Heat Pumps for Industrial Process Heating

April 5th 2022
SWRI IPER Conference
Agenda

2. Basic Working Principles of Heat Pumps
3. Heat Pumps for Industrial Processes
   a) ‘Low’ Temperature 80-160°C
   b) ‘Mid’ Temperature 160-270°C
   c) ‘High’ Temperature 270°C and greater
4. Conclusion
Global heat is largely produced from fossil fuels, technology must shift to achieve sustainability targets according to IEA.

Decarbonizing heat production requires:

1) Efficiency improvements (insulation, reduction of system losses, etc.)
2) Replacement of fossil fuels with low-carbon-electrified heat supply

Source: IEA / IRENA 2020 (Renewable Energy Policies in a Time of Transition, Key World Energy Statistics). All rights reserved.
Basic Principle of Compression Heat Pumps
Cycle design, components, and typical terminal points

Cycle Design & Main Components:

- **P, H-Diagram:**
  - Counter-clockwise cycle
  - "Consumes" work to rise heat from a low temperature level to a higher temperature level

- **Heat Sink**
- **Expansion Valve**
- **Compressor**
- **Evaporator**
- **Condenser**
- **Heat Source**

- **Liquid (sub-cooled)**
- **Vapor (super-heated)**
- **Vapour (super-heated)**
- **2-Phase**

- **W**
- **Q**

- **Single Shaft Compressor**
- **Integrally Geared Compressor**

- **Boiling point line**
- **Dew point line**
- **Wet steam area**
Basic principle of compression heat pumps
Cycle design, components and typical terminal points

**CYCLE DESIGN AND MAIN COMPONENTS**

- Counter-clockwise cycle
- “Consumes” work to rise heat from a low temperature level to a higher temperature level
Industrial Heat Pumps for Process Heat at 80-160°C
Typical waste heat streams and heat sinks of selected industries

<table>
<thead>
<tr>
<th>Sector</th>
<th>Processes</th>
<th>Typ. Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brewing</td>
<td>Hot water, process cooling</td>
<td>5-60 °C</td>
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<tr>
<td>Dairy</td>
<td>Hot water, process cooling</td>
<td>5-60 °C</td>
</tr>
<tr>
<td>Paper</td>
<td>Wastewater, wire pit water, hot condensate, exhaust air</td>
<td>30-100 °C</td>
</tr>
<tr>
<td>Brick</td>
<td>Exhaust air, waste heat</td>
<td>50-90 °C</td>
</tr>
<tr>
<td>Starch</td>
<td>Exhaust air, hot condensate</td>
<td>50-90 °C</td>
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<tr>
<td>Chemical</td>
<td>Waste heat, process cooling</td>
<td>60-120 °C</td>
</tr>
<tr>
<td>Sugar</td>
<td>Waste heat, hot condensate, process cooling</td>
<td>60-120 °C</td>
</tr>
</tbody>
</table>

Typ. Range | Processes                                      | Sector          |
<table>
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<tr>
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<tbody>
<tr>
<td>60-120 °C</td>
<td>Hot water/steam for brewing, filling, and cleaning processes</td>
<td>Brewing</td>
</tr>
<tr>
<td>80-150 °C</td>
<td>Hot water/steam for pasteurization</td>
<td>Dairy</td>
</tr>
<tr>
<td>80-160 °C</td>
<td>Water/steam preheating, hot air for drying, boiling and bleaching</td>
<td>Paper</td>
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<tr>
<td>110-140 °C</td>
<td>Hot air for brick drying</td>
<td>Brick</td>
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<tr>
<td>140-160 °C</td>
<td>Hot air for starch drying</td>
<td>Starch</td>
</tr>
<tr>
<td>80-270 °C</td>
<td>Hot water/steam for boiling, compression and distillation</td>
<td>Chemical</td>
</tr>
<tr>
<td>80-160 °C</td>
<td>Hot water/steam for preheating of thick juice</td>
<td>Sugar</td>
</tr>
</tbody>
</table>

Source: An estimation of the European industrial heat pump market potential, A. Marina et al.
Strong Demand for Process Heat above 200°C

Energy Use by Industry Sector and Temperature Range EU28 (2015)

Total: ~2.400 TWh

HTHP Steam generation + Steam Compressor

**HEAT PUMP**
**TEMPERATURES UP TO 140°C**
- Single Shaft Compressor
- Integrally Geared Compressor
- Refrigerant → Steam → Water

**STEAM COMPRESSOR**
**TEMPERATURES UP TO 270°C**
- Heat Sink Fluid
- Saturated Steam
- Condensate Return
- Boiler Feedwater
- Refrigerant Condenser & Steam Generator

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Integration of Industrial Heat Pump
Process Steam Production in chemical plant | Overview & key figures

OVERVIEW

Feedwater 20 °C

Process Water 90 °C

Heat Pump

Steam Compressor

Process Steam 19 bara, 240 °C

BACKGROUND

• High temperature heat pump utilizes waste heat from process water of reactors to produce saturated steam from feedwater
• Saturated steam is fed to steam compressor (multi-stage intercooled/attemporated)
• Final adjustment of steam parameters by attemporation

KEY FIGURES

CAPACITY
36 MWth HP & Steam Compressor = 50 MWth

AVERAGE COP
~ 2.5 (incl. steam compression)

REFRIGERANT
Hydro-(-chloro)-fluoro-olefin (H(C)FO)

ARRANGEMENT
Brownfield (integration in existing building)

HEAT SOURCE
Process water return from reactors (90 → 70°C)

HEAT SINK
Process Steam (20°C → 19 bara, 240°C)

COMPRESSOR
Geared type radial compressor

LUBE & SEAL OIL SYSTEM
Combined lube and Seal Oil System

HEAT EXCHANGER
Shell & Tube Heat Exchangers (Evaporator, Condenser, Subcooler)
Future Applications: Temperatures above 270°C

- Steam topping enables higher sink temperature than HFO-based heat pumps alone.

- Steam topping would require significant head to reach temperatures in the 300°C - 500°C range. In this range, schemes based on ideal gas are likely preferred.

- Elevated pressure leads to improved heat transfer and reduces heat exchanger size and cost compared to a fired heater with atmospheric pressure flue gas.

- Further benefit possible if a process has simultaneous cooling need.

**Diagram:**

- **Integrally Geared Compressor / Expander**
- **Recuperator**
- **Process Fluid Being Heated**
- **Heat Source Fluid – process condensor or heat transfer media**
- **N₂ Working Fluid COP ~ 1.25**
Conclusion

• Decarbonization of process heat is essential to meet climate goals.

• Heat pumps are a leading technology to improve efficiency in heat delivery and to electrify heat.

• Heat pumps can already be implemented for process heating needs up to 270°C with high COPs.

• Developments for temperatures above 270°C are still needed. Cycles based on ideal gases are likely to show the greatest benefit.
Contact page

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