Performance Testing of a 4-bed Adsorption Chiller

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ABSTRACT

The use of waste heat of low temperatures is an important problem from the environmental considerations. Despite the advent of the micro-turbines and the fuel-cells systems, the adsorption cycles is deemed to have a distinctive advantage over these systems because of their ability to produce cooling by using low temperature waste heat and also being absolutely benign for the environment. With a novel design, the range of outlet and inlet temperatures of hot water is 80 to 50℃, respectively, where the heat recovery can be maximized. Thus, there is needed to develop such adsorption chillers for the above-mentioned objectives. The 4-bed adsorption chiller is one such chiller that can be adapted to a large heat recovery, namely a larger temperature difference as 20℃ between the heat input and outlet. In addition, the multi-bed chiller delivers a steady cooling rate at a high coefficient of performance (COP) and yet with minimal peak temperature oscillation when compared to a conventional 2-bed chiller. This paper presents the performance testing of a prototype 4-bed adsorption chiller with a cooling capacity of 5 RT when supplied with a heat source of 80℃ and an estimated cooling COP larger than 0.6.

Introduction

Conventional 2-bed adsorption chillers whose outlet chilled water temperatures with time are going down to the minimum and then gradually going up to their chilled water inlet due to the characteristics of adsorbents, and their temperature differences between heat source inlet and outlet are set to be small as 5 ℃ in order to get higher regeneration temperatures of adsorbents.

Whereas the objective of this paper is to leveling off the chilled water outlet temperature so as to generate a more stable chilled water and also is to increase the recovery efficiency of waste heat with a higher temperature difference of 15 to 20 ℃ applying for a 4-bed adsorption chiller. Our proposed machine is quite effective for combining with distributed energy sources like micro gas turbines and fuel cells to enhance an overall system performance and also reduction of CO_2 emissions.

Working Principle of 4-Bed Chiller

The proposed 4-bed chiller is an extension from the 2-bed operation. In a conventional 2-bed adsorption chiller, outlet temperatures of condenser and evaporator are changing and indicating a peak temperature during cycle times so that the obtained chilled water outlet temperature is not steady. The very peak temperatures ask for larger heat transfer surfaces. As will be demonstrated later, the 4-bed scheme will serve to leveling off the peak temperatures in both the condenser and evaporator.

Table 1 Energy utilization schedule for a 4-bed chiller over two cycles

Bed 1	sw	ads(2)	ads(1)		sw	des(2)	des(1)	
Bed-2	des(1)		sw	ads(2)	ads(1)		sw	des(2)
Bed-3	sw	des(2)	des(1)		sw	ads(2)	ads(1)	
Bed-4	ads(1)		sw	des(2)	des(1)		sw	ads(2)

Legend:
ads: adsorber
des: desorber
sw: switching from adsorber to desorber, and receiving heating from des(1) or switching from desorber to adsorber, and receiving cooling stream from ads(1)
(1): this refers to the situation when the bed receives either cooling stream from the condenser(or cooling tower in parallel) or heating stream directly from the heat source.
(2): this refers to the situation when the bed receives either cooling stream from ads(1) or heating stream from des(1).
Note: The width of each box is a not-to-scale indication of the relative time duration.

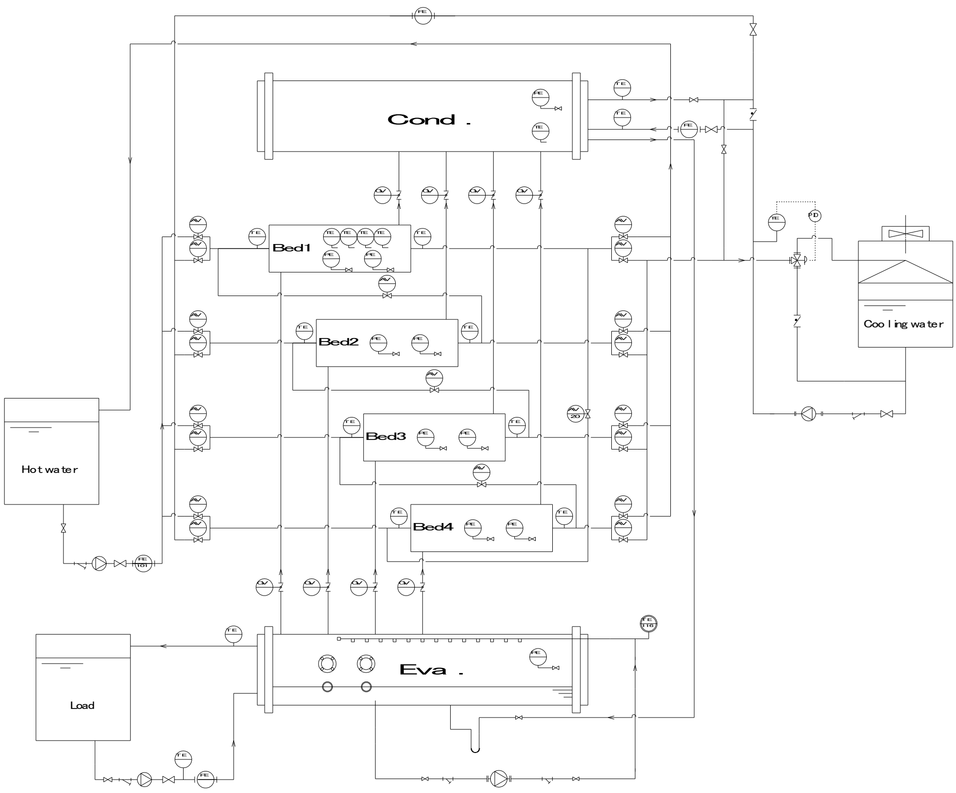

Fig. 1 A schematic flow diagram of a 4-bed chiller.

Table 1 and Figure 1 illustrate the time sequence chart of 4-bed adsorption and desorption cycle , and a schematic flow diagram of the 4-bed adsorption chiller, respectively. By capitalizing on the phase difference between the two pairs of beds, the heat source from a hotter desorber can be used to regenerate another cooler desorber for pre-heating before returning to the heat source. Similarly, the cooling water from a cooler adsorber can be used to further cool a hotter adsorber for pre-cooling and returns to a cooling tower.

It can be readily appreciated that all the beds are being used equally, unlike in a master-and slave configuration, so that there is no under-utilization of resources. The evaporator and condenser designs are identical to that of a conventional two-bed chiller.

Design Specification of The Prototype Machine

Table 2 shows the specification of a prototype machine which is expected to be installed for testing. The expected COP value is here evaluated by the simulation. Figure 2 shows a set up view of the prototype 4-bed adsorption chiller with a cooling capacity of 5RT.

Fig.2 Set up view of the prototype 4-bed adsorption chiller with a cooling capacity of 5RT.

As shown in the Figure 1 the flow diagram is planed so as to be able to operate under two operation modes for comparison, that is, a 4-bed chiller and a 2-bed chiller operations, in order to confirm the characteristics of the two modes.

Table 2 The specification of a prototype machine.

Item	Unit	
Adsorbent/refrigerant Adsorbent weight/bed	– kg	Silica-gel/water 36
Cooling capacity	RT	≒5
COP	–	≒0.6
Chilled water Inlet/outlet temperature Flow rate	 ℃ kg/s	 14.0/9.0 0.84
Cooling water inlet temp. Flow rate	℃ kg/s	31 0.8
Hot water inlet temperature Flow rate	℃ kg/s	85 0.8
Cooling water of condenser Flow rate	 kg/s	 2.1

Simulation Analysis

A simulation analysis has been carried out to predict the performance of 4-bed adsorption chiller. The values for the parameters used in the analysis is given in the Table 3, where the heat transfer surface of the adsorber is taken into total outer surfaces of copper tubes. In actual the adsorption heat exchager are composed of copper tubes and aluminum fin plates.

Table 3 The values for the parameters used in the analysis.

Heat transfer surface Adsorber Condenser Evaporator	m^2 4.5 6.0 4.0
Heat transfer coefficient Adsorber(desorption) Adsorber(adsorption) Condenser Evaporator	$W/(m^2 K)$ 1,000 1,000 3,460 2,330

Figure 3 demonstrates a typical cyclic steady state temperature profile versus time, where a cycle time is 650 sec(ad(1)+ad(2)) and Figure 4 shows its deuhring diagram, respectively. Notice that the chilled water outlet temperature in operation is quite stable.

Figure 5 demonstrates a cycle time dependency on a cooling capacity and COP.
It was confirmed that the design values were satisfied to meet the requirements of specification.

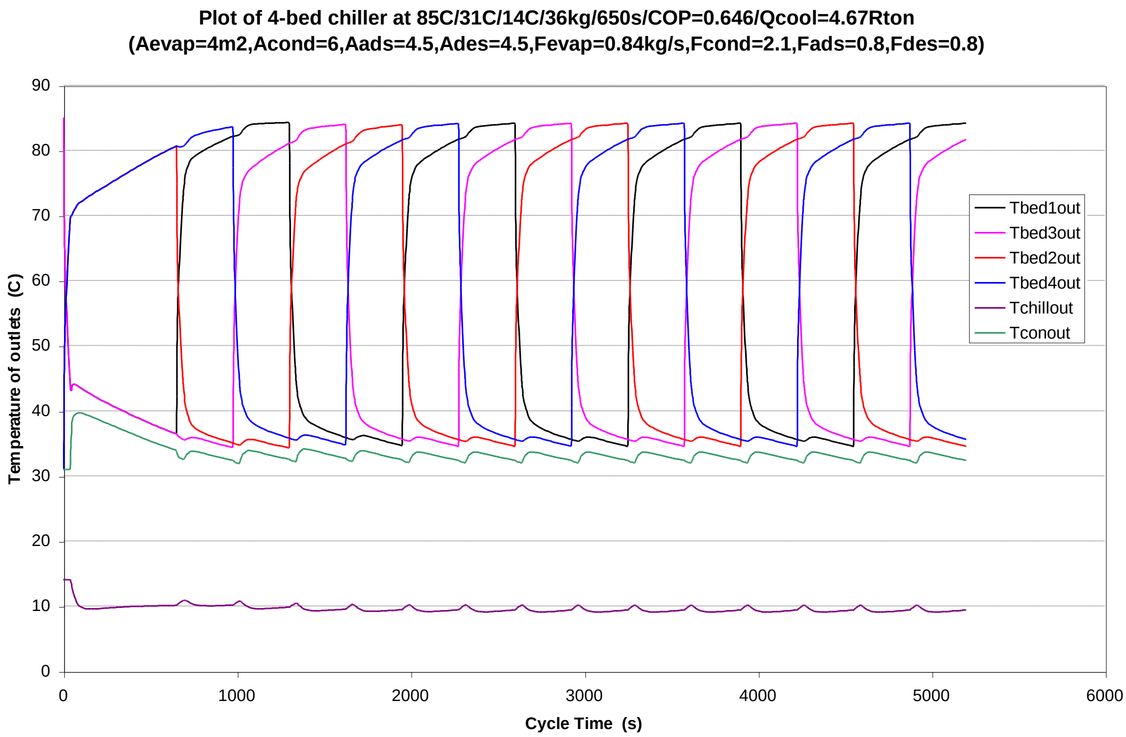

Fig.3 A typical cyclic steady state temperature profile versus time

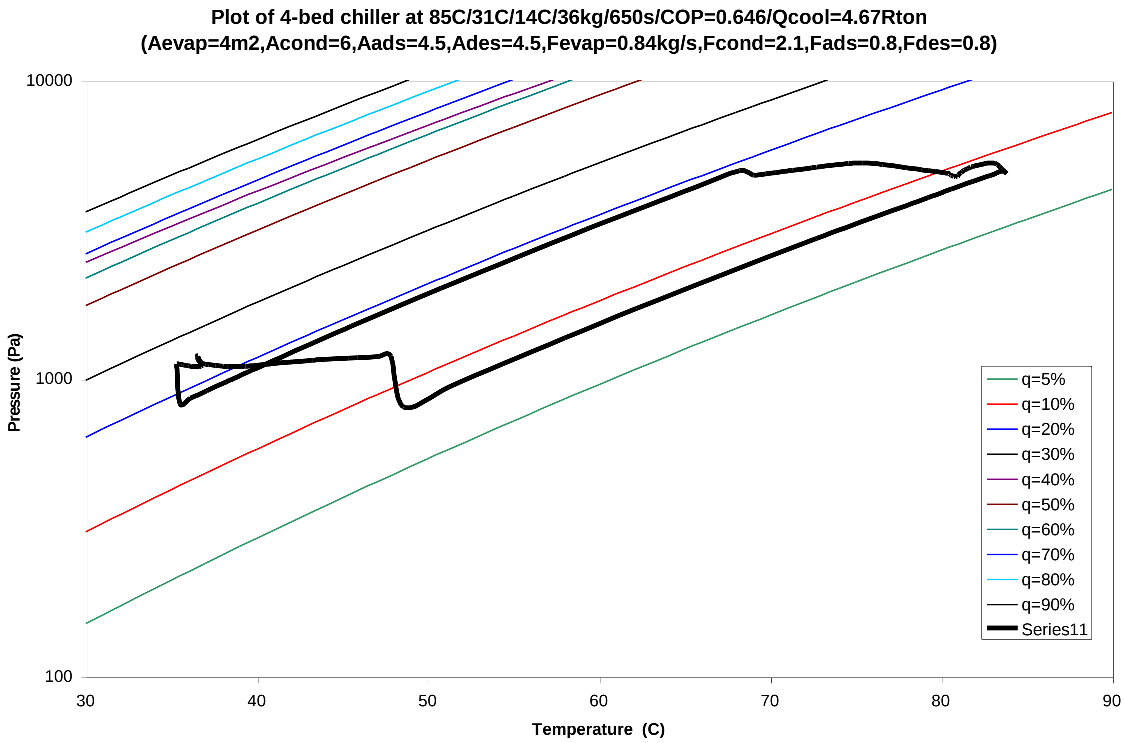

Fig.4 Deuhring diagram of 4-bed chiller .

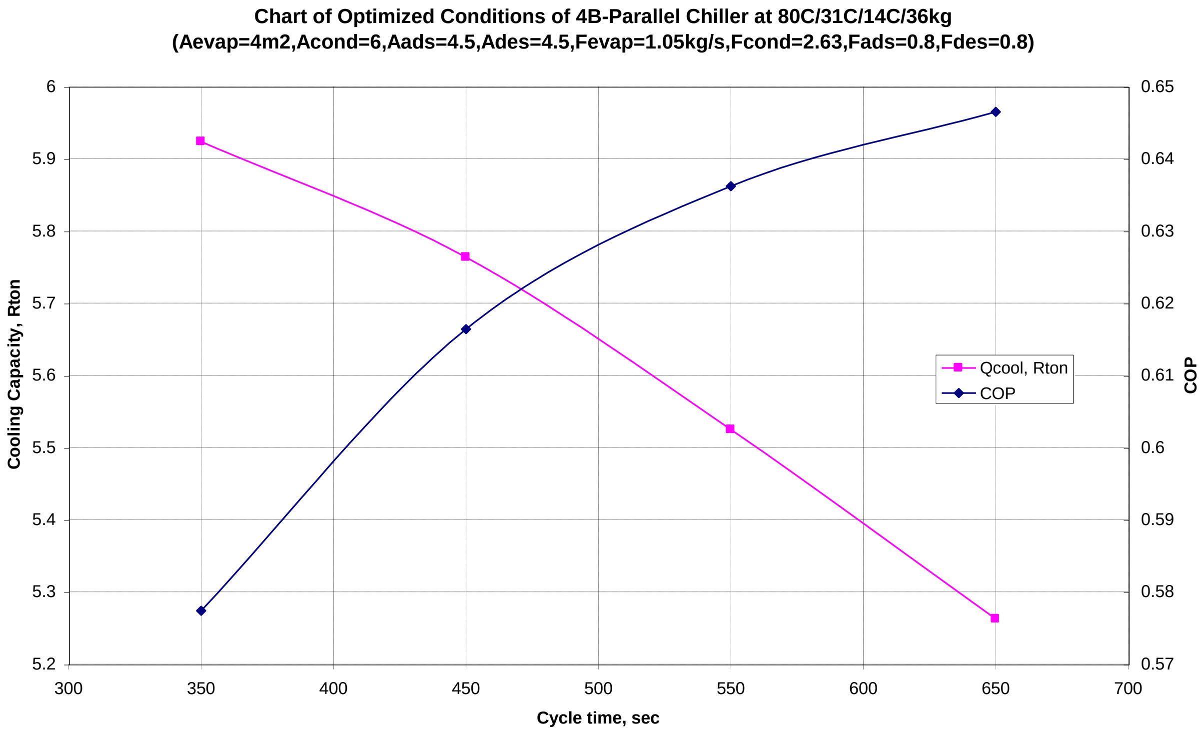

Fig.5 A cycle time dependency on a cooling capacity and COP.

Results and Discussion

The performance testing is expected to be carried out at the NUS in February. So let me discuss the tested results later.

Conclusion

In this study, the following conclusions were obtained.

1) It was found that the simulation program was quite effective to predict its performance.
2) Based on our analysis it was confirmed the design values were adequate to obtain the specified performance.
3) From the performance testing results, main features will be stated later.

Reference

H.T.Chua, K.C.Ng and et al., "A Four-bed Regenerative Adsorption Chiller" , Proc. of The ISHPC '99, Munich, Germany, March, 1999.