Available online at www.sciencedirect.com
SCIENCE DIRECT®
Applied Thermal Engineering 26 (2006) 288–294
APPLIED THERMAL ENGINEERING
www.elsevier.com/locate/apthermeng

Cooling performance and energy saving of a compression–absorption refrigeration system assisted by geothermal energy

L. Kairouani *, E. Nehdi

Unité de Recherche Energétique et Environnement, Ecole Nationale d'Ingénieurs de Tunis, BP 37, Le Belvédère 1002, Tunisia

Received 14 June 2004; accepted 1 May 2005
Available online 1 July 2005

Abstract

The objectives of this paper are to develop a novel combined refrigeration system, and to discuss the thermodynamic analysis of the cycle and the feasibility of its practical development. The aim of this work was to study the possibility of using geothermal energy to supply vapour absorption system cascaded with conventional compression system. Three working fluids (R717, R22, and R134a) are selected for the conventional compression system and the ammonia–water pair for the absorption system.

The geothermal temperature source in the range 343–349 K supplies a generator operating at 335 K.

Results show that the COP of a combined system is significantly higher than that of a single stage refrigeration system. It is found that the COP can be improved by 37–54%, compared with the conventional cycle, under the same operating conditions, that is an evaporation temperature at 263 K and a condensation temperature of 308 K.

For industrial refrigeration, the proposed system constitutes an alternative solution for reducing energy consumption and greenhouse gas emissions.

Keywords: Absorption system; Ammonia–water; Combined system; Geothermal energy; Refrigeration system

1. Introduction

Geothermal energy, solar energy and waste heat have immense application potential for production of refrigeration through combined vapour compression–absorption systems.

The aim of this work is to develop a novel cycle where geothermal energy assists a simple vapour compression system, and to discuss the thermodynamic analysis of the cycle and the feasibility of its practical development. The combined refrigeration system consists of a conventional vapour compression refrigeration system cascaded with a geothermal-driven vapour absorption system. The ammonia–water pair is selected for the absorption system and thirteen different refrigerants are evaluated to find the best candidate for the vapour compression cycle: R717, R22, R134a, R32, R123, R410a, 404a, 407c, R143a, R152a, R125, R507 and R227. In the present study the best candidate for the novel combined cycle is selected which provides the highest cycle efficiency and the lowest degree of environmental damage.

This refrigerating effect could be exploited in air-conditioning, ice production, storage of agricultural produce and fishery products.

2. Tunisian geothermal resources

Several investigating works were carried out in the south of Tunisia, in order to determine the physicochemical characteristics of geothermal water in that area.

* Corresponding author. Tel.: +216 71874700; fax: +216 71872729.
E-mail address: lakdar_kairouani@yahoo.fr (L. Kairouani).

1359-4311/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.applthermaleng.2005.05.001

Nomenclature

COP	coefficient of performance
C_P	specific heat, J kg^{-1} K^{-1}
f	strong solution circulation
h	specific enthalpy, J kg^{-1}
m	mass flow rate, kg s^{-1}
P	pressure, Pa
Q	heat flow rate, W
T	absolute temperature, K
x	concentration fraction of the ammonia in liquid form, kg kg^{-1}
x'	concentration fraction of the ammonia in vapour form, kg kg^{-1}
W_e	compressor electrical consumption, W
ΔP	pressure difference, Pa
Δx	concentration fraction difference, kg kg^{-1}
ΔT_{pin}	pinch temperature, K

Greek symbols

η_e	electrical efficiency
η_{is}	isentropic efficiency
ρ	density, kg m^{-3}

Subscripts

a	absorber
ab	absorption system
c	ammonia condenser
cc	condenser of the vapour compression system
ev	ammonia evaporator
f	evaporator of the vapour compression system
F	geothermal source
g	generator
pp	pump
R	refrigerant in the vapour compression system
s	strong
w	weak

Geothermal wells which show the most favourable thermodynamic characteristics, such as the highest temperatures and flows, are localized in the area of Chotts: Kebili, Tozeur and El Hamma (Fig. 1). Some of these geothermal sources are mainly exploited in agriculture [1], in heating of buildings and in aquaculture [2]. In order to supply the neighbouring areas with drinking water and water for industrial use, the geothermal water of Chott Fdjej (southern Tunisia), which has a temperature above 343 K, is cooled down in cooling towers [3]. These waters are used for agricultural greenhouses and for feeding reverse osmosis plants [4].

The thermodynamic characteristics and physico-chemical proprieties of the waters are summarized in Tables 1 and 2.

The calcium carbonate deposit that follows from loss of CO_2 as water enters in contact with the atmosphere. In this study, the geothermal water will not be in direct contact with air.

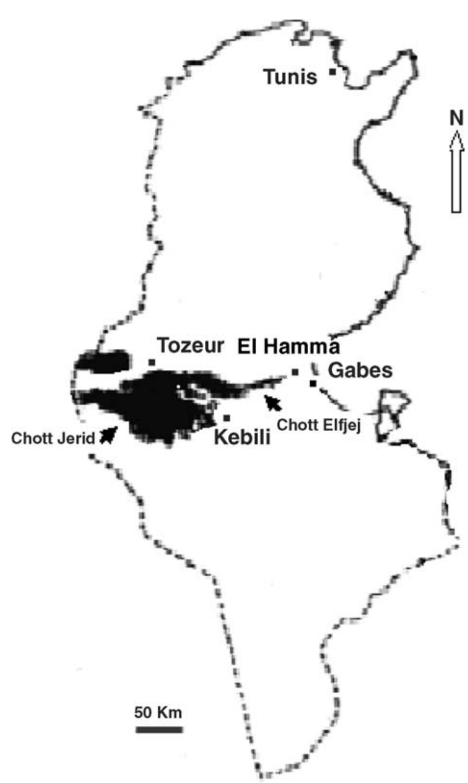

Fig. 1. Location of geothermal well (Tunisia map).

Table 1
Thermodynamic characteristics of the geothermal water

Label	Geothermal well	Location	T (K)	Mass flow rate (kg s^{-1})
1	El Mahassen	Tozeur (Hamma Djerid)	348	100
2	Debbacha	Kebili (Menchia)	344	100
3	Limaguess NCI8	Kebili	345.5	70
4	Seftimi NC17	Kebili	345.6	70
5	Zaouiet Echourfa	Kebili (Menchia)	343.2	90
6	Menchia NCI6	Kebili (Menchia)	344	70
7	Zaouia NCI5	Kebili (Menchia)	343.9	70
8	Chott Fdjej 2	El Hamma	343	70
9	Degache CI2	Tozeur (Hamma Djerid)	346	22