Energy Conversion and Management 52 (2011) 1520–1525

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

On the pressure drop in Plate Heat Exchangers used as desorbers in absorption chillers

N. García-Hernando [a,*], J.A. Almendros-Ibáñez [b,c], G. Ruiz [d], M. de Vega [a]

[a] *Energy System Engineering (ISE), Departamento de Ingeniería Térmica y de Fluidos, Universidad Carlos III de Madrid, Avda. Universidad, 30, 28911 Leganés, Madrid, Spain*
[b] *Escuela de Ingenieros Industriales de Albacete, Departamento de Mecánica Aplicada e Ingeniería de Proyectos, Universidad de Castilla La Mancha, Campus Universitario s/n, 02071 Albacete, Spain*
[c] *Renewable Energy Research Institute, c/de la Investigación s/n, 02071 Albacete, Spain*
[d] *Energy Efficiency and Renewables Department, Técnicas Reunidas S.A., C/Arapiles No. 13, 10ª, 28015 Madrid, Spain*

ARTICLE INFO

Article history:
Received 17 June 2009
Received in revised form 2 February 2010
Accepted 6 October 2010
Available online 30 October 2010

Keywords:
Absorption system
Desorption
Plate Heat Exchangers
Pressure drop
Plate exchanger

ABSTRACT

The influence of the pressure drop in Plate Heat Exchangers (PHE) in the boiling temperature of LiBr–H_2O and NH_3–H_2O solutions is studied. For the NH_3–H_2O solution, the pressure drop-temperature saturation relationship estates that high pressure drops can be allowed in the solution with negligible changes in the saturation temperature, and in the PHE performance. Besides, in the case of the LiBr–H_2O solution, as the working pressure is usually very low, the analysis of the pressure drop must be taken as a main limiting parameter for the use of Plate Heat Exchangers as vapour generators. In this case, the pressure drop may considerably change the boiling temperature of the solution entering the heat exchanger and therefore a higher heating fluid temperature may be required. A guideline to design these systems is proposed.

1. Introduction

Absorption chillers, compared to mechanical refrigeration systems, are generally larger in size and that limits to a great extend their use in low and medium power applications. For instance a typical value for the volume to refrigeration power ratio in single effect absorption chillers is in the order of 0.04 m^3/kW (without considering the volume occupied by the cooling system) for refrigeration capacities between 10 and 30 kW, whereas the mechanical compressor systems can have a ratio equal to 0.02m^3/kW for the same range of refrigeration capacities. This is a clear inconvenient for the generalization of the absorption technology use, limiting its benefits in the contribution to the reduction in CO_2 emissions, specially in the case of the LiBr–H_2O solution as this system can be fed with low heat temperature sources as solar panels [1,2].

In order to avoid this large volume concern, attempts have been made to scale down their size. One way of reducing the size of these systems is the use of compact heat exchangers. Plate Heat Exchangers (PHE) have been used not only for the solution heat recover [3] but also for the absorber [4,5] or the generator [6]. The precautions when using this last possibility relative to the solution pressure drop and its influence on the boiling temperature are studied here.

In the present work, we are interested in the relationship between pressure drop and saturation temperature, and its effect on the temperature profile in the PHE generator of an absorption chiller. This new consideration must be taken into account as a relatively important pressure drop may occur in a PHE used as the generator of an absorption system. This was not the case until now as in pool boiling the pressure drop is not appreciable. Even if some authors have experimentally measured these high pressure drop values [6], to the authors knowledge, the effect on the heat exchanger design and performance have never been studied. Both aspects are treated here.

2. Description of the absorption cycle, without pressure drop in the generator

In most of the cases, absorption systems are theoretically studied considering a negligible pressure drop in the heat exchangers [7]. The resulting ideal thermodynamic cycle can be easily solved in this case and as a result, knowing the evaporation and the condensation temperatures, the inlet and outlet temperatures of the flowing fluids in the different heat exchangers can be calculated. In the present study, a LiBr–H_2O and a NH_3–H_2O ideal cycles have been taken as reference cases, with an evaporation temperature

---

* Corresponding author. Tel.: +34 916 248 885; fax: +34 916 249 430.
E-mail address: ngarcia@ing.uc3m.es (N. García-Hernando).

0196-8904/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enconman.2010.10.020

Nomenclature

ch	chilled water
CW	cold water
D_h	hydraulic diameter
DP	pressure drop
f	friction factor
G	fluid mass flux
Hf	hot flow
L	channel length
$\dot{m}$	mass flow rate
Pc	condensation pressure
T	temperature
V	mean velocity
x	mass fraction
y	vapour mass fraction

Greek symbols

ρ	density
μ	dynamic viscosity
υ_m	specific volume of the vapour–liquid mixture

Subscripts

eq	equivalent
g	vapour
i	inlet
l	liquid
m	mean
o	outlet
REF	refrigerant
DIS	solution

equal to 7 °C and a condensation temperature equal to 40 °C. The procedure for the calculation is similar to that presented in de Vega et al. [8], and the corresponding equipment is depicted in Fig. 1. In the case of the NH_3–H_2O, the vapour separator should also include a rectifier for the final distillation of NH_3.

The resulting calculated temperatures of the solution at the inlet (7: t_{INLET}) and at the outlet (8: t_{OUTLET}) of the desorber, and the corresponding initial boiling temperatures at the given inlet concentration of the solution ($t_{BOILING}$) are presented in Figs. 2 and 3 for different vapour mass fractions of the refrigerant separated during the desorption. In these figures, the mass fraction y is the ratio between the refrigerant mass flux entering the condenser and the solution mass flux entering the desorber. In terms of the inlet and outlet concentrations, it can be expressed as:

$$y = \frac{\dot{m}_{REF}}{\dot{m}_{DIS}} = \frac{x_7 - x_8}{x_1 - x_8} \tag{1}$$

$$y = \frac{\dot{m}_{REF}}{\dot{m}_{DIS}} = \frac{x_8 - x_7}{x_8} \tag{2}$$

where x_7 and x_8 are the NH_3 (1) or the LiBr (2) mass fractions.

These temperatures in the ideal cycle increase as the solution and the generated vapour are circulating through the heat exchanger during the desorption. In fact, for a given operating pressure of the generator, the initial temperature for the boiling condition is the same (for given evaporator and condenser temperatures), independent of the vapour mass fraction of the refrigerant separated y as shown in Figs. 2 and 3. In these figures, as well as in the rest of figures of the paper, the temperature profiles are just estimated, as in Gabrielii and Vamling [9]: the interesting point is that in all the cases, for the solution, $t_{INLET} < t_{BOILING} < t_{OUTLET}$. This allows in principle the use of a counter-current flow PHE configuration for the heating fluid.

Without considering pressure drop, the maximum temperature in the cycle is the one at the exit of the generator and therefore the temperature of the heating fluid has to be in accordance with this value. In the case of the NH_3–H_2O this temperature can be larger than 100 °C for a mass vapour fraction separated of 16.6% and it could be around 95 °C for the LiBr–H_2O case with a mass vapour fraction separated in the order of 7%, which allows the use of solar collectors as the heating source.

3. Boiling temperature and pressure drop in PHE

The assumption of a negligible pressure drop is consistent with the use of pool boiling for the vapour generation. Nevertheless,

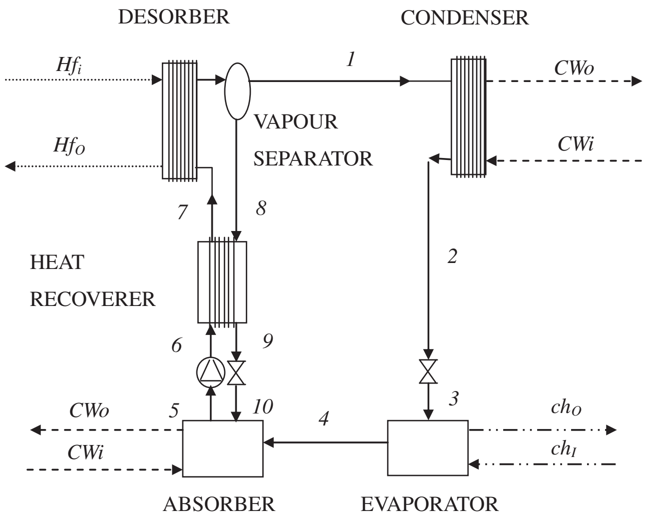

Fig. 1. Components of the absorption chiller.

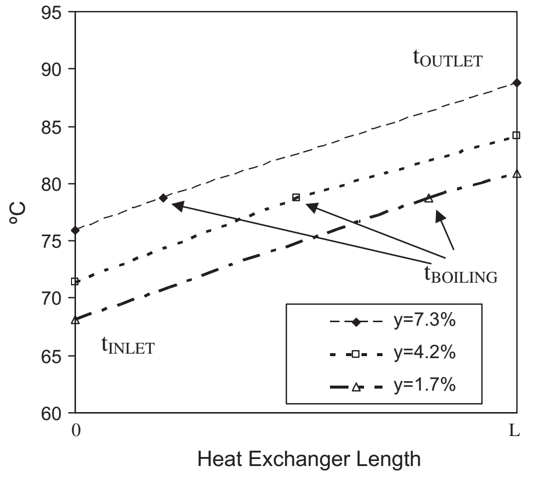

Fig. 2. Estimated temperature profiles along the desorber of a NH_3–H_2O cycle without pressure drop, for different vapour mass fractions of refrigerant: evaporation temperature = 7 °C; condensation temperature = 40 °C (xin_{NH3} = 52.4%; $xout_{NH3}$ = 42.9%, 46.9% and 48.9%).