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Performance of a large capacity propane heat pump with low charge heat exchangers

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ABSTRACT

The experimental performance of a 100 kW heat pump using propane is presented. The charge minimization is a priority in the design of such a device and thus shell-and-tube heat exchangers using minichannels and providing low charge have been installed in the unit, along with conventional brazed plate heat exchangers, in order to compare different working configurations, both in terms of energy efficiency and refrigerant charge.
The performance when using the minichannel condenser is here compared to the one obtained when using a brazed plate condenser and the influence of a minichannel internal heat exchanger on the performance of the equipment is measured and discussed.
It is shown that a 100 kW heat pump without a liquid receiver could be run with around 3 kg of propane using a plate condenser and a plate evaporator. Using the minichannel condenser, around 0.8 kg reduction can be obtained with a negligible performance loss.

Performance d'une pompe à chaleur au propane d'une grande puissance avec des échangeurs de chaleur à faible charge

Mots clés : Pompe à chaleur ; Eau-eau ; Système à compression ; Propane ; Expérimentation ; Performance ; Micro-canal ; Réduction ; Charge en frigorigène

1. Introduction

The use of hydrocarbons as refrigerants is a good opportunity to develop environmentally friendly HVAC equipment, since the direct effect on the anthropogenic global warming due to atmospheric emissions is almost completely avoided, while the indirect effect can be reduced by exploiting the favorable thermodynamic properties of these fluids.

In the case of large systems for heating and cooling of buildings, roof top equipment using a hydronic system to

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Nomenclature

COP	coefficient of performance
h	specific enthalpy, [J kg^{-1}]
HX	heat exchanger
IHX	internal heat exchanger (see Fig. 1)
m	refrigerant mass flow rate, [kg s^{-1}]
PHE	plate heat exchanger
W_{comp}	compressor electric power, [W]
η_{GLOBAL}	global compressor efficiency (see Eq. (1)), [–]

distribute chilled or hot water is an ideal solution to address the safety problems due to flammability of hydrocarbons.

Because of flammability, charge minimization is a major design objective for such equipment using hydrocarbons. However, the same restriction in charge should be adopted also in systems operating with halogenated fluids when trying to reduce the atmospheric emissions, or when using refrigerants with some degree of toxicity, like, for example, ammonia. The refrigerant charge minimization can therefore be considered one of the most important targets for HVAC applications to cope with the new environmental challenges.

In a paper by Harms et al. (2003), the estimated charge of three unitary air conditioners with capacity varying from 9 kW up to 26 kW and using R22 and R407C is expected to be mainly trapped in the heat exchangers. In particular, the computed charge in the condenser varied from 30% up to 70% of the total amount, while the charge in the evaporator was about 15%. Similar results have been obtained in an estimation by Corberán and Martínez (2008) of the charge inventory distribution among the components of a water-to-water propane heat pump using plate heat exchangers (PHEs): 50% of the total charge is expected to be found in the condenser, while about 15% should be trapped in the evaporator.

At the system level, the use of an indirect system with secondary fluid loops drastically reduce the total charge when compared to direct systems, while, at the level of components, heat exchangers specially designed for low charge are needed. PHEs can be considered the current industrial benchmark in charge minimization for liquid-to-refrigerant condensers and evaporators, however minichannels technology appears to be a very good opportunity to further minimize the charge without energy performance loss.

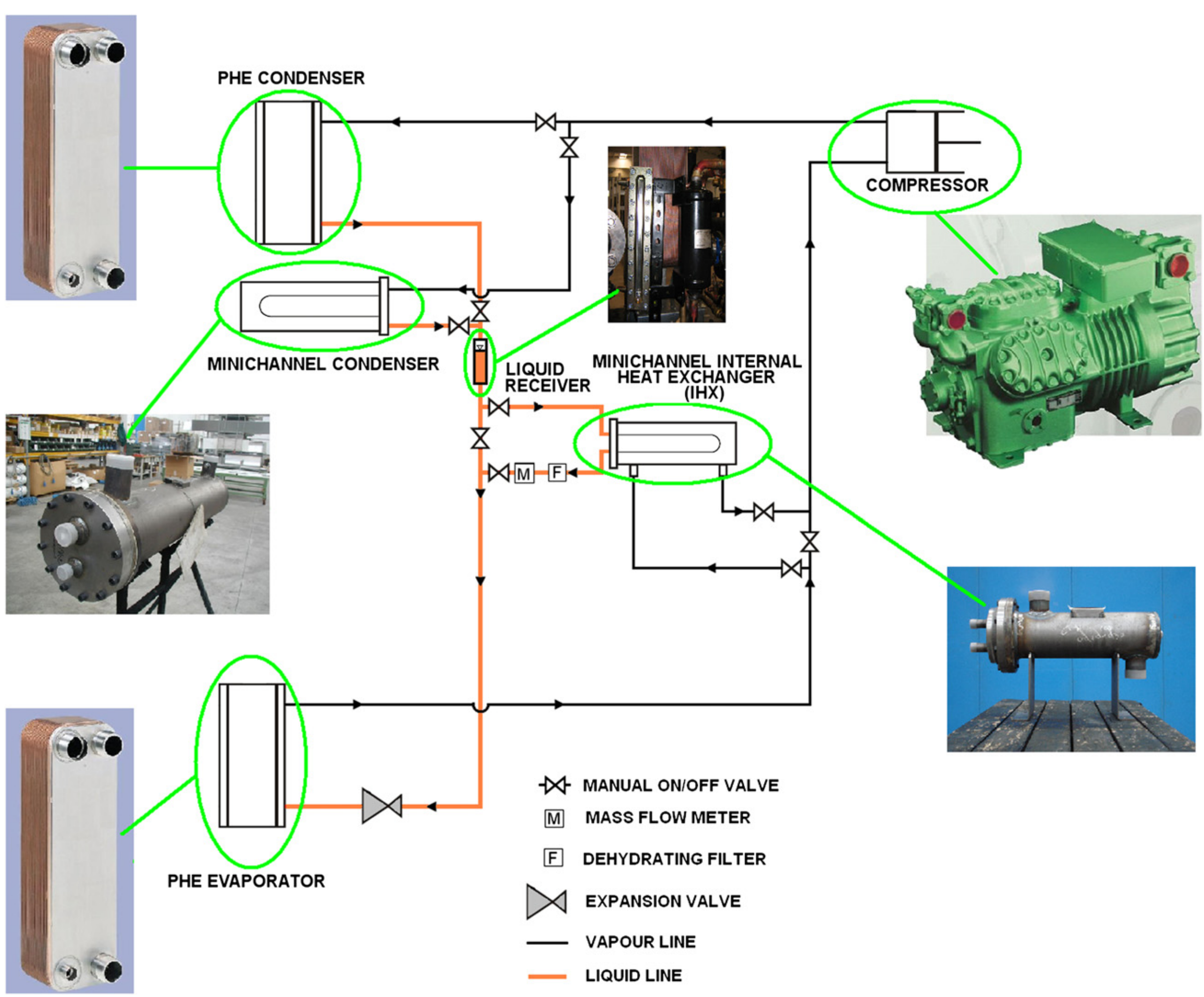

Fig. 1 – Heat pump facility.