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# Appropriate heat load ratio of generator for different types of air cooled lithium bromide–water double effect absorption chiller

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ABSTRACT

The lower coefficient of performance and higher risk of crystallization in the higher surrounding temperature is the primary disadvantage of air cooled lithium bromide–water double effect absorption chiller. Since the coefficient of performance and risk of crystallization strongly depend on the heat load ratio of generator, the appropriate heat load ratio of generator can improve the performance as the surrounding temperature is higher. The paper mainly deals with the appropriate heat load ratio of generator of air cooled lithium bromide–water double effect absorption chiller. Four type systems named series, pre-parallel, rear parallel and reverse parallel flow configuration were considered. The corresponding parametric model was developed to analyze the comprehensive effect of heat load ratio of generator on the coefficient of performance and risk of crystallization. It was found that the coefficient of performance goes up linearly with the decrease of heat load ratio of generator. Simultaneously, the risk of crystallization also rises slowly at first but increases fast finally. Consequently, the appropriate heat load ratio of generator for the series and pre-parallel flow type systems is suggested to be 0.02 greater than the minimum heat load ratio of generator and that for the rear parallel and reverse parallel flow chillers should be 0.01 higher than the minimum heat load ratio of generator. Besides, the changes of minimum heat load ratio of generator for different type systems with the working condition were analyzed and compared. It was found that the minimum heat load ratio of generator goes up with the increase of temperature of high pressure generator as well as surrounding temperature and it goes down with the rise of evaporator temperature and effectiveness of high temperature heat exchanger. The dependence of minimum heat load ratio of generator for the series and rear parallel flow system on the effectiveness of low temperature heat exchanger is weak. While the minimum heat load ratio of generator of pre-parallel and reverse parallel flow chiller rises with the increase of effectiveness of low temperature heat exchanger. The minimum heat load ratio of generator of reverse parallel flow configuration is independent upon the distribution ratio. The minimum heat load ratio of generator of pre-parallel flow system goes up fast with the rise of distribution ratio when the distribution ratio exceeds to 0.55. But the minimum heat load ratio of generator of rear parallel flow configuration just rises slightly with the increase of distribution ratio as the distribution is greater than 0.5. The paper is helpful to the development and performance improvement of air cooled lithium bromide–water double effect absorption chiller.



## 1. Introduction

Recently, the demand of air conditioning grows significantly because of the effect of global warming. However, the consequent increasing consumption of air conditioning can further worsen global warming, in turn the demand of air conditioning continues to rise inevitably. Therefore, it is urgent to reduce the consumption of air conditioning. Since the $LiBr/H_2O$ solution is nontoxic and the corresponding absorption chiller can be driven by solar energy or waste heat, the application of $LiBr/H_2O$ absorption chiller is an effective way that lowers the consumption of air conditioning. Comparing with the single effect or water cooled system, the air cooled $LiBr/H_2O$ double effect absorption chiller is better and more flexible due to the high efficient, absence of cooling tower and the independence upon water.

Although the simulation showed that the working characteristic of air cooled $LiBr/H_2O$ absorption chiller is close to the water cooled one as the solar irradiance is strong [1], the development

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**Nomenclature**

| | |
|---|---|
| COP | coefficient of performance |
| $h$ | enthalpy (kJ/kg) |
| $m$ | mass flow rate (kg/s) |
| $Q$ | energy (kW) |
| $T$ | temperature (°C) |
| $\Delta T$ | temperature difference (°C) |
| $x$ | concentration of solution |

*Greek symbols*

| | |
|---|---|
| $\alpha$ | heat load ratio of generator |
| $\varepsilon$ | heat exchanger effectiveness |

*Subscripts*

| | |
|---|---|
| $a$ | absorber |
| $c$ | condenser |
| $e$ | evaporator |
| $hg$ | high pressure generator |
| $i$ | inlet |
| $lg$ | low pressure generator |
| $o$ | outlet |
| $s$ | surrounding |

of air cooled LiBr/$H_2O$ absorption chiller is difficult due to the poor heat transfer coefficient of air. A small indirect air cooled LiBr/$H_2O$ single effect absorption chiller was firstly developed by Izquierdo et al. [2]. Nevertheless, this prototype is not compact and its performance is lower because of the complicated cooling of absorber and condenser. Hence, the direct air cooled LiBr/$H_2O$ single effect absorption chiller was developed subsequently [3]. This prototype works without the crystallization when the surrounding temperature is up to 37.7 °C [4]. The comparative test showed that the absorber temperature and the condenser temperature of direct air cooled prototype are lower than that of indirect one under the same working condition [5]. Based on the above mentioned successful development, the small air cooled LiBr/$H_2O$ double effect absorption chiller was developed as well [6]. This prototype is more compact and it can work without the crystallization as the surrounding temperature is up to 45 °C due to the better performance of new flat-sheet adiabatic absorber. Recently, a new solar air cooled LiBr/$H_2O$ double effect absorption chiller was developed by Izquierdo et al. [7]. The prototype works as the double effect cycle when the solar energy is sufficient and it can work as the single effect cycle as the solar irradiance is insufficient to drive the double effect operational mode.

The double effect LiBr/$H_2O$ absorption chiller has many different configurations and the performance of each configuration is different even the working condition is identical. For the series flow type double effect LiBr/$H_2O$ absorption chiller, it was gotten that the coefficient of performance (COP) and total heat transfer area goes down slightly with the increase of solution concentration [8]. Gomri and Hakimi [9] pointed out that the exergy loss of high pressure generator (HPG) and absorber is the highest in the series flow type double effect LiBr/$H_2O$ absorption chiller. Besides, in the series flow configuration, the pressure drop of absorber and evaporator plays an important role in the COP and exergy efficiency [10] and the relative humidity has less effect on the exergy efficiency [11]. Misra et al. [12] carried out the thermoeconomic analysis on the series flow type double effect LiBr/$H_2O$ absorption chiller and it was concluded that the variation of optimal decision variable is not sensitive to the fuel cost. For the parallel flow configuration, it was obtained that the change of distribution ratio varies the COP less [13]. It was found that the coefficient of performance (COP) of rear parallel flow configuration is more sensitive to the change of evaporator temperature [14]. In the rear parallel flow configuration, it was shown that the COP goes up but the exergy efficiency reduces with the rise of load factor [15]. The comparison of COP and exergy efficiency for different type double effect LiBr/$H_2O$ absorption chillers showed that the performance of parallel flow configuration is superior to the series flow one [16]. Moreover, it was concluded that the product cost flow rate of reverse flow type chiller is the lowest while that of series flow one is the highest by the exergoeconomic analysis [17]. For the different type air cooled LiBr/$H_2O$ double effect absorption chillers, it was obtained that the COP of pre-parallel flow configuration is the lowest under the same working condition [18].

Because of rise of absorber temperature and condenser temperature with the increase of surrounding temperature, the air cooled LiBr/$H_2O$ absorption chiller suffers from crystallization easily especially when the outdoor temperature is higher. Izquierdo et al. [19] pointed out that the double stage air cooled LiBr/$H_2O$ absorption chiller is more suitable than the single effect one as the outdoor temperature exceeds to 40 °C. A new air cooled LiBr/$H_2O$ absorption cycle which can operate without crystallization as the outdoor temperature is up to 50 °C was proposed by Kim and Infante Ferreira [20]. Han et al. [21] presented that the distribution ratio of pre-parallel flow type double effect LiBr/$H_2O$ absorption chiller should vary in term of working condition to prevent the crystallization and the suitable range of distribution ratio becomes narrow with the increase of HPG temperature, evaporator temperature and the effectiveness of solution heat exchanger. The analysis on the risk of crystallization in the double effect LiBr/$H_2O$ absorption chiller was carried out by Garousi Farshi et al. [22]. It was concluded that the rear parallel configuration and the reverse parallel configuration are more difficult to suffer from the crystallization than the series system in the same working condition.

The lower COP and higher risk of crystallization in the higher surrounding temperature is the primary disadvantage of air cooled LiBr/$H_2O$ double effect absorption chiller. The heat load ratio of generator is the important parameter to the design of area of low pressure generator (LPG). And it was found that the variation of heat load ratio of generator can significantly change the system performance [23]. Consequently, the appropriate heat load ratio of generator that maximizes the COP and still prevents the crystallization can make the air cooled LiBr/$H_2O$ double effect absorption chiller work efficiently and reliably as the outdoor temperature is higher. However, the influence of heat load ratio of generator on the system performance is not studied adequately. Furthermore, the relationship of appropriate heat load ratio of generator with the working condition is also not clear.

Therefore, the objective of paper is to obtain the appropriate heat load ratio of generator of air cooled LiBr/$H_2O$ double effect absorption chiller. Four configurations named series, pre-parallel, rear parallel and reverse parallel flow type system were considered. The corresponding parametric model was developed to investigate the effect of heat load ratio of generator on the COP and risk of crystallization. The changes of appropriate heat load ratio of generator for four type chillers were compared and analyzed. The paper is helpful to the development and performance improvement of air cooled LiBr/$H_2O$ double effect absorption chiller.