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Single-effect absorption refrigeration cycle boosted with an ejector-adiabatic absorber using a single solution pump

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ABSTRACT

This paper presents a numerical model of a single-effect absorption refrigeration cycle incorporating a triple purpose liquid–vapor ejector acting as pressure booster for refrigerant vapor, adiabatic absorber and controlled solution expansion valve. The promising ammonia-lithium nitrate solution is selected as working pair, being able to produce cold at subzero temperatures, thus valid either for air conditioning or industrial refrigeration. With the use of the liquid–gas ejector, the absorption pressure becomes higher than the evaporation pressure, besides recovering part of the solution pump energy. Results of the simulation show that this innovation behaves like a compressor boosted hybrid cycle without carrying its complexity. It allows decreasing the activation temperature (about 15 °C for a recirculation ratio of 3) and increasing the cooling capacity (reaching a gain of about 100% for a generation temperature of 80 °C).

Cycle frigorifique à simple effet à absorption augmenté par un absorbeur à éjecteur adiabatique utilisant une pompe à solution unique

Mots clés : Cycles hybrides à absorption ; Nitrate de lithium-ammoniac ; Refroidissement ; Ejecteur diphasique ; Absorbeur adiabatique ; Refroidissement solaire

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Nomenclature

A	area, m^2
d	diameter, m
COP_T	thermal coefficient of performance
COP_E	electrical coefficient of performance
h	specific enthalpy, J kg^{-1}
$\dot{m}$	mass flow rate, kg s^{-1}
P_1	condenser-generator pressure, Pa
P_4	evaporator pressure, Pa
P_{abs}	absorber pressure, Pa
pr	ejector pressure ratio: P_5/P_4
$\dot{Q}$	thermal power, W
Q	volumetric flow, m^3 s^{-1}
rr	recirculation ratio
T	temperature, °C
T_c	condensation temperature, °C
T_e	evaporation temperature, °C
U	global heat transfer coefficient, W m^{-2} K^{-1}
V	velocity, m s^{-1}
$\dot{W}_p$	pump power, W
X	ammonia mass fraction

Greek:

α	ratio of ammonia absorbed in the mixing tube
ρ	density, kg m^{-3}
η_D	ejector diffuser efficiency
η_{hyd}	pump hydraulic efficiency
η_M	ejector mixing efficiency
η_{emec}	electro-mechanical pump motor efficiency
η_N	ejector nozzle efficiency
ω	ejector mass flow ratio: $\dot{m}_r/\dot{m}_{10}$
ϕ	ejector volumetric flow ratio: Q_r/Q_{10}

Subscripts:

1,2, …	cycle locations, see Fig. 1
a	absorber
bo	boiling
c	condenser
col	vapor cooling
D	ejector diffuser outlet
e	evaporator
eq	equilibrium
g	generator
i	inlet
M	ejector mixing tube outlet
N	ejector nozzle outlet
o	outlet
r	refrigerant
rr	recirculation ratio
she	solution heat exchanger
sol	solution
sub	sub-cooling
sup	super-heating
tp	two-phase

1. Introduction

The diabatic absorber is currently the largest size element of absorption single-effect machines due to transferring heat and mass at the same time, using a two-phase flow configuration, Herold et al. (1996). In contrast, the adiabatic absorber separates the processes of heat and mass transfer, Ryan (1993). The absorption heat evacuation occurs in a conventional single-phase heat exchanger (sub-cooler), which allows reducing its size and cost as well, as it can be a commercial standard model. Therefore, the plate heat exchanger technology with adiabatic absorber seems to be an enabling factor for reducing the size and cost of the absorber, Flamensbeck et al. (1998).

In the adiabatic absorber, as the absorption heat is not evacuated, the usual diabatic equilibrium cannot be reached inside this single-pass absorber, Ventas et al. (2010a, b); instead, the equilibrium is at a higher temperature, thus with less refrigerant absorbed. Hence, externally recirculating and sub-cooling the poor in refrigerant solution more refrigerant vapor can be absorbed in successive passes. A second low-head pump, in addition to the main solution pump, can provide this recirculation. In small capacity chillers, this could in

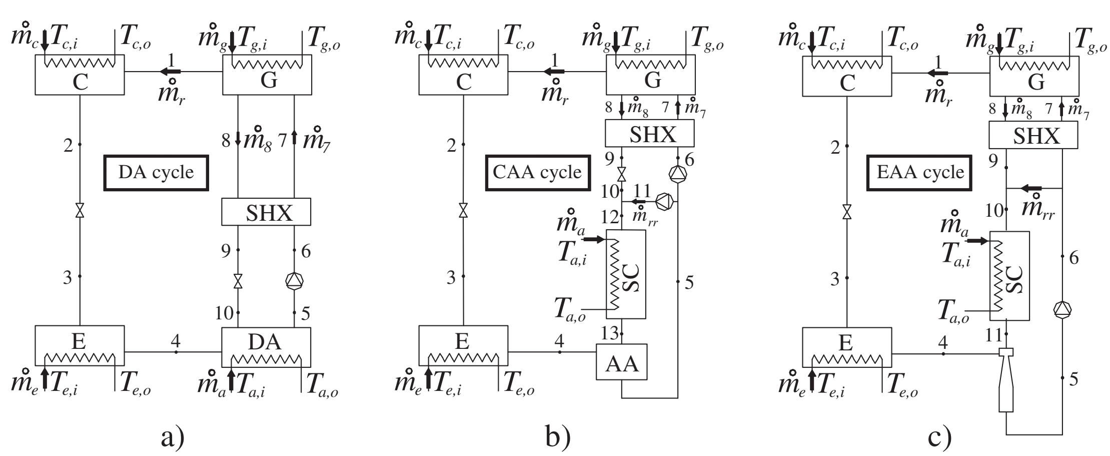

Fig. 1 – Layout of single-effect absorption cycles: a) with diabatic absorber (DA), b) with conventional adiabatic absorber (CAA) and c) with ejector-adiabatic absorber (EAA). Components legend: evaporator (E), condenser (C), generator (G), solution heat exchanger (SHX), sub-cooler (SC), diabatic absorber (DA) and adiabatic absorber (AA).