industrial | Commercial | Residential
Heating & Cooling | Components & Equipment

hp-summit.de
Higher Heat Pump COP through better temperature match

HPT TCP Annex 48: Commercial and Industrial Heat Pump Application VI DK

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Content

- DTI: short presentation
- Theoretical maximum Heat Pump COP
  A pre assessment tool for system integration?
- Gradually heating of water
  The ISEC project
- Split condensing
  The FOSCAP project
- Utilizing the glide of the working fluid
  The High Heat and the MiReHP projects
Danish Technological Institute

- A world class research and technology company converting the newest knowledge and technology into value
- 111 Years old, +1.100 people, 71 laboratories
- +13.000 clients in 65 countries
- Expert in production, materials, life science, business, energy, agro technology, meat research, robotics and more
- Revenue 150 m. EUR

Refrigeration and Heat pump technology
- 35 people
- +1.200 m² laboratories, up to 2 MW cap, 9 climate chambers
Industrial heat pump development at DTI

- Flexible Energy Optimized Split Condenser Ammonia Heat Pump - Foscap
- Mixed Refrigerant Heat Pump – MiReHP
- Ultra-high temperature hybrid heat pump for process application – HighHeat (HighHeat)
- Gradually heating of water – ISEC
- Development of Rotrex turbocompressor for steam compression
- Experimental Development of Electric Heat Pumps in Greater Copenhagen District Heating System – SVAF 2
- Direct contact heat exchangers (water vapor, heat uptake at freezing)
- Projects on COP optimization of heat pump cycles
- Heat pumps and storage (hot and/or cold)
Maximum HP COP
A generic first assessment tool

Motivation

Postulate: *Heat pumps are just “nice to have”*

- *The only purpose is heat supply in a more appropriate way (like cost (incl. taxes), CO\(_2\) footprint, CSR, ...)*
- *They do not solve technical problems*

*It is “all” about COP... (....and first cost, maintenance...)*

- Many heat pump solutions exist
- A way to first assessment is needed...????
Heat pump COP and system design calculations

Theoretical limit: Carnot cycle

\[ COP_{HP, Car} = \frac{T_H}{T_H - T_L} \] (T in K)

Constant temperature source and sink: 15/90°C > COP\(_C\) = 4,84
Higher COP by splitting up
Higher COP by splitting up

<table>
<thead>
<tr>
<th>Process</th>
<th>T_L [°C]</th>
<th>T_H [°C]</th>
<th>COP_{HP,Car} [-]</th>
<th>Q_H [kW]</th>
<th>P [kW]</th>
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<tr>
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<tr>
<td><strong>Total</strong></td>
<td><strong>5</strong></td>
<td><strong>Total</strong></td>
<td><strong>0,7549</strong></td>
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</table>

**COP = 6,62 (+37%)**

Lorenz COP

\[
COP_{HP,Lor} = \frac{T_{lm,H}}{T_{lm,H} - T_{lm,L}}
\]

(+ 51%)
Theoretical maximum COP

Heat sink outlet temperature 150°C

COP [-] vs. Source outlet temperature [°C]

- COPc
- COP_L DT = 10K
- COP_L DT = 20K
- COP_L DT = 30K
(First) system design calculation

Theoretical COP can be used for first assessment analysis of system design without knowing the heat pump technology.

Carnot and Lorenz efficiency:

- How good a real heat pump system is compared to theoretical maximum

\[
\eta_{Car} = \frac{COP_{HP}}{COP_{HP, Car}} \quad \eta_{Lor} = \frac{COP_{HP}}{COP_{HP, Lor}}
\]
(First) system design calculation

- In the best industrial refrigeration systems 60% of COP$_C$ have been realized, so high COP can also be expected by heat pumps...

\[
COP_{HP} = COP_{HP,Lor}\eta_{Lor} > COP_{HP,Lor} = \frac{COP_{HP}}{\eta_{Lor}}
\]

Example:
- System requirement to the heat supply: 150°C
- Based on the precalculations (energy cost etc.) COP = 3,0 is needed.
- Using $\eta_{Lor} = 60\% > COP_{HP,Lor} = \frac{3,0}{0,6} = 5$
(First) system design calculation

Heat sink outlet temperature 150°C

\[ COP_{HP, Lor} = \frac{3.0}{0.6} = 5 \]
Fundamental process analysis

Case:
- Sink: Heating from 35 to 80°C
- Source: Cooling from 25 to 15°C

- COP_C = 5.4, COP_L = 8.9

Pinch temperature 1K
- COP_C = 5.3 > -2.7%
- COP_L = 8.5 > -4.8%
ISEC “Highly Efficient Thermodynamic Cycle with Isolated System Energy Charging”

- Traditionally full temperature increase in one step

Objective:

- up to 50 % better energy efficiency of heat pumps by optimum storage usage which reduces the average temperature level in the heat pump
- ...For systems having high temperature change on hot (and/or cold) side

- Suppored by the Danish EUDPprogram (no. 64013-0110)
- Partners: Svedan, Innotek, Alfa Laval, Arla Foods, Bjerringbro DH, Metro Therm, DTU and DTI.
ISEC “Highly Efficient Thermodynamic Cycle with Isolated System Energy Charging”
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FOSCAP “Flexible Energy Optimized Split Condenser Ammonia Heat Pump”

Objective: Improvement of performance and cost of HP’s by use of

- Split condenser
- Optimized heat exchangers
- Higher outlet temperature

Single condenser: ex. 300 plates
FOSCAP “Flexible Energy Optimized Split Condenser Ammonia Heat Pump”

Two heat exchangers:
- Desuperheater: 50 plates
- Condenser: 200 plates (reduc. 17%)
- Condenser I: 50 plates
- Condenser II: 150 plates (reduc. 33%)
FOSCAP “Flexible Energy Optimized Split Condenser Ammonia Heat Pump”

Higher outlet temperatures:
Higher condensing pressure =
Lower COP

Split streams
Ex. 40% @ 130°C, 60% @ 65°C
Same COP
FOSCAP

- In some cases: Reduction of condensing pressure possible = Higher COP

- Supported by the Danish PSO and EUDP program (no. 64013-0543)
- Partners: Svedan, Innotek, AlfaLaval, HOFOR, Mayekawa, Egaa S&M, Bjerringbro DH, DTU and Arla
HighHeat: Development of ultra-high temperature hybrid heat pump for process application

Objective

- Increase the operating limits of the hybrid process by using the new standard components for higher pressures.
- Demonstrate efficient and reliable high capacity heat pump for high temperatures up to 130-145°C.
- Investigation of possible implementation into specific processes and the conduction of a general market survey.
- Lab (160-180°C) and full scale (>1 MW) demonstration.

Absoprtion compression heat pump process
Absorption compression heat pump process
Absorption compression heat pump process
Absorption compression heat pump process
800kW three-stage system in sewage treatment plant

\[ T_{L,i} = 22.5^\circ C, \ T_{L,o} = 19.4^\circ C, \ T_{H,i} = 79.1^\circ C, \ T_{H,o} = 108.4^\circ C, \]
\[ Q_H = 540 \ kW, \ P_{tot} = 198 \ kW. \]
\[ \text{COP}_{HP} = 2.72, \ \eta_{Car} = 63\%, \ \eta_{Lor} = 54\% \]
Thank you

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