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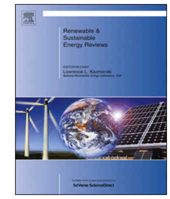

Absorption heat transformers – A comprehensive review

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ABSTRACT

In recent years, the use of absorption heat transformers (AHTs) has reached a remarkable edge. AHTs have great potential in the utilization and upgrading of low-level heat sources. These are typically waste heat obtained from industrial processes and those supplied from solar and geothermal sources. Other benefits of absorption cycles include using significantly less electricity, potentially having less CO_2 emission, causing no ozone layer depletion, and using natural refrigerants; and these contribute to increasing the attractiveness of these machines. The use of absorption heat transformers has become even more popular as the cost of fossil fuel continues to rise. In the present work, a comprehensive literature review has been carried out on AHTs, their applications, crystallization risk, working fluids, as well as performance evaluation by applying different models and economic aspects.

Contents

1. Introduction

A heat transformer is a device which can deliver heat at a higher temperature than the temperature of the fluid by which it is fed. Absorption heat transformer systems are attractive because they use waste heat from industrial processes and renewable energy sources such as solar and geothermal. In addition, they can be used to upgrade low temperature waste heat to that of higher temperatures to be employed in a secondary process. The integration of AHTs with different thermodynamic cycles plays an important role in recovering the heat rejected by them or even increasing the energy efficiency of the whole system. There is a great number of review papers about absorption refrigeration systems [1–3]; yet to the best of the authors' knowledge, there is no work on the review of absorption heat transformers (AHTs). Therefore, this review shall help in filling this gap, and this paper will discuss the major issues related to AHTs. Firstly, single and double effect absorption heat transformers will be considered. Then, applications of AHTs and the working fluids utilized in them will be reviewed. Finally, risk analysis methods for crystallization in AHTs and economic aspects will be considered.

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Principally, the absorption heat transformers can be configured to be single stage absorption heat transformers (SAHTs), double stage and double effect absorption heat transformers (DAHTs), or triple absorption heat transformer (TAHTs).

The present work will substantially review the advances in SAHTs and DAHTs in the subsequent sections. Since TAHTs have been introduced only recently, hence the references that can be found on them are limited [4].

2. Single stage AHTs

Fig. 1 shows the general schematic of the absorption heat transformer in single stage mode. The SAHT basically consists of an evaporator, a condenser, a generator, an absorber, and a solution heat exchanger (SHE). The generator and evaporator are supplied with waste heat at the same temperature, leading to increased heat that can be collected at the absorber [5]. The AHT performs in a cycle which is the reverse of that of an absorption heat pump [6].

Refrigerant vapor is produced at state 4 in the evaporator by low or medium-grade heat source. The refrigerant vapor dissolves and reacts with the strong refrigerant-absorbent solution that enters the absorber from state 10, and the weak solution returns back to the generator at state 5.

The heat released from the absorber will be higher than the input heat in generator and evaporator due to the exothermic reaction of LiBr and water in it. In the generator, some refrigerant vapor is removed from the weak solution to be sent to the condenser and, consequently, the strong solution from the generator is returned to the absorber. After condensing the vaporized refrigerant in the condenser, it is pumped to a higher pressure level as it enters the evaporator. The waste heat delivered to the evaporator causes its vaporization. Again, the absorber absorbs the refrigerant vapor at a higher temperature. Therefore, the absorption cycles have the capability of raising the temperature of the solution above the temperature of the waste heat [7].

Kurem and Horuz [6] analyzed the absorption heat transformers using ammonia–water and water–lithium bromide solutions. Their results showed that the AHT system using H_2O/LiBr solution performed better than the system using ammonia water solution. Although water–lithium bromide solution was well suited for use in AHTs, it still had some disadvantages, namely corrosion, high viscosity, limited solubility, and a practical upper temperature limit. Horuz and Kurt [8] investigated an industrial application of the AHT system to obtain hot process water. For this purpose, the industrial textile company which had waste heat sources at $90 \pm 2\,^{\circ}C$ (4×15 t/h) and required hot water for process at 120 °C was chosen. In the first case, in a basic single AHT, the waste heat was supplied to the generator and absorber at the same time (Fig. 2). The second used system had such a configuration that the waste hot water was directed first to the evaporator and then to the generator (Fig. 3). In the third system, in addition to the waste hot water configuration of the second system, an absorber heat exchanger was included instead of the solution heat exchanger (Fig. 4).

Finally, the last configuration incorporated the second and third systems with the addition of a refrigerant heat exchanger at the evaporator inlet (Fig. 5).

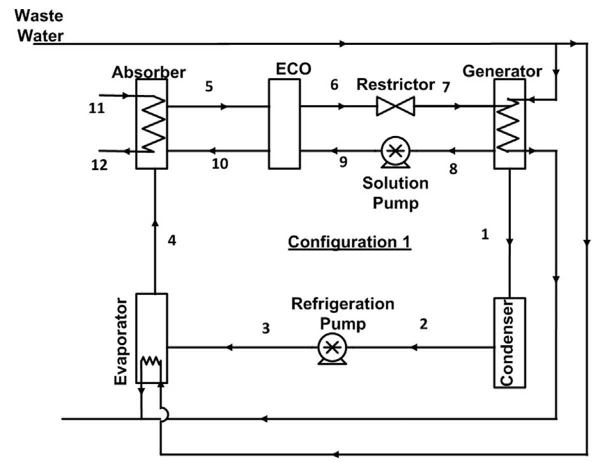

Fig. 2. Schematic diagram of SAHT (S-Type I) [8] (redrawn by authors).

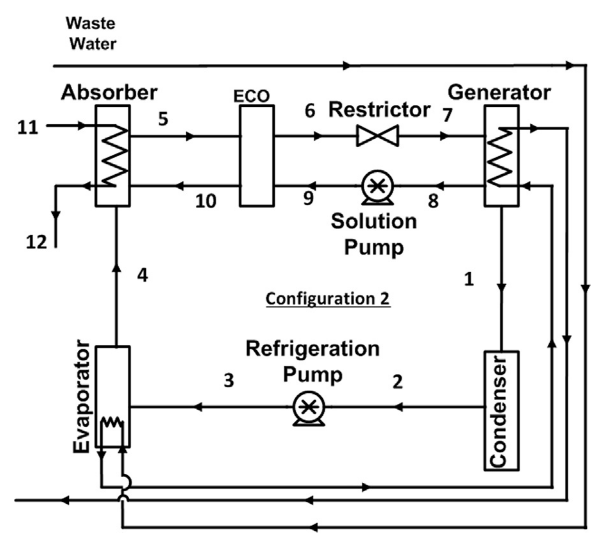

Fig. 3. Schematic diagram of SAHT (S-Type II) [8] (redrawn by authors).

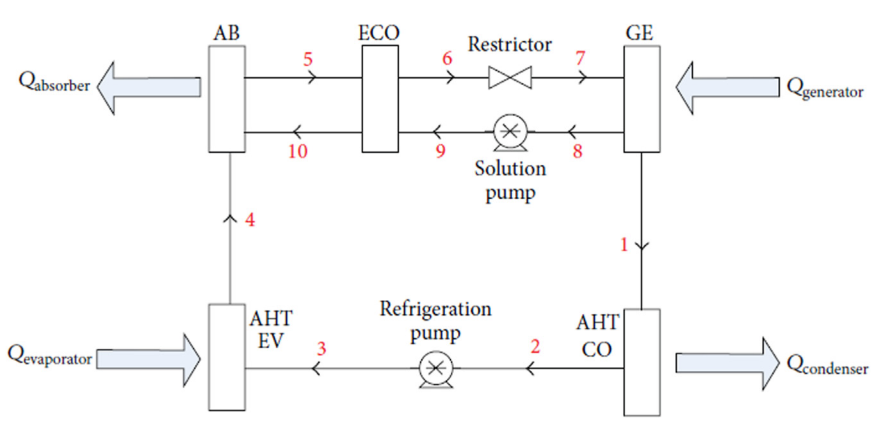

Fig. 1. Single stage absorption heat transformer [6].