



# New flat-fan sheets adiabatic absorber for direct air-cooled LiBr/H<sub>2</sub>O absorption machines: Simulation, parametric study and experimental results

A. González-Gil<sup>a,b,e,\*</sup>, M. Izquierdo<sup>a,b,e</sup>, J.D. Marcos<sup>c</sup>, E. Palacios<sup>d</sup>

<sup>a</sup> Instituto de Ciencias de la Construcción Eduardo Torroja (CSIC), c/Serrano Galvache 4, 28033 Madrid, Spain

<sup>b</sup> Escuela Politécnica Superior, UC3M, Avenida de la Universidad 30, 28911 Leganés, Madrid, Spain

<sup>c</sup> Escuela Técnica Superior de Ingeniería Industrial, UNED, c/Juan del Rosal 12, 28040 Madrid, Spain

<sup>d</sup> Escuela Universitaria de Ingeniería Técnica Industrial, UPM, c/Ronda de Valencia 3, 28012 Madrid, Spain

<sup>e</sup> Unidad de Asociada de Ingeniería de Sistemas Energéticos CSIC-UC3M, Spain

## ARTICLE INFO

### Article history:

Received 28 September 2011

Received in revised form 26 January 2012

Accepted 7 March 2012

Available online 27 April 2012

### Keywords:

Absorption

Lithium bromide

Adiabatic absorber

Direct air-cooled

Modeling

Experimental validation

## ABSTRACT

A new generation of highly efficient absorbers for direct air-cooled LiBr/H<sub>2</sub>O absorption machines is presented and discussed in this paper. As distinguishing aspects of these absorbers, it is worth mentioning that they are adiabatic units, which improves the heat and mass transfer; besides, they distribute the solution in flat-fan sheets, which allows for compact absorber designs; lastly, they are directly air-cooled units, which eliminates the need of cooling towers. Additionally, the paper includes the development of a mathematical modeling for analysis and simulation of this kind of absorbers. Based on that model, a parametric study of the proposed absorber design is carried out to optimize its use in a particular air-cooled single-double-effect absorption machine. Simulation outcomes of that specific absorber were compared with some experimental results obtained by using the aforementioned absorption machine as testing facility to validate the model. A good agreement was found between predictions and experimental results for most of the characteristic operation parameters of the absorber. Finally, it was observed that the proposed absorber design enables air-cooled LiBr/H<sub>2</sub>O absorption machines to work far from crystallization limits even at ambient temperatures around 40 °C.

© 2012 Elsevier Ltd. All rights reserved.

## 1. Introduction

Absorption technologies for air-conditioning in buildings have been receiving growing attention for the last years. In this sense, water-cooled absorption chillers seem to be a very attractive option to replace conventional electrically driven systems in large installations, as reported by [1] or [2]. In turn, the use of air-cooled absorption machines is generally preferred for low capacity applications, as stated, for instance, in [3]. As compared to water-cooled systems, they do not need a cooling tower to remove the heat from condensation and absorption processes, but they use the surrounding air as a free coolant. Consequently, both the installation and operational costs are lower and, what is more, health problems such as Legionella are avoided. Furthermore, the lack of water consumption makes air-cooled machines very adequate for regions where this source is a precious commodity. However, in spite of all those advantages, currently in the market one cannot find any air-cooled absorption chiller. The last air-cooled LiBr/H<sub>2</sub>O absorption chiller marketed was the *Rotartica 045v*, which consisted of

a single-effect machine indirectly air-cooled (re-cooling) designed to work with solar energy, see for instance [4] or [5]. However, it is interesting to note that, since the manufacturing company went bankrupt a few years ago, that chiller is no longer available in the market.

On the other hand, LiBr/H<sub>2</sub>O solution is regarded as one of the most interesting working fluids for absorption chillers because of its high performance, see [6] or [7]. However, a relatively high risk of solution crystallization appears in working at high absorption temperatures, as reported by [8] or [9]. Due to the heat transfer limitations of air as cooling source, air-cooled absorbers normally operate at higher temperatures than water-cooled ones and, as a result, solution is forced to work riskily closer to crystallization limits. Nowadays, this is regarded as a major obstacle for commercialization of air-cooled absorption machines based on LiBr/H<sub>2</sub>O.

Even though in the literature there are only a few publications about air-cooled absorption machines, one can find some interesting works reporting on possible solutions to overcome the crystallization problem. Some of them are investigations on new salt mixtures that do not crystallize in such working conditions, see for instance [10–12] or [13]. Other reports like [14] or [15] analyzed new configurations for falling film absorbers, traditionally used with water-cooled technology; however, the main problems

\* Corresponding author at: Instituto de Ciencias de la Construcción Eduardo Torroja (CSIC), c/Serrano Galvache 4, 28033 Madrid, Spain. Tel./fax: +34 918713248.  
E-mail address: [arturogzgil@gmail.com](mailto:arturogzgil@gmail.com) (A. González-Gil).

## Nomenclature

$A$	area (m <sup>2</sup> )
$c_p$	isobaric specific heat (kJ/kg K)
$F$	approach to equilibrium factor
$HG$	high-pressure generator
$h$	specific enthalpy (kJ/kg)
$h_{abs}$	specific heat of absorption (kJ/kg)
$\bar{h}_m$	mean mass transfer coefficient (m/s)
$LG$	low-pressure generator
$\dot{m}$	mass flow rate (kg/s)
$Q$	heat transfer rate (kW)
$RSP$	recirculation solution pump
$SP$	solution pump
$T$	temperature (K)
$t$	time (s)
$U$	global heat transfer coefficient (W/m <sup>2</sup> K)
$W$	power consumption (kW)
$X$	concentration of LiBr in the solution (%)

### Greek symbols

$\Delta P$	pressure drop (Pa)
$\Delta T_{sub}$	initial subcooling of the solution sheet flow (°C)
$\Delta X$	increment in the solution mass fraction (%)
$\Delta X_{lm}$	logarithmic mean mass fraction difference
$\eta$	efficiency
$\rho$	density
$\theta$	aperture angle of the sheet (°)

### Subscripts

$a$	absorber
$abs$	absorption
$ac$	air-cooler of the absorber
$air$	air flow
$b$	bulk conditions
$bank$	bank of sprayers in the absorber
$e$	evaporator/evaporation
$eq$	equilibrium conditions
$exp$	experimental
$f$	final position in a flat-fan sheet
$fan$	fan of the absorber air-cooler
$g$	single-effect generator
$HG$	high-pressure generator
$i$	inlet/initial position in a flat-fan sheet
$LG$	low-pressure generator
$o$	outlet
$out$	outdoors air
$pipes$	pipes of the absorber air-cooler
$pred$	predicted
$rsp$	recirculation solution pump
$s$	solution
$sheet$	solution flat-fan sheet in the bank of sprayers
$v$	vapor
$\infty$	complete adiabatic saturation

associated with falling film type absorbers could not be solved: low mass transfer, low heat transfer and large volume. Alternatively, a new control strategy based on increasing the chilled water temperature was proposed by [16]. Lastly, the use of lower driving temperature was proposed as a different option to develop air-cooled LiBr/H<sub>2</sub>O absorption chillers, [17].

In spite of the fact that the above exposed options seem to be adequate to solve the crystallization problems in air-cooled absorption machines, they are either complex to implement or reduce the performance of LiBr/H<sub>2</sub>O cycles. Besides, those alternatives do not contribute to reducing size of absorbers, which is also regarded as a major barrier for commercialization of low capacity absorption chillers. In this sense, the utilization of a hydrophobic membrane contactor at the liquid-vapor interface was proposed as a possible solution to obtain compact absorbers for LiBr/H<sub>2</sub>O absorption chillers, [18]. However, the use of this promising innovation has not been tested in air-cooled systems yet. In contrast, the utilization of adiabatic absorbers looks like a valid choice to reduce the risk of crystallization and to keep the operation of LiBr/H<sub>2</sub>O absorption cycles simple. Additionally, adiabatic absorbers allow for a considerably reduction in the size of absorption chillers, as pointed out in different publications such as [19]. Unlike traditional falling film absorbers, in adiabatic absorbers heat and mass processes are separated. Absorption of the evaporated refrigerant takes place in an adiabatic chamber while the absorption heat is removed from the solution in a separate heat exchanger. Note that by facing the mass and heat transfer problems separately, higher improvements in both processes can be achieved.

With the aim of achieving compact absorption chambers in adiabatic absorbers, different configurations for the solution distribution have been proposed. To begin with, some authors like [20] or [21] suggested the solution atomization to increase the vapor-solution interface area and therefore enhance the absorption process. The spray absorber developed and patented by Ryan [20] presented the following drawbacks, according to the inventor himself:

low liquid flow rates, calling for many sprayers and great absorber volumes; variable droplet diameter and significant proportion of droplets under 150  $\mu\text{m}$ , which means that a considerable part of the pumped solution is of no use for absorption purpose; important head loss and high pumping consumption. Aiming at solving these problems, a new spray absorber with 400- $\mu\text{m}$  diameter was proposed by [21]. This new approach was reported to deliver high mass transfer than Ryan's spray and multiplied the performance of commercial falling film absorbers by about fourfold.

However, in [22] it was reported that energy consumed in those spray absorbers is relatively high. The authors of that paper experimentally proved that films falling along sloping ramps is a more adequate configuration as any artificially generated pressure difference is needed, but it requires large absorption chambers. In [23] it was reported that conical liquid sheets can considerably scale down the absorber chambers, nevertheless, at the cost of consuming about 5 or 6 kJ of mechanical energy per kg of absorbed vapor. Lastly, the experimental investigation carried out in [24] demonstrated flat-fan sheets configuration performs better than falling film and spray absorbers. Thus, it was reported that this configuration allows for mass transfer coefficients about five times greater than the Warnakulasuriya and Worekx proposal [21]. Besides, although the rate of vapor absorbed per absorption chamber volume is slightly lower than for conical sheets, the energy demanded is much lower, around 1.5 kJ per kg of absorbed vapor.

To summarize, the use of flat-fan sheet sprayers can be regarded as a very adequate configuration for LiBr/H<sub>2</sub>O air-cooled adiabatic absorbers. It enables a reasonably high rate of vapor absorption per chamber volume and, what is more, with a comparatively low demand of mechanical energy. On these grounds, the "Energy Saving and Emissions Reduction in Buildings" research group, sponsored by the Eduardo Torroja Institute for Construction Science (CSIC), patented a new absorber-evaporator assembly to efficiently operate at air-cooling conditions with LiBr/H<sub>2</sub>O, [25]. It essentially consists of an adiabatic absorber with flat-fan sheets configuration which is assembled together with a falling film evaporator.

Download English Version:

<https://daneshyari.com/en/article/243201>

Download Persian Version:

<https://daneshyari.com/article/243201>

[Daneshyari.com](https://daneshyari.com)