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Part-load characteristics of a new ammonia/lithium nitrate absorption chiller

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ABSTRACT

A pre-industrial prototype of a new water-cooled ammonia/lithium nitrate absorption chiller was characterised at part-load operation mode. The chiller was built using brazed plate heat exchangers in all its components, including the absorber and the generator.

A test campaign was carried out varying the thermal load in the chilled water circuit and keeping the hot and cooling water temperatures constant.

Part-load curves of the thermal and electrical coefficients of performance were obtained, plotted and compared with data from the literature on small capacity absorption chillers with conventional working pairs, namely ammonia/water and water/lithium bromide. The experimental results showed that to achieve a higher electrical coefficient of performance at part-load operation, it was much more convenient to use an ON-OFF control than to modify the hot water temperature. Furthermore, using a simple ON-OFF control strategy, the behaviour of the new absorption chiller was more agile and responded more quickly.

The part-load curve of the electrical coefficient of performance was obtained by adjusting the experimental data to the shape of the curve proposed in the standard prEN-14825:2011 for air-to-water chillers. The Cc coefficient was 0.7985 matching the value obtained dividing the remaining electrical consumption measured during the OFF half cycles by the total energy consumption generated.

Caractéristiques à charge partielle d'un nouveau refroidisseur à absorption ammoniac/nitrate de lithium

Mots-clés : Refroidisseur à absorption ; Ammoniac ; Nitrate de lithium ; Fonctionnement à charge partielle ; Régulation

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Nomenclature

BPHE	brazed plate heat exchanger
COP_{ther}	thermal coefficient of performance
COP_{elec}	electrical coefficient of performance
P	pressure (bar)
$\dot{Q}$	thermal power (kW)
T	temperature (°C)
PLR	part-load ratio $= \frac{\dot{Q}_C}{\dot{Q}_{EN}}$
Pw	electrical power input (kW)

Subscripts

1	inlet to the chiller (*)
2	outlet to the chiller (**)
AC	absorber/condenser
E	evaporator/evaporation
G	generator/generation
C	cooling load
hyd	hydraulic power
N	full capacity
w	water side
(*)	When not indicated, T_E denotes chilled water outlet temperature
(**)	When not indicated, T_G, T_{AC}, denote temperatures at the chiller inlet

Greek letters

$\dot{v}$	volumetric flow rate ($m^3 \cdot h^{-1}$)
ΔP	pressure drop (bar)
ΔT	temperature difference (°C)
η	pump efficiency
Π	period. Interval of time for a steady state cycle
n	number of selected periods considered for energy integration

1. Introduction

In the last 50 years there have been several studies that have analysed the control of large-scale absorption chillers (Mann and Stewart, 1963; Anderson, 1966; Ogawa et al., 1992; Yeung et al., 1992; Koeppel et al., 1995; Chow et al., 2002; Jenkins, 2003; Pérez de Viñaspre et al., 2004; Park et al., 2004). The control of these large-scale absorption chillers is usually obtained by the use of a capacity valve in the hot medium circuit.

Two variants of this control are currently the most common. The first variant consists of modulating the heat medium (usually steam or hot water) flow from 10 to 100%. The second variant is achieved by adjusting the heat medium temperature at the inlet. Either of these modulating techniques used in conjunction with internal control of solution flow rate itself achieved by variable frequency drives, enables faster chiller response time to the changing thermal load and the cooling medium conditions (Labus et al., 2012). However, recently published works (Yeung et al., 1992; Koeppel et al., 1995; Chow et al., 2002; Park et al., 2004) have also included the control of the cooling tower as a way of reducing power consumption.

In contrast to large-scale absorption chillers, which have been available on the market for a long time, the interest for small-scale absorption chillers has only recently arisen. This is due to the increasing interest in the introduction of solar cooling systems and the reduction of electricity consumption. With only a few commercial units and with scarce research done yet in this field, the control issues are still in the development phase. Most papers published are based on the results of theoretical simulations which used the characteristic equation model to estimate the performance of the absorption chiller at the different thermal conditions of the external circuits (Storkenmaier et al., 2003; Clauβ et al., 2007; Albers et al., 2008; Kühn et al., 2008).

The catalogues of the commercial units (Rotartica, 2007; Chilli, 2008; Yazaki, 2009) show that most small capacity absorption chillers are controlled by a simple ON-OFF control switch. When the absorption chiller is started up, it remains in operation as long as there is a demand for cooling. The hot water circuit pump or bypass valve is cycled ON and OFF to control the flow of the hot water supply to the generator in response to the chilled water temperature.

Lazzarin (1980, 2007a, 2007b) studied the performance at a steady state and transient state of two water/lithium bromide units of 4.5 kW and 25 kW. The chillers were equipped with a vapour-lift pump. The analysed units had an ON-OFF control that was described by the author as unsatisfactory. The system start-up time took 30 min because, until the heat energy supplied to the generator ensured the first boiling of the refrigerant and the absorption began, there was no frigorific effect, so a prolonged stop just after a start-up can waste all the heat energy supplied to the chiller. Lazzarin analysed the results at part-loads of 25%, 50% and 75% and concluded that the thermal coefficient of operation (COP_{ther}) was heavily penalized. For instance, for a test with 50% load and one cycle per hour (30 min ON and 30 min OFF), the cooling capacity was reduced by 60% and the accumulated COP_{ther} dropped by 36%, which is considered an unacceptable penalty for part-load operation. Finally as a more suitable control method, the author suggested varying the hot water flow in the generator to regulate the cooling capacity.

Didion and Radermarcher (1984) performed an experimental study on the part-load operation of a 10 kW gas-fired absorption chiller using ammonia/water as a working pair and a dry coil for dissipating the heat released in the absorber and condenser. The unit had an ON-OFF control so that during the part load tests the machine operated according to starting and stopping cycles. The data analysis technique was based on the representation of the thermal coefficient of performance (COP_{ther}) versus the part load ratio (PLR). For a PLR of 20%, the COP_{ther} was equal to 74% of the full capacity value (coefficient of degradation Cd = 0.74). The explanation for this loss in the performance was directly related to the design of the absorption machine. In the case of the machine analysed by Didion and Radermarcher (1984) the absorber was of the falling film type and it was the limiting component during the start-up phase in each ON half cycle. The explanation given by the authors was that the generator accumulated the weak solution and during the OFF half cycle this migrated back to the absorber which was flooded thus delaying the heat and mass transfer processes when a new ON half cycle was