HeatBooster
Industrial High Temperature Heat Pump System

Measured Performance of a Novel High Temperature Heat Pump with HFO-1336mzz(Z) as the Working Fluid
ONE TECHNOLOGY PLATFORM, TWO PRODUCT LINES
MONITORING SYSTEM

- Running hours
- Energy production
- Notification system
LARGE HEAT PUMPS AND ORC ENGINES BASED ON THE SAME PISTON MACHINE

Current products:

**CraftEngine**

<table>
<thead>
<tr>
<th>Power (kW)</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1-CYL</td>
</tr>
<tr>
<td>40</td>
<td>4 x 1-CYL</td>
</tr>
</tbody>
</table>

**HeatBooster**

<table>
<thead>
<tr>
<th>Power (kW)</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>1-CYL</td>
</tr>
<tr>
<td>200</td>
<td>4 x 1-CYL</td>
</tr>
</tbody>
</table>

New design of larger units:

**ORC engines** (ORC expanders)

<table>
<thead>
<tr>
<th>Power (kW)</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>2-CYL</td>
</tr>
<tr>
<td>200</td>
<td>4-CYL</td>
</tr>
<tr>
<td>300</td>
<td>6-CYL</td>
</tr>
<tr>
<td>400</td>
<td>8-CYL</td>
</tr>
</tbody>
</table>

**HTHPs** (HT compressors)

<table>
<thead>
<tr>
<th>Power (kW)</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>2-CYL</td>
</tr>
<tr>
<td>800</td>
<td>4-CYL</td>
</tr>
<tr>
<td>1.2</td>
<td>6-CYL</td>
</tr>
<tr>
<td>1.6</td>
<td>8-CYL</td>
</tr>
</tbody>
</table>

**LARGE ORC FAMILY**

**LARGE HTPF FAMILY**

(Note: Output thermal power assumes COP = 4)
HEATBOOSTER – HOW IT WORKS

Input (temp) range (approx.):
30 – 110 °C

Output (temp) range (approx.):
80 – 160 °C

Q_L: 150 kW
Q_H: 200 kW

COP = 4

50 kW
Electricity

WASTE HEAT IN
USEFUL HEAT OUT
Proven performance:
- Temperature lifts from 20 to 65°C
- Max. heat output at temperature lifts of up to 40°C
HeatBooster™

Measured Performance with HFO-1336mzz(Z)
HEATBOOSTER PILOT PLANT

- 1-Cylinder, electrical capacity 12.5 kW
- Single stage vapor compression with recuperator
- 100s of tests during a ten-month period

Test conditions:
- Engine speed: 900-1350 RPM
- Working fluids:
  - HFO-1336mzz(Z)
  - HFC-245fa
- Heat source and heat consumer units had limited temperature and flow capacity ->
  Therefore maximum heat capacity was limited
**PROPERTIES: HFO-1336mzz(Z) VS. HFC-245fa**

<table>
<thead>
<tr>
<th></th>
<th>HFO-1336mzz(Z)</th>
<th>HFC-245fa</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_b$, °C</td>
<td>33.38</td>
<td>15.14</td>
</tr>
<tr>
<td>$T_{cr}$, °C</td>
<td>171.28</td>
<td>154.01</td>
</tr>
<tr>
<td>$P_{cr}$ MPa</td>
<td>2.901</td>
<td>3.651</td>
</tr>
<tr>
<td>Molecular Formula</td>
<td>Z-CF$_3$CH=CHCF$_3$</td>
<td>CHF$_2$CH$_2$CF$_3$</td>
</tr>
<tr>
<td>Flammability limit</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Occupational Exposure Limit, ppmv</td>
<td>500</td>
<td>300</td>
</tr>
<tr>
<td>Safety Class</td>
<td>A1</td>
<td>B1</td>
</tr>
<tr>
<td>Atmospheric Lifetime, yrs</td>
<td>0.0603 (22 days)</td>
<td>7.7</td>
</tr>
<tr>
<td>$GWP_{100}$</td>
<td>2</td>
<td>858</td>
</tr>
</tbody>
</table>
TEST RESULTS: TEMPERATURE LIFT WITH HFO-1336mzz(Z)

Trend:
- COP increases linearly with the temperature lift

Graph A

- HFO-1336mzz(Z)
- HFC-245fa
TEST RESULTS: COP VS. OUTPUT TEMPERATURE WITH HFO-1336mzz(Z)

COP varies due to:
- Temperature lift
- Output temperature
- Heat output (engine speed, superheat, etc.)
- System optimization (recuperator, fluid quantity, valves)
With increasing pressure, the following applies:

- More gas fit into the compressor
- Higher energy density and power in the compression stroke

COP varies due to:

- Temperature lift, heat output, optimization, etc.
TEST RESULTS: CARNOT EFFICIENCY WITH HFO-1336mzz(Z)

COP:
- Includes all losses
- \( \frac{\text{COP}}{\text{(theor. max. COP)}} \) = 50% is typ. for heat pumps in the low temperature range
MAIN BENEFITS

- **High-temperature heat:** up to 160°C
- **Energy efficiency increase:** up to COP = 8 by the use of your low-temperature (waste) heat
- **Easy to install:** “Plug-and-play”
- **Service:** 24/7 remote service package
- **Available to order:** up to 200 kW per unit

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