Experimental Analysis of the Use of R134a, R450A and R513A in a Small Water-to-Water Heat Pump

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Purpose of the present study

- Experimentally assess the performance of R450A and R513A in a water-to-water heat pump in a drop-in application.

- Tests are carried out setting the vapour superheating at evaporator outlet and the outlet temperatures of the secondary fluids that flow through the heat exchangers rather than the evaporating and the condensing temperatures. The system find its own operating point (evaporating and condensing pressures, subcooling at condenser outlet) depending on the refrigerant used.
Experimental set-up – Layout

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Heat pump heating capacity

\[ \dot{Q}_{\text{COND}} = \frac{1}{2} \left[ m_R (h_{R,\text{IN,COND}} - h_{R,\text{OUT,COND}}) + m_W c_p,w (T_{W,\text{OUT,COND}} - T_{W,\text{IN,COND}}) \right] \]

Heat pump COP

\[ COP = \frac{\dot{Q}_{\text{COND}}}{\dot{W}_{\text{COMP}}} \]
Experimental conditions

Two groups of tests:

- **Group 1**: tests with the **same rotational frequency** of the compressor shaft and the **same temperatures** of the secondary fluids at the outlet of the heat exchangers → different mass flow rates → **different heating capacities** and COPs.

- **Group 2**: tests with the **same mass flow rates** and the **same temperatures** of the secondary fluids at the inlet and outlet of the condenser → different rotational frequency of the compressor shaft → **same heating capacities** but different COPs.
Experimental conditions – Group 1

**Reference conditions:** conditions used to identify mass flow rates. \( \Delta T \) across heat exchanger fixed to 5 °C.

**Testing conditions:** the mass flow rate and the outlet temperature are kept constant.
Experimental conditions – Group 1 – Heating capacity

**R450A** shows 6.59% - 15.02% capacity reduction with respect to R134a. This is due to both a lower refrigerant mass flow at compressor suction, related to a lower density at the compressor suction, and a lower enthalpy difference across the condenser.

**R513A** shows -8.78% - +3.16% capacity variation as a consequence of a higher refrigerant mass flow at the compressor suction (+5.84% - + 25.78%) but lower enthalpy difference across the condenser (-12.50% - 19.03%).
Experimental conditions – Group 1 – Heating capacity

$T_{W,OUT,COND} = 55^\circ C$

$T_{W,OUT,COND} = 75^\circ C$
**Experimental conditions – Group 1 – COP**

R450A shows COP variations in the range -2.48% - +2.99%, whereas R513A shows COP variation from -7.48% to +2.22%.

This behaviour is related to the different thermophysical properties of the two alternative refrigerants, namely the critical temperature and the reference isobaric heat capacity, with respect to those of the R134a.
Experimental conditions – Group 1 – COP

$T_{W,OUT,COND} = 55^\circ C$

$T_{W,OUT,COND} = 75^\circ C$
## Experimental conditions – Group 2

<table>
<thead>
<tr>
<th>Run</th>
<th>f [Hz]</th>
<th>Evaporator</th>
<th>Condenser</th>
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<tr>
<td></td>
<td></td>
<td>$m_G$ [kg·h⁻¹]</td>
<td>$T_{G,IN}$ [°C]</td>
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<tr>
<td>26</td>
<td>Variable</td>
<td>Variable</td>
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</tr>
<tr>
<td>30</td>
<td>Variable</td>
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</table>
R450A needs 10% - 16% increase in the rotational frequency of the compressor shaft, whereas R513A needs 2% - 8% increase in the rotational frequency of the compressor shaft.

These results are consistent with the trend of the heating capacity previously discussed.
Experimental conditions – Group 2 – COP

COP variations are in the -5.22% - + 0.14% for R450A and in the range -6.48% - -2.34% for R513A.

This behaviour arises from the increase in the rotational frequency of the compressor shaft that causes an increase in mass flow rate which, in turn, forces the evaporating and condensing temperatures to separate and the COP to reduce.
Conclusions

- The two low-GWP mixtures generally show slightly lower heating capacity and COP compared to the R134a under the same operating conditions. In the analysed working conditions, R450A shows the most similar COP to R134a, whereas R513A shows the most similar heating capacity.

- An increase in the rotational frequency of the compressor shaft is an effective way to bring the heating capacity of the heat pump working with the two mixtures back to the R134a level. In this working conditions, the COP further reduces, but the difference is not very high.
Future works

- On-going: analysis on R515B performance.
- Mid/Long-term: Analysis of R410A alternatives (R32, R452B, R454B, R466A etc...). Experimental set-up update is needed.
THANK YOU FOR YOUR KIND ATTENTION!