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Optimal design criterion for Heat Transformer operating with Water/Carrol

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***Abstract*— This paper shows a discussion for selection of thermodynamic operating conditions in an absorption heat transformer (AHT). An AHT is the only thermal machine that increases the source temperature using heat for does it with a negligible mechanical energy. Thermodynamic parameters for AHT are the same than for heat pumps: Coefficient of performance (COP) and Gross Temperature Lift (GTL). Those parameters are not linearly correlated. Instead GTL increases its value when COP decrease. The criterion for an optimal design is based on an objective function with COP and GTL. This paper use AHT thermodynamic data operating with Carrol – water for show the best design operating conditions.**

***Keywords*— Thermodynamic design, coefficient of performance, Carrol – water, thermal machines, gross temperature lift**

I. Introduction

The revaluation of energy is an important issue in industrial sectors, as for operation requires large amounts of energy. The rest of the energy is provided by a variety of sources including nuclear energy, geothermal energy and renewable resources, in addition to the use of fossil fuels continues to cause an increase in emissions and the release of CO_2 and greenhouse effect gases (GEG) to the atmosphere [1].

Several countries are investing significant amounts in the development of equipment to facilitate recovery and efficient use of energy [3]. This is of interest in new research and techniques to improve the use of energy resources. Because of this problem has interest in new research and techniques to improve the use of energy resources, absorption cycles are an option. Thermal energy recovery cycle may be used in another process [5].

In the case of thermal energy is necessary to use technologies that enable a) efficient heat exchange to reduce consumption, b) determining the thermal behavior by modeling c) thermodynamic adjustment system components in order to achieve rational use of energy and reduction of environmental impact.

II. Description of system

A AHT basically consists of an evaporator, a condenser, a generator, an absorber and a solution heat exchanger. Fig 1 shows a schematic diagram of this absorption cycle. A constant quantity of waste heat (Q_{GE}) is added at a relatively low temperature (T_{GE}) to the generator to vaporize part of the working fluid at low pressure (P_{CO}), from the diluted salt solution, containing a low concentration of absorbent. The vaporized working fluid flows to the condenser, delivering an amount of heat (Q_{CO}) at close ambient temperature (T_{CO}). The liquid leaving the condenser is pumped, driven by a small energy power source, to the evaporator at a higher-pressure zone. The working fluid is then evaporated at high pressure (P_{EV}) using a second quantity of heat waste (Q_{EV}), which is added to the evaporator at an intermediate temperature (T_{EV}). Next, the vaporized working fluid goes to the absorber, inside of which, it is absorbed by the concentrated absorbent salt solution; this stream comes from the generator. The absorption process delivers useful heat (Q_{AB}) at a higher temperature (T_{AB}). Finally, the diluted salt solution returns to the generator, to preheat the concentrated salt solution in a heat exchanger, called "economizer", before restarting the cycle again [2].

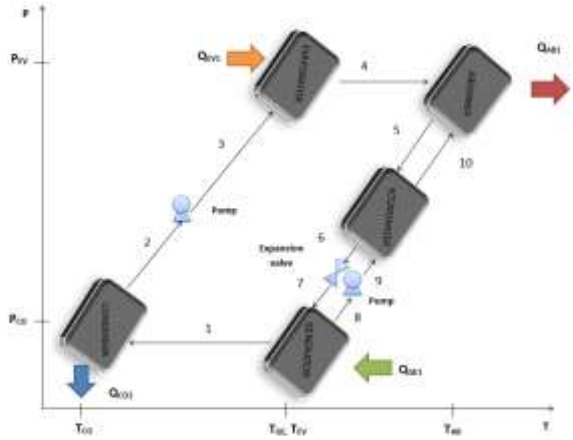

Figure 1. Schematic diagram of Heat Transformer

The water/Carrol mixture was developed by Carrier Corporation. The mixture of water /lithium bromide mixture has been the only working for AHT commercially used. However, this mixture shows a big disadvantage: the risk of crystallization for concentrations greater than 70%. The water/Carrol mixture has almost the same characteristics as the thermodynamic water /lithium bromide but has a higher solubility of about 80%. Carrol is a mixture of aqueous LiBr a crystallization inhibitor (ethylene glycol) in the ratio 1: 4.5 by weight [4].

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III. Experimental methodology

The main components of experimental AHT are all Plate Heat Exchangers (*PHE*) made of 316L stainless steel. The generator, economizer, evaporator and absorber are PHE and have 7 corrugated plates and 3 channels per pass. The condenser has 4 corrugated plates and 1 channel per pass for working fluid (water) and 2 channels per pass for water from cooling tower.

Type T thermocouples were installed to measure the input and output temperature of each component; these thermocouples have a preciśión of ± 0.5 °C for an operating range from 0 to 120 °C. Agilent data acquisition unit (6½ digits) and Agilent HP Vee Pro software are used for temperature measurement.

A. *Important parameters*

The Coefficient of Performance (COP) represents the efficiency of a SSHT. It is defined as the heat delivered in the absorber per unit of heat load supplied with the generator and the evaporator.

$$COP = \frac{Q_{AB}}{Q_{GE} + Q_{EV}} \tag{1}$$

Concentration of the mixture is an important parameter for the calculation of the effectiveness in the generator and absorber mass transfer.

The Gross Temperature Lift (GTL) is defined as the difference between the absorber temperature and the evaporator temperature:

$$GTL = T_{AB} - T_{EV} \tag{2}$$

Equations for calculating power for each of the heat exchangers shown.

Generator:

$$Q_{GE} = M_{GE,\,V1}\, H_{GE,V1} + M_{GE,S6}\, H_{GE,S6} - M_{AB,S9}\, H_{V,S9} \tag{3}$$

Evaporator:

$$Q_{EV} = M_{EV1}\,(HE,_{V4} - H_{CO,\,S3}) \tag{4}$$

Absorber:

$$Q_{AB} = M_{CO}\, H_{EV,V4} + M_{GE,\,S10}\, H_{GE,S10} - M_{AB,S5}\, H_{AB,S5} \tag{5}$$

Condenser:

$$Q_{CO} = M_{CO}\,(H_{CO,S2} - H_{GE,\,V1}) \tag{6}$$

IV. Results

As previously mentioned two important parameters are the COP and the GTL, because they are functions to maximize for greater appreciation of energy waste. In Figures 2 to 5 the analysis of the relationship of the COP shown and GTL for the four tests runs.

According to the operating conditions shown the product is observed operation coefficient and gross temperature lift.

Only the energy sector produces about two-thirds of emissions of greenhouse gases, more than 80% of world energy consumption is based on fossil fuels [6], then this optimal criterion conduct to design for recovery energy from temperatures sources since 50 °C to 80 °C at best conditions.

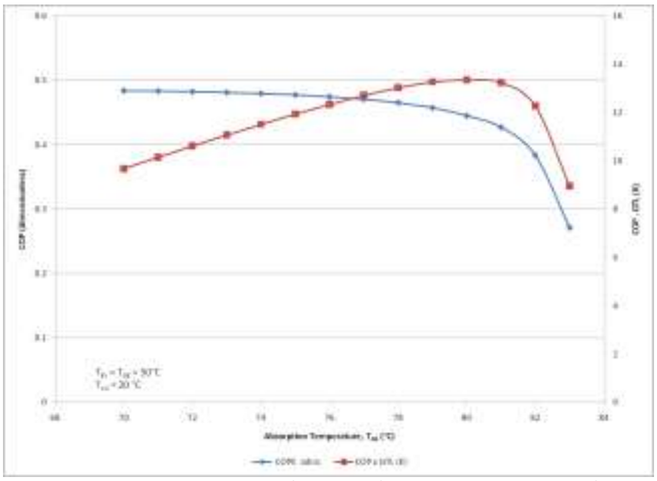

Figure 2. COP and COP.GTL as function of absorption temperature for $T_{GE} = T_{EV} = 50$ °C and $T_{CO} = 20$ °C

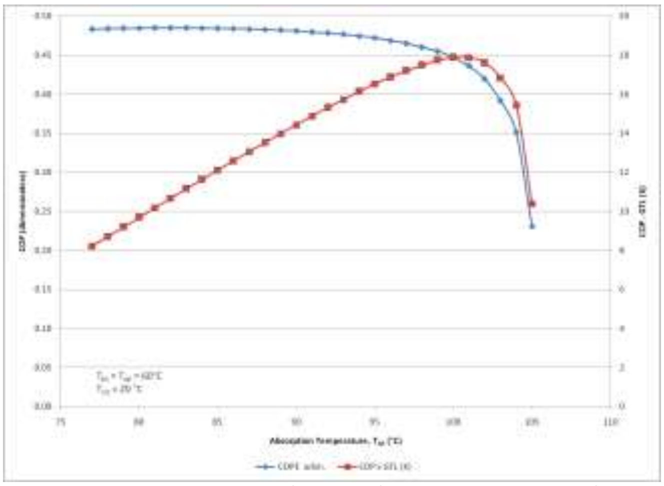

Figure 3. COP and COP.GTL as function of absorption temperature for $T_{GE} = T_{EV} = 60$ °C and $T_{CO} = 20$ °C

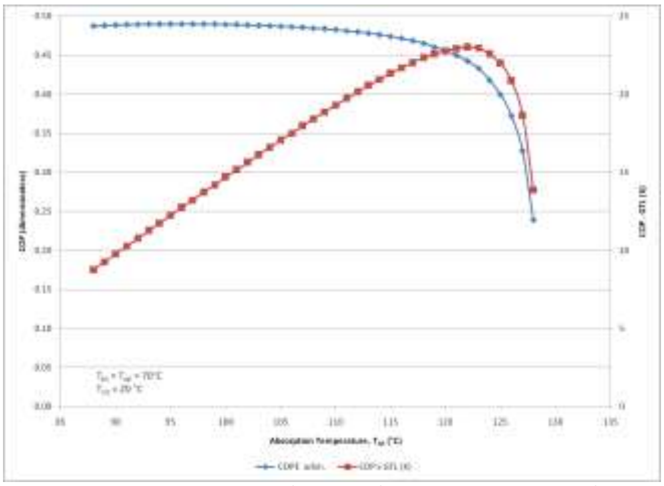

Figure 4. COP and COP.GTL as function of absorption temperature for $T_{GE} = T_{EV} = 70$ °C and $T_{CO} = 20$ °C

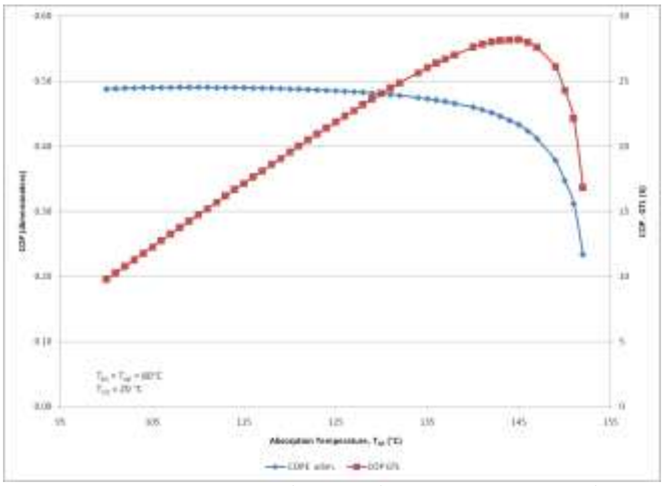

Figure 5. COP and COP.GTL as function of absorption temperature for $T_{GE} = T_{EV} = 80$ °C and $T_{CO} = 20$ °C

The surroundings affect the COP for AHT operating conditions. Considering condensation constant for the study near to ambient, the condenser temperature T_{CO} was selected at 20 °C. Figure 2 show a detailed variation from 70 °C to 83 °C in absorption temperature (T_{AB}). Non lineal behavior is exhibited for COP and COP GTL parameters. However, there are two maximum values in that figure: COP maximum value at minimum T_{AB} but COP GTL maximum value at T_{AB} equal to 80 °C. This means that the thermal machine has an optimal condition for the designing for source heat at 50 °C.

Similar to previous analysis, for Figure 3 the maximum COP has an absorption temperature equal to 82 °C; however, this is not the best operating condition, because the GTL for that is just a lift of 22 Kelvin. The best operating conditions for revalorization with heat source at 60 °C is absorption temperature at 100 °C. For this heat source, operating conditions with absorption temperature higher than 100 °C lead to lowest COP.

In Figure 4, the COP and GTL design parameter are show as function of absorption temperature. The maximum COP is located at 96 °C for heat source at 70 °C. The best operating condition for this thermal machine with $T_{CO} = 20$ °C is at T_{AB} equal to 122 °C. This conditions warranty applications beyond boiling water at standard pressure with moderate source temperatures.

Finally, there is a maximum COP for heat source at 80 °C thermodynamically at absorption temperature at 111 °C, but the best operating conditions is at 145 °C for constant condensation temperature at 20 °C. Any operating different conditions of this have lower values for GTL and COP.

V. Conclusions

Thermodynamic criterion for optimal AHT prototype design operating with water/Carrol mixture was carried out. This analysis determines the absolute conditions in which an AHT can be operate with maximum COP and maximum absorption temperature. Both parameters can maximize instead they are not independent for operating conditions with condensation temperature at constant value.

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