High Efficiency Heat Pump with Subcooling for Sanitary Hot Water Production Working with Propane

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Air to water inverter heat pump of 40 kW
Water to water heat pump of 60 kW
Water to water booster for shw production.

Air to water water heater up to 60°C
Air to water water heater up to 80°C

- Heat pump able to heat water up to 65 °C with a temperature lift of 55 K.

- Nominal Point: 47 kW
- Nominal Point: COP 5,62.
- Recovering water at 20°C.
- Air to water inverter heat pump of 40 kW
- Water to water heat pump of 60 kW
- Water to water booster for shw production.
- Air to water water heater up to 60°C
- Air to water water heater up to 80°C

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Source</th>
<th>T(°C)</th>
<th>Sink</th>
<th>T(°C)</th>
<th>Application</th>
<th>(kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC (Propane)</td>
<td>Water (Neutral loop)</td>
<td>10 to 15 (Sewage water) or 25 to 30 (Condensation loop)</td>
<td>Water</td>
<td>60</td>
<td>Domestic hot water production</td>
<td>50</td>
</tr>
</tbody>
</table>
- CO₂ Transcritical cycles vs. subcritical cycles with 0 subcooling.

Theoretical results with IMST-ART for hot water at 60ºC (Pitarch \textit{et al.}, 2014).
Transcritical cycles are used for high temperature lift.

Temperature profiles of water and refrigerant match better along the gas cooler in Transcritical systems.

Theoretical results with IMST-ART for hot water at 60°C (Pitarch et al., 2014).
Heat transfer in the condenser can be optimized by adding subcooling in the subcritical system.

Theoretical results with IMST-ART for hot water at 60°C.
- Subcooling in a separate heat exchanger.
- The Liquid Receiver ensures saturated liquid at the condenser outlet and accommodate changes in the refrigerant charge.
Test Rig is able to control all the water inlet & outlet water temperatures

The measured points have been checked to lie under the limits marked by the norm UNE-EN 14511-3
Relative and absolute uncertainty intrinsic to the sensor

For the calculated parameters such as heating COP, the equation of propagating error has been used

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Model</th>
<th>Relative uncertainty</th>
<th>Absolute uncertainty</th>
<th>Units</th>
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<tbody>
<tr>
<td>Pressure</td>
<td>Differential 1151 Smart Rosemount</td>
<td>0.1256 % of Span</td>
<td>4.684E-04 bar</td>
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<td>Pressure</td>
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<td>7.889E-02 bar</td>
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<tr>
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<td>3.782E-02 bar</td>
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<tr>
<td>Temperature</td>
<td>Thermocouple T Type</td>
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<tr>
<td>Temperature</td>
<td>RTD</td>
<td>0.06 K</td>
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<tr>
<td>Flow</td>
<td>Coriolis SITRANS F C MASS 2100</td>
<td>0.29 % of Reading</td>
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<tr>
<td>Flow</td>
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<tr>
<td>Power</td>
<td>DME 442</td>
<td>0.3 % of Reading</td>
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</table>
Results

- Water inlet temperature to evaporator: $T_{w,ei}=20^\circ C$. Producing hot water at $60^\circ C$
- COP calculations include the consumption of the water pumps (European standard 14511-3)
- COP increase with subcooling for all water inlet temperature range
Results

- COP and heating capacity as a function of the water inlet temperature at the subcoolor for different water inlet temperature to the evaporator ($T_{w,ei}$)
- Producing hot water at 60°C
Results

- COP and heating capacity as a function of the water inlet temperature at the subcooler for different water inlet temperature to the evaporator ($T_{w,ei}$)
- Producing hot water at 60°C
Conclusions

- Heating COP is improved by adding subcooling in the Propane cycle. 31% in the nominal point

- The degree of improvement depends on the degree of subcooling

- At the nominal point, COP and heating capacity are 5.61 and 47.1 kW, respectively.

- Subcooling depends mostly with the water inlet temperature to the subcooler, and not with the inlet water temperature to evaporator. $T_{w,ci}=10^\circ C \rightarrow SC=43K$ ; $T_{w,ci}=55^\circ C \rightarrow SC=9K$

- Low refrigerant quality or even subcooled liquid can be find at evaporator inlet with points working at elevated evaporating pressure and high subcooling
Thanks!