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A techno-economic case study using heat driven absorption refrigeration technology in UK industry

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Abstract

This paper reports a case study on a UK industry using heat driven absorption refrigeration technology. The system performance of the absorption refrigerator to recovery the industry wasted heat and economic analysis using the heat driven absorption system have been conducted. Results indicates when the evaporating temperature is 5°C , the optimal COP of the absorption chiller is about 0.825 under 60°C generator temperature and the maximum COP of the system under 10°C evaporating temperature can be as high as 0.86 with 55°C generator temperature. Under the optimal operating condition to recover 200 kWh from exhaust gases, the average required heat load of absorber and condenser are 190 kWh and 175 kWh, respectively. When the generator temperature is eat at 60°C , the cooling production from the absorption chiller is 172 W. The economic analysis suggests the average payback period to use the absorption system for UK industry application is about 2.5 years and the highest annual electricity cost saving can be as high as £105 per kw thermal heat input.

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Keywords: absorption refrigeration; techno-economic analysis; industry heat recovery

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1. Introduction

From 2015, the Department for Environment, Food & Rural Affairs in UK has introduced bans on the sale of fluorinated greenhouse gas filled equipment, and the report pointed out from 2020 the refrigerants with global warming potentials of more than 150 such as R134a, R245fa and R365mfc will be banned to be used in hermetically sealed system, which affects the utilization of the existing electricity driven compression refrigerators and raise the maintenance cost of the system [1]. Heat driven absorption refrigerator can therefore be promoted to be used as alternative refrigeration system in the place, where huge amount of heat is available, and can save the operational cost of using electricity driven refrigerator. Extensive research efforts have been focused on absorption cooling technology over the past few decades to compete this technology with vapour compression system through the development of energy efficient, cost effective, environmentally friendly and compact size systems [2-5]. Florides et al. [3] reports the experimental study of a 1kW absorption chiller using LiBr-H2O and the COP of the system is about 0.7. When the absorption refrigeration technology is used in data centers, a novel system combining an on-chip two-phase cooling system and an absorption refrigeration system can potentially meet the cooling demands with 4-5 months payback period as reported by Ebrahimi et al. [4]. The optimization of a LiBr-H2O absorption chiller using a Non-Liner Programming model has been introduced by Carlos et al. [5], which can be simply constructed to predict and optimise the annual operating cost of the system. Salmi et al. [6] conduct the study of using absorption chiller for ship wasted heat recovery. Results suggest the potential saving of 70% of electricity in accommodation, which enables between 47 and 95 tons of annual fuel saving [6]. The paper reports a case study using heat driven absorption refrigeration technologies in UK industry to explore the potential energy saving of using heat driven refrigerator. All the data presented in this paper are real and effective data, which are valuable for the both industry and academia to explore the market potential of using heat driven absorption refrigeration technologies in UK industry application.

2. 2. Description of a heat driven absorption chiller to recover STACK heat from a UK industry

The case study conducted in this paper is for the heat recovery from the exhaust STACK using heat driven absorption refrigeration technology. Due to the limitation of the exhaust temperature, which is only about 200°C in this UK industry case study, single effect LiBr-H2O absorption chiller has been selected to recover the wasted heat. The schematic diagram of the system for the STACK heat recovery has been illustrated in Fig. 1. A hot water loop has been used to recover the heat from the exhaust STACK, store the heat in a hot water tank and provide the heat to the generator of the absorption chiller as shown in Fig. 1. The working principle of the single effect absorption chiller can be summarised as follows

- From absorber $1 \xrightarrow{\text{pump}} 2 \xrightarrow{\text{SHE}} 3$ to Generator The weak solution has been pumps from absorber through the heat exchanger to preheat the solution before entering the generator.
- From Generator $4 \xrightarrow{\text{SHE}} 5 \xrightarrow{\text{EV}} 6$ to Absorber The strong solution containing less refrigerant (water) flows through the heat exchanger to firstly transfer the heat to weak solution and then expands in the expansion valve.
- From Generator $7 \xrightarrow{\text{Condenser}} 8 \xrightarrow{\text{EV}} 9 \xrightarrow{\text{Evaporator}} 10$ to Absorber In this process, the refrigerant (water) flows from the generator to the condenser, where dumps the heat towards environment and cools down by the cooling tower. The condensed and high pressure refrigerant (water) is then expanded from the expansion valve. The low pressure refrigerant (State 9) enters the evaporator, where adopts heat through the refrigerant evaporating process and therefore provides the cooling effect.

The absorption heat Q_{abs} from the absorber is rejects to the environment by the cooling water from the cooling tower.