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HFC32, a low GWP substitute for HFC410A in medium size chillers and heat pumps

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ABSTRACT

This paper presents the experimental heat transfer coefficients and pressure drops measured during refrigerant HFC32 condensation inside a commercial Brazed Plate Heat Exchanger (BPHE) and compares this data with similar measurements previously obtained for refrigerant HFC410A to assess its capability as low GWP substitute for HFC410A in medium size chillers and heat pumps. The effects of saturation temperature, refrigerant mass flux, and vapour super-heating are investigated. HFC32 exhibits heat transfer coefficients much higher and frictional pressure drop slightly higher than those of HFC410A. Therefore, considering that HFC32 exhibits a GWP just one-third that of HFC410A, taking into account also its good thermodynamic properties, it seems to be a very promising low GWP substitute for HFC410A in medium size chillers and heat pumps.

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Le HFC32, un frigorigène de remplacement pour le HFC410A à faible GWP dans des refroidisseurs de dimension moyenne et des pompes à chaleur

Mots clés : GWP ; HFC32 ; Refroidisseur ; Pompe à chaleur ; Condensation ; Èchangeurs de chaleur à plaques brasées

1. Introduction

HydroFluoroCarbons (HFCs) are the most commonly used refrigerants in developed countries. HFC134a dominates the applications in household refrigeration, mobile air-conditioning systems, and large chillers; HFC404A is the leader of commercial refrigeration, and HFC410A is the most used refrigerant in split air-conditioning units, residential heat pumps, and medium size chillers.

However all the above HFC refrigerants exhibit a relatively high Global Warming Potential (GWP): HFC134a GWP is 1430, HFC410A GWP is 2090, and HFC404A reaches 3922 of GWP, the highest value among the commonly used refrigerants. Therefore a number of substances are investigated as low GWP candidates for traditional HFC refrigerants replacement: HFC32, a HFC with a relatively low GWP (675); HFO refrigerants, which have a GWP between 1 and 7; and natural substances such as CO_2 and propane, which have reduced or no environmental impact. The choice of a new refrigerant is

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Nomenclature

A	area of the plate (m^2)
b	depth of the corrugation (m)
COP	coefficient of performance
c_p	specific heat capacity ($J\ kg^{-1}K^{-1}$)
d_h	hydraulic diameter, $d_h = 2\ b$ (m)
f.s.	full scale
g	gravity acceleration ($m\ s^{-2}$)
G	mass flux, $G = m/(n_{ch}\ W\ b)$ ($kg\ m^{-2}s^{-1}$)
h	heat transfer coefficient ($W\ m^{-2}K^{-1}$)
J	specific enthalpy ($J\ kg^{-1}$)
k	coverage factor
L	flow length of the plate (m)
m	mass flow rate ($kg\ s^{-1}$)
n_{ch}	number of channels
p	pressure (Pa)
P	corrugation pitch (m)
Pr	Prandtl number, $Pr = \mu\ c_p/\lambda$
q	heat flux, $q = Q/S$ ($W\ m^{-2}$)
Q	heat flow rate (W)
Re	Reynolds number, $Re = G\ d_h/\mu$
Re_{eq}	equivalent Reynolds number, $Re_{eq} = G\ [(1 - X) + X\ (\rho_L/\rho_G)^{1/2}]\ d_h/\mu_L$
S	nominal heat transfer area (m^2)
T	temperature (K)
VCC	Volumetric Cooling Capacity ($J\ m^{-3}$)
W	width of the plate (m)
X	vapour quality, $X = (J - J_L)/\Delta J_{LG}$

Greek symbols

β	inclination angle of the corrugation
Δ	difference
ΔJ_{LG}	latent heat of condensation ($J\ kg^{-1}$)
ϕ	enlargement factor
λ	thermal conductivity ($W\ m^{-1}K^{-1}$)
μ	viscosity ($kg\ m^{-1}s^{-1}$)
ρ	density ($kg\ m^{-3}$)

Subscripts

a	momentum
ave	average
c	manifold and port
e	evaporator
eq	equivalent
f	frictional
fc	forced convection
g	gravity
G	vapour phase
in	inlet
L	liquid phase
LG	liquid gas phase change
ln	logarithmic
Nu	Nusselt (1916).
out	outlet
p	plate
r	refrigerant
t	total
sat	saturation

subjected to several constrains other than its simple contribution to Global Warming, such as safety, economic viability, and thermodynamic efficiency. Similarly, the characteristics required to a refrigerant depend also on the size and type of the inverse cycle machine; therefore it's necessary to select the most suitable refrigerant for each specific application.

HFC32 seems to be a very promising low GWP substitute for HFC410A in split air-conditioners, residential heat pumps, and medium size chillers. First HFC32 GWP is just one-third that of R410A. Second HFC32 exhibits excellent thermodynamic efficiency that leads to lower greenhouse gases emission and to a refrigerant charge reduction.

Domanski et al. (2014) compared the thermodynamic performance of HFC32 to those of traditional synthetic refrigerants, such as HCFC22, HFC134a, HFC410A, and HFC125; natural refrigerants, such as HydroCarbons (HCs) (HC600a Isobutane, HC290 Propane) and Ammonia, and also alternative low GWP refrigerants, such HFO1234yf and HFO1234ze(E). The thermodynamic comparative analysis considered four different inverse vapour compression cycles (simple vapour compression cycle, vapour compression cycle with regenerative heat exchanger, economizer cycle with two-stage compression, and cycle with work recovery from expansion device) and two operating parameters, namely the Coefficient of Performance (COP) and the Volumetric Cooling Capacity (VCC). The performance of HFC32 falls below the Pareto fronts developed for the objective functions COP and VCC, which represents the thermodynamic limits of the analysis (optimal refrigerant), however it exhibits in general higher COP and VCC than HFC410A.

In 2012 Daikin started to use HFC32 in residential air-conditioners instead of HFC410A and nowadays HFC32 is the most commonly used refrigerant substitute for HFC410A in residential and commercial air-conditioners in Japan, China, and India. Other interesting applications for HFC32 as substitute for HFC410A are medium size chillers and residential heat pumps. In general this type of units involves the use of Brazed Plate Heat Exchangers (BPHE) to compact the systems reducing also the refrigerant charge. This feature is extremely interesting for HFC32 which is classified as a mildly flammable refrigerant (class A2L) (ASHRAE (2013)). In fact the first attempt to reduce the risk of flammable or mildly flammable refrigerants is to decrease the refrigerant charge.

Palmer et al. (2000) measured the average Nusselt number during refrigerant mixture HFC32/HFC152a (50/50 wt%) vaporisation and condensation inside a BPHE in presence of lubricant oil. The performance of this mixture was compared to HC refrigerant (HC290) and HC refrigerant mixture (HC290/HC600a (70/30 wt. %)).

Mancin et al. (2013) presented HFC32 super-heated vapour condensation data inside a BPHE with refrigerant mass flux from 13 to 37 $kg\ m^{-2}\ s^{-1}$ finding heat transfer coefficients higher than those of HFC410A and HFC407C.

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