Developments in High Temperature Heat Pumps

By Alexander Cohr Pachai
Technology Manager
Sabroe Factory
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York, Frick & Sabroe, since 19th century

First Frick Compressor, built in 1885
- Two 12 x 18 cylinders
- Ammonia
- 50 RPM
- Steam Engine Driven

Sabroe CO₂-compressor, No. 2, built in 1897
- Capacity of 15 kW at -10/+25°C
- 90 rpm
- For a Danish dairy from 1897 to 1940

York Since 1874
The Cycle

Waste heat from your primary processes

Compressor

Valve

Reused heat for your secondary processes
Heat pump technology is defined as sustainable.
Heat Pumps

Heat source:
- Ground source
- Waste heat from industrial process
- Waste water
- River water

Energy source:
- Sustainable
- Traditional

Types of heat pumps:
- Compressors
- Refrigerants
- Systems

Heat sink:
- District heating
- Domestic hot water
- Industrial production/process
- Disinfection/bacterial kill

Johnson Controls
Heat Pump solutions
Johnson Controls Heat Pumps solutions overview

### Compressor Technology and Refrigerant

<table>
<thead>
<tr>
<th></th>
<th>Compressor Technology</th>
<th>Refrigerant</th>
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<tbody>
<tr>
<td>I</td>
<td>Scroll, recip, screw</td>
<td>R717, R134a, R410A</td>
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<td>II</td>
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<td>R717, R134a</td>
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<td>III</td>
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<td>R717, R245fa</td>
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### Graph

- **Source temp. °C**
- **Outlet Water temp. °C**
- **Today**
- **Coming**

The graph illustrates the temperature ranges for different compressor technologies and their corresponding refrigerants.
Heat Pump solutions

HeatPAC Recip
variable-speed drive
**R717** (max. 48 kg charge)
Hot water up to **70° C**
Heating capacity up to 1200 kW at 40° C source
Heat Pump solutions

HeatPAC Screw
variable-speed drive
R717
Hot water up to 90° C
Heating capacity up to 1600 kW at 40° C source
Heat Pump solutions

HeatPAC Custom
Two-stage cascade
variable-speed drive
R717
Hot water up to 90° C with screw
Hot water up to 70° C with recip
Heating capacity up to +3000 kW at 40° C source
What is a HeatPAC?
Heat from cooling tower/dry cooler principle

Connect to cooling tower/dry cooler water side

Pro: Simple installation – shut down of refrigeration plant not necessary
Cons: Not as efficient as direct suction – or cascade.

Existing refrigeration plant

Heat Pump System

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Heat from cooling tower/dry cooler principle

Connect with cascade exchanger to refrigeration circuit

**Pros:** Higher efficiency than water solution. No direct contact between circuits (oil).

**Cons:** More complex installation. Requires cut-in on existing refrigeration circuit

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**Diagram:**

- **Existing refrigeration plant**
  - 40 bar condenser
  - 70°C Water
  - Condenser
  - Discharge
  - Liquid to plant

- **Heat Pump System**
  - Cascade cooler
  - 35°C Condenser
  - Receiver
What can a system can look like?

- Removal of non-condensable gases
- Heat pump
- Warm water supply

To system

From system
Efficiency
Efficiency in an industrial process

\[ \text{COP}_{\text{cool}} = \frac{(h_1-h_4)}{(h_2/h_1)} \]

\[ \text{COP}_{\text{HP}} = \frac{(h_2-h_3)}{(h_2-h_1)} \]

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<tr>
<th>COP</th>
<th>Value</th>
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<tr>
<td>COPheating</td>
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\[ \text{COP}_{\text{combi}} = 7.35 \]
From another system we know

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<td>€/year</td>
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<td>Chemicals</td>
<td>1,210.40</td>
<td>€/year</td>
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<td>inspection</td>
<td>0.00</td>
<td>€/year</td>
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<tr>
<td><strong>Saving on tower</strong></td>
<td>7,926.56</td>
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<tr>
<td>Net Energy savings</td>
<td>33,115.28</td>
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<tr>
<td><strong>Total savings</strong></td>
<td>41,041.84</td>
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<td>Aprox price</td>
<td>80,000</td>
<td>€</td>
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<td>ROI</td>
<td>1.95</td>
<td>Year</td>
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Some examples
NL projects: Orbis Hospital, Sittard (2007)
Seasonal thermal storage (ground) using Sabroe & YORK

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<th>1x YORK</th>
<th>1x YORK</th>
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<td>Type:</td>
<td>Screw - PAC193S-R</td>
<td>Screw – YN</td>
<td>Centrifugal – YK-R</td>
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<td>Refrigerant:</td>
<td>Ammonia</td>
<td>R134a</td>
<td>R134a</td>
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<tr>
<td>Heating capacity:</td>
<td>1234 kW</td>
<td>1251 kW</td>
<td>--</td>
</tr>
<tr>
<td>Cooling side Tin/Tout:</td>
<td>14 / 6 °C</td>
<td>14 / 6 °C</td>
<td>--</td>
</tr>
<tr>
<td>Heating side Tin/Tout:</td>
<td>32.5 / 53 °C</td>
<td>32.5 / 53 °C</td>
<td>--</td>
</tr>
<tr>
<td>COP Heating:</td>
<td>4.6</td>
<td>4.1</td>
<td>--</td>
</tr>
</tbody>
</table>

| Cooling capacity: | 1197 kW | 1000 kW | 1690 kW |
| Cooling side Tin/Tout: | 18 / 10 °C | 18 / 10 °C | 18 / 10 °C |
| Heating side Tin/Tout: | 27 / 35 °C | 27 / 35 °C | 26 / 34 °C |
| COP Cooling: | 5.8 | 6.4 | 6.3 |
Heat recovery from cleaned waste/sewer water, AWZI Harnaschpolder.

JCI installed a factory assembled two-stage Heat Pump based on Sabroe reciprocating compressors (Low stage: 1x SMC112E / High stage: 2x HPO28):

- Sink water inlet/outlet temp. +50 / +75°C
- Source water inlet/outlet temp. +8 / +4°C
- Heating capacity 1220 kW
- COP heat pump = 3.4
- Ammonia charge = 200 kg
- Performance guarantee by JCI
Production site: Domo, Beilen, producing baby food ingredients / nutritions

Heatpump capacity: 4 MW heatpump to produce hot water of 90 °C

Heat source: Water around 45° C is available from production. It is removed from milk by the Vacuum evaporation device before the air drying

Heat sink (useful): Pre-heating the fresh air flow inlet into the spray dryer device by using water of 90 °C

Difficulties: Systems performance window: complex interaction / disturbances on input (heat source) and output (heat sinks)

Performance:
Sink water inlet/outlet temperature: 45 / 90° C
Source water outlet temperatuer: 12° C
Heating capacity, maximum: +/- 4.5 MW
COP range heat pump: 3.0 up to 5.0
Ammonia charge: 3x250 + 2x60 kg
JCI branches are involved in:

**Design / Engineering, JCI Dordrecht Netherlands**
- Thermodynamics / hydraulics (optimized concepts)
- Review specifications, functional design control systems
- P&ID’s, GA, construction & service manuals
- Project Management
- Supervision, startup & commissioning
- Service and after sales
- Assembly of heat exchanger- and pump skids (hydraulics according to FC welding specs)

**Manufacturing Sabroe, Holme Denmark**
- Production & assembly of heatpumps
- End Of Line test; full load performance test
JCI solution is based on standard ‘blocks’ (modular):
✓ 3x Sabroe HeatPAC157 with VSD (high temperature)
✓ 2x Sabroe ChillPAC112 (low temperature / chiller mode)
✓ Pump units, heat exchangers
✓ Advanced control system (Siemens PLC)
✓ Safety systems
District heating Bræstrup

Application: District heating
Place/site: Brædstrup, DK
Supply temperature: 72°C
Capacity: 1MW
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Conclusions
Conclusions

Heat pump technology is defined as being a sustainable technology.

There are many sources and sink combinations possible.

In industrial applications where you can use both the cooling and heat capacity, the combined COP increases considerably.

Recovering heat on the cooling water helps saving chemicals and water.

Heat pumps enable recovery of heat and boosting supply temperature in remote parts of big district heating systems.

With the modern district heating system with lower supply temperatures, the losses are also reduced.
## References

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Thank you for your attention