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# Dynamic testing and modeling of a diffusion absorption refrigeration system

*Radhouane Ben Jemaa* *, *Rami Mansouri*, *Ahmed Bellagi*

*U.R. Thermique et thermodynamique des procédés industriels, Ecole Nationale d'Ingénieurs de Monastir, ENIM, University of Monastir, Av. Ibn Jazzar, Monastir 5060, Tunisia*

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ABSTRACT

This paper presents experimental investigations and modeling in dynamic or transient mode of a commercial diffusion-absorption refrigerator powered by an electric heater. The instantaneous cooling capacity is experimentally determined for different electric heater inputs. A first order transfer function with delay is found to be an adequate model of the refrigerator behavior for each heat input. The fitting quality of the model ranges between 93% and 97%. The three parameters of the model are expressed in a further step as functions of energy input to the machine in order to construct a generalized model for the machine. The steady state performances of the refrigerator are quite good predicted, with deviations in cooling capacity not exceeding 8%. The proposed generalized model could be very useful for the prediction of the transient behavior of the commercial diffusion-absorption refrigerator.



# Essai dynamique et modélisation d'un système frigorifique à diffusion-absorption

*Mots clés :* Froid par diffusion-absorption ; Modélisation dynamique ; Modèle de boite noire ; Fonction de transfert

## 1. Introduction

The diffusion absorption technique for producing cold has been proposed in 1928 by the two Swedish engineers Von Platen and Munters (1928). In this uniform pressure refrigerator, ammonia is used as refrigerant, water as absorbent and hydrogen as inert gas to equalize the pressure. Fig. 1 shows the constituting elements of a modern version of this kind of refrigerator (Ben Jemaa et al., 2008), incorporating an insulated gas heat exchanger between absorber and evaporator. Since the time of this invention, numerous researchers have tried to improve the performances and reduce the response time of these machines. Many aspects were discussed such as the mechanical design of the various components of the unit, the thermodynamic cycle and the nature of the working fluids. Kouremenos and Stegou-Sagia (1988) examined the possibility of using helium instead of hydrogen as inert gas. They found that this

* *Corresponding author.* U.R. Thermique et thermodynamique des procédés industriels, Ecole Nationale d'Ingénieurs de Monastir, ENIM, University of Monastir, Av. Ibn Jazzar, Monastir 5060, Tunisia. Tel.: +216 23 582 003; Fax: +216 75 650 534.

*E-mail address:* r_bjemaa@yahoo.fr (R. Ben Jemaa).

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**Nomenclature**

| | |
|---|---|
| $E(t)$ | unit step function |
| $G_R$ | transfer function |
| $K_p$ | static gain |
| Q | heat transfer rate [W] |
| s | Laplace variable |
| T | temperature [K] |
| t | time [s] |
| $T_d$ | time delay [s] |
| $T_p$ | time constant [s] |
| U, Y | Laplace transform of input and output |
| (UA) | heat exchanger capacity [W $K^{-1}$] |
| W | heating power [W] |

*Subscripts*

| | |
|---|---|
| *cab* | refrigerator cabinet |
| *elec* | electric |
| *ext* | exterior |
| *f* | cooling |
| $f\infty$ | generalized model in steady-state |
| $fw\infty$ | relative model in steady-state |
| *int* | refrigerator interior |

gas behaves in a similar manner as hydrogen. Chen et al. (1996) improved by 50% the coefficient of performance of the DAR by modifying the design construction of the generator by integrating a tube in tube solution heat exchanger in the generator. Vicatos (2000) studied experimentally a modified domestic DAR in order to reduce the response time of the system. Srikhirin and Aphornratana (2002) developed a mathematical model of a DAR working with the ternary system ammonia/water/helium. The performance of the bubble pump was obtained from a separate experiment. The model was validated experimentally. Zohar et al. (2005) also developed a thermodynamic model of a DAR with which they performed a parametric study that shows that the best performances would be obtained with an ammonia mass concentration of 30% for the rich solution and 10% for the weak solution. They also found that the *COP* of an optimized system with helium as inert gas is 40% higher than that of the conventional machine. Ben Ezzine et al. (2010) investigated the feasibility of a DAR operating with the working

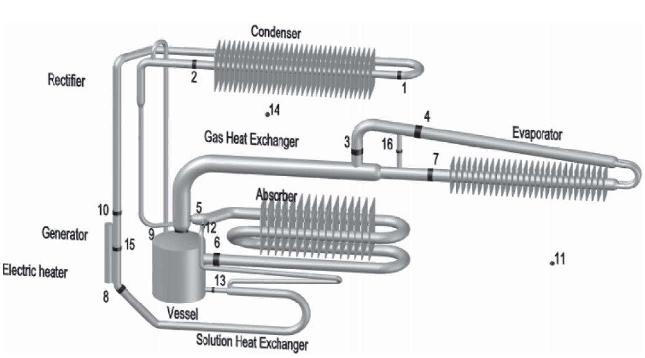


**Fig. 1 – Schematic representation of the diffusion-absorption refrigerator with locations of thermocouples.**

fluid system DMAC-R124-He and coupled to a solar collector. They showed that the *COP* and the produced cold temperature depend largely on the effectiveness of the absorber and on the generator temperature. For solar applications, the considered fluid mixture might be an alternative to conventional water–ammonia–hydrogen system. In reference Sayadi et al. (2013) presented a HYSYS simulation model for a water-cooled DAR using different binary mixtures of light hydrocarbons ($C_3$/*n*-$C_6$, $C_3$/cyclo-$C_6$, $C_3$/cyclo-$C_5$, propylene/cyclo-$C_5$, propylene/i-$C_4$, propylene/i-$C_5$) as working fluids and helium as inert gas. The generator heat is assumed to be provided by evacuated tube solar collectors. The most appropriate binary mixture is found to be ($C_3$/*n*-$C_6$) with a generator temperature of 126°C. Starace and De Pascalis (2013) incorporated a domestic magnetron to activate the bubble pump, thus reducing the start-up time of the refrigerator. Mazouz (2014) and Mazouz et al. (2014) studied experimentally a commercial absorption refrigerator in order to determine its performances under various operating conditions and established a theoretical simulation model in steady state mode, for various DAR system configurations. Recently, Rodriguez-Munoz and Belman-Flores (2014) presented a review of 70 publications about DAR technologies. Starace and De Pascalis (2012) and Starace et al. (2015) provided a thermodynamic model and a parametric study of the DAR cycle without any assumption regarding the purity of the refrigerant. It is found to give a better prediction of the real operation of the refrigerator. Ersoz (2015) investigated experimentally the effect of three different generator heat inputs (62, 80 and 115 W) on the energy performance of the DAR.

Most of the work on diffusion absorption refrigerators reported in the literature involves thermodynamic modeling associated with or not to experimental tests. However, few research have been performed on theoretical and practical investigations of the dynamic behavior of this type of machine. The present paper is a contribution to this neglected field. Its objective is to model the dynamic behavior of an absorption diffusion refrigerator and contribute to develop a methodology for the investigation of the transient behavior of this kind of refrigerator. The low coefficient of performance and the large response time are among the problems of these units. Dynamic modeling might be useful in investigating the start-up of the machine, developing control schemes and in optimizing the system design for better performances.

## 2. Dynamic models

Dynamic models describe the time evolution or transient behavior of the unit (start-up, shutdown). They can be obtained by either a theoretical approach based on physical laws, or an experimental approach based on measurements. The most intuitive approach to model a system is perhaps the physical one – called white box modeling. For this purpose, it is assumed that one has a detailed knowledge of all the processes taking place in the system and can describe them with the adequate equations and assign values to all the parameters in these equations. Black box or empirical modeling is an opposite approach basing on a set of methods to model a system without the need of any physical insight. The purpose is to find