Danfoss dedicated heat pump compressor improves the seasonal energy efficiency up to almost 10%!

This year Danfoss has launched a new dedicated heat pump compressor – the HHP compressor. The HHP is designed for Air/Water heat pump applications and is suitable for Brine/Water or Water/Water heat pump applications as well.

The dedicated design and optimization of the compressor makes it possible to achieve high energy efficient performance when producing heating or sanitary hot water at very low ambient temperatures.
Danfoss has combined two features of the compressor to be able to achieve this. Firstly, the compressor has an extended operating envelope which makes it possible to produce heating at low outdoor temperature while reducing use of less efficient supplementary heaters.

Secondly, the innovative design of the compressor which includes three reed valves makes it possible to achieve up to approximately 10% higher yearly energy efficiency compared to competing compressors (see below calculation).

All scroll compressors have a characteristic efficiency curve. Every scroll reaches an efficiency maximum when the unit is operating at a certain pressure ratio. This is the compressors optimization point. The compressor can be operated at different pressure ratios, but the efficiency will decrease the further the operating conditions deviate from the optimization point (see diagram).

Refrigerant compressors are optimized for certain running conditions due to the fixed internal pressure ratio. However, it can happen that more than 90% of the time the running conditions do not represent the internal pressure ratio! This means that the compressor is operating with running conditions far away from the optimization point resulting in decreased efficiency. The more the real operation conditions differ from the optimization point the more the efficiency decreases.

If a heat pump could always be operating in conditions close to the optimization point it would reach the best efficiency. However, usually operating conditions vary throughout the year – especially for air source heat pumps and houses with radiator systems.

In these cases, the heat pump often needs to operate under conditions quite far away from the optimization point, which causes reductions in efficiency. Danfoss’ HHP compressor has an improved efficiency curve due to the innovative use of the three reed valves.

The two intermediate valves improve the efficiency at lower pressure ratio conditions. For example in case of high suction and low condensing condition which causes internal over compression in a standard compressor and thereby efficiency losses due to expansion of the “over compressed” gas to condensing pressure. This will be avoided with the intermediate valves that release the gas when the pressure reaches the needed conditions.

The centre valve is for high efficiency at high pressure ratio conditions. For example when the internal pressure ratio is too low because the compressor is running in low suction and high condensing conditions the high pressure gas at discharge causes a brief back flow each time the last pocket of the scroll opens to discharge. The center reed valve prevents the back flow and thereby avoids decreasing the performance.

Innovative features like reed valves are the basis for these improvements. For the heat pump, this will result in a higher efficiency all year around, which will increase the seasonal COP of the unit.

Especially for air source heat pumps, the new Danfoss HHP compressor series offers a unique possibility to improve yearly energy efficiency and reduce the energy costs for the end-user.
**Calculations to prove the energy efficiency**

To prove the energy efficiency of the dedicated heat pump compressor design, Danfoss made a simulation study.
One year of operation was simulated for an “air to water” unit with a HHP and a competing compressor. The same yearly heating requirement profile, weather conditions, and operating parameters were used in all the simulations.

Each simulation was performed on an hourly basis by performing one steady state simulation for each hour in the year. In each hour the heating requirement was known from an hourly requirement profile for the entire year. By stepping through the compressor capacity stages of the simulated unit it was determined which capacity stage(s) that best matched the average heating requirement during the hour. If no capacity stage was able to match the heating requirement exactly, which is usually the case for units without a speed controlled compressor, then the results for the hour were calculated by time weighing results for the two closest matching capacity stages.

The calculations performed for each capacity stage took into account the finite capacities of the condenser and evaporator.

**Method**

The yearly heating requirement profile varied between 0 kW and 9.5 kW with an average requirement of 3.3 kW. Below graph shows a histogram of the total hourly requirement.

Weather data for Helsinki, Finland was used. The evaporation temperature varied with the weather conditions and was kept 7K below the ambient temperature. A maximum evaporation temperature of 10°C was specified. As ambient temperature, the dry bulb temperature was used. The heated water supply temperature was kept constant. The supply flow was varied proportional with the load. The condenser (indoor) pump was running with the compressor. A constant superheat of 7K and a constant sub cooling of 5K were specified.

**Operating conditions**

The results from the simulations are summarized in the table below.

<table>
<thead>
<tr>
<th></th>
<th>(Danfoss HHP38 - reference)</th>
<th>Competition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirement met [%]:</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Compressor energy consumption [kWh]:</td>
<td>11510</td>
<td>14578</td>
</tr>
<tr>
<td>Evaporator fan energy consumption [kWh]:</td>
<td>704</td>
<td>604</td>
</tr>
<tr>
<td>Off-cycle energy consumption [kWh]:</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Additional heat energy consumption [kWh]:</td>
<td>1083</td>
<td>461</td>
</tr>
<tr>
<td>Total yearly energy consumption [kWh]:</td>
<td>13297</td>
<td>15643</td>
</tr>
<tr>
<td>Yearly energy savings [kWh]:</td>
<td>2346</td>
<td></td>
</tr>
<tr>
<td>Yearly energy savings [%]:</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Average COP heating [-]:</td>
<td>2.03</td>
<td>1.87</td>
</tr>
</tbody>
</table>

Conclusion: The Danfoss HHP compressor provides ~15% saving on energy and ~9% increase in SCOP.

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