Chapter 2

The Diffusion Absorption Refrigerator Operation and Performance

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ABSTRACT

This chapter focuses on the Diffusion Absorption Refrigerator (DAR) cycle and describes a new advanced thermodynamic model which allows good predictions of the chiller performance in terms of efficiency and cooling capacity, starting from a precise evaluation of the thermo-physical properties of the working mixture at each point of the circuit. A steady state thermodynamic analytical model of the thermal pump driving the DAR is also included. In addition, the experimental validation of the model, performed on a prototype built coupling a domestic 750 W-magnetron with a small purposely modified commercial DAR to activate the thermal pump, is here included: a maximum mismatch of 2.32% in the weak mixture mass flow rate and lower than 5% in COP between the predicted and measured data were found.

THE DIFFUSION ABSORPTION REFRIGERATOR CYCLE FUNDAMENTALS

The Diffusion Absorption Refrigerator (DAR) cycle was introduced by Von Platen and Munters (1928) and uses a binary mixture of ammonia (refrigerant) and water (absorbent) as working fluids in solution with either hydrogen or helium as auxiliary inert gas. The latter plays its role to reduce the partial pressure of the refrigerant in the evaporator according to Dalton’s law and to allow the fluid to evaporate and to produce the cooling effect.

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The main characteristic of the DAR is of having no moving parts: a thermally driven pump (also referred to as the thermal pump) acts to circulate the fluid instead of a mechanical device. Therefore, the refrigerator is also both reliable and quiet. Nowadays, it is commercially available only in small cooling capacities up to 100 W where heat is supplied to the thermal pump by electrical heating cartridges or natural gas burners. Due to the noiseless operation and to the possibility of using natural gas as a source of energy, the system is nowadays used as hotel and domestic refrigerator, portable freezer and ice-maker, caravan and boat coolbox, wine cellar and so on.

The cycle can be described (Figure 1) starting from the thermal pump, where the heat power $\dot{Q}_H$ is supplied to the strong mixture to reach the state 2. The hot refrigerant and absorbent vapor mix arises in the riser tube and, at point 4, is separated from the remaining weak liquid mixture that returns through the shell of the riser tube (state 3). The vapor at state 5 goes through the rectifier and is cooled down to separate most of the absorbent fluid. The remaining near-pure ammonia vapor at state 6 moves towards the condenser where condenses (7). Then it flows to the evaporator entrance (9) after a cooling in the gas heat exchanger (also named as the gas HX). The uncondensed refrigerant flows to a reservoir through the gas bypass. At the evaporator entrance, the liquid refrigerant reduces its partial pressure as it mixes with the auxiliary inert gas arriving from the absorber through the gas HX. The resulting mixture leaves the evaporator and the following pre-heating in the gas HX allows the refrigerant to become a saturated vapor (state 10). Then, the gas and vapor mixture passes through the reservoir, entering the absorber coil from the bottom by flowing upward in a counter-current arrangement to the weak mixture, that enters the absorber coil from the top (state 8) through the liquid mixture heat exchanger (liquid HX). The refrigerant vapor is absorbed in the weak mixture. The resulting strong mixture flows to the reservoir. Then it leaves the reservoir (11) towards the thermal pump. The inert gas is not absorbed and returns to the evaporator.

The cycle here described makes the DAR small and simple to be built (no particular manufacturing technologies have to be used), but not really efficient with very low COPs (defined as the ratio between the cooling power removed at the evaporator and the heat power supplied to the thermal pump) and, therefore, with high energy consumptions. This is mainly due to:

- The presence of the auxiliary gas inside the evaporator, that reduces the refrigerant mass flow rate evaporating and thus the cooling capacity;
- The rectifier, which dissipates towards the ambient a not negligible amount of the supplied heat.

The above issues explain the reason why the DAR cycle is widely employed in the refrigeration and not in the HVAC applications; here single and double stage absorption systems filled either with water and lithium bromide, or ammonia and water as working mixtures are the most appropriate and provide the highest performance and efficiencies.

OVERVIEW

This chapter contains a review of the state of the art and the research lines about the DAR technology as well as a description of the latest results found by the authors, in order to create an up-to-date and complete source of information and knowledge about the DAR.