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# Exergetic analysis of a double stage LiBr–$H_2O$ thermal compressor cooled by air/water and driven by low grade heat

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**Abstract**

In the present paper, an exergetic analysis of a double stage thermal compressor using the lithium bromide–water solution is performed. The double stage system considered allows obtaining evaporation temperatures equal to 5 °C using solar heat coming from flat plate collectors and other low grade thermal sources. In this study, ambient air and water are alternatively used as cooling fluids without crystallization problems up to condensation–absorption temperatures equal to 50 °C. The results obtained give the entropy generated, the exergy destroyed and the exergetic efficiency of the double stage thermal compressor as a function of the absorption temperature. The conclusions obtained show that the irreversibilities generated by the double stage thermal compressor will tend to increase with the absorption temperature up to 45 °C. The maximum value corresponds to 1.35 kJ $kg^{-1}K^{-1}$. The entropy generated and the exergy destroyed by the air cooled system are higher than those by the water cooled one. The difference between the values increases when the absorption temperature increases. For an absorption temperature equal to 50 °C, the air cooled mode generates 14% more entropy and destroys 14% more exergy than the water cooled one. Also, the results are compared with those of previous studies for single and double effect air cooled and

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water cooled thermal compressors. The conclusions show that the double stage system has about 22% less exergetic efficiency than the single effect one and 32% less exergetic efficiency than the double effect one.


*Keywords:* Double stage thermal compressor; Low-grade heat; Entropy generated; Exergy destroyed; Exergetic efficiency

## 1. Introduction

Cooling through absorption cycles has been traditionally considered one of the most desirable applications for residual and renewable energy sources. In the same way, the ability to use low grade heat, such as that obtained from fuel cells and residual heat from engines, is a strong reason for using absorption machines. Some fuel cells employ the mechanism where hydrogen is separated from methane, and then the hydrogen is ionized and reacts with oxygen, producing an electric current and water vapor. This water vapor, at a temperature of about 60–85 °C, can be used to feed a single effect absorption cooling cycle. Other facts, as independence from electric grids, reduction of $CO_2$ emissions and use of natural refrigerants, contribute to increase the attractiveness of absorption refrigeration systems.

The interest in absorption refrigeration systems operated with low temperature heat has increased considerably in the last years [1–4]. Lamp and Ziegler [5] reviewed the European efforts in this direction for solar air conditioning applications and highlighted the most outstanding ideas and experiences. They emphasize in their conclusions that remarkable advances are needed in absorption technology.

Alternatives for using low temperature heat sources imply necessarily the use of absorption systems able to work with low grade heat, i.e. with temperatures lower than 90 °C. To take advantage of this heat at high condensation temperatures, advanced multistage absorption cycles should be adopted. These cycles have lower COPs than standard ones but allow operation with generation and condensation temperatures within the indicated limits [6].

Some experimental and theoretical works related to the use of low temperature heat using double stage absorption systems include the works developed by Arzoz et al. [7], Venegas et al. [8], Medrano et al. [9], Schweigler et al. [10], Lamp et al. [11] and Ziegler and Riesch [12]. Recently, Sumathy et al. [2] reported the successful operation of a double stage absorption cycle for solar air conditioning employing LiBr–$H_2O$ as the working pair, feeding the generators with hot water at temperatures ranging from 60 to 75 °C. Also, in a recent paper of Kim and Machielsen [13], the authors conclude that single stage systems can yield higher average cooling efficiency than double stage systems only with a vacuum tube collector or its comparable types. Further, they recommend a low cost double stage chiller for use with flat plate collectors.

The final absorption temperature of air cooled systems is higher than that of similar water cooled ones. As result, the temperature of the heat source driving the absorption machine is higher, decreasing the contribution of the low temperature heat source. An entropic balance taking into account the entropy generation between internal fluids and between these and the external fluids is also useful. However, there is little bibliography on the irreversibilities generated, which can only be evaluated on the basis of the second law. Some works analyzing this problem include