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First Double Stage Heat Transformer (Dsht) In Latinamerica

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In this paper the design and the thermodynamic modeling of the first system of a double stage heat transformer installed in Latin America is detailed. For the calculation of this system a ternary mixture of hydroxides has been used. This mixture is based in sodium, potassium and cesium. The considerations and assumptions for its application in industrial systems are also shown. The calculation of the system shows that it is possible to recover more than 25% of energy of industrial waste and to upgrade it 50 °C higher than energy source. The theoretical results are shown in form of graphics and they are compared with a single stage system. Both systems have settled and tested in the Applied Thermal Engineering Laboratory in the Engineering and Applied Sciences Research Center (CIICAP) of the Autonomous University of Morelos State (UAEM). The preliminary tests indicate that a difference of 23.3 % exists between the calculated data and the advanced system. The conclusions of the work show the temperature levels from which are possible to recover heat from waste heat for different concentrations of the working mixture; the temperatures of the upgraded heat are also shown.

1. Introduction

The heat pumps can be classified by their operation process in two types: compression and absorption. The compression process is carried out by means of the mechanical vapor recompression (MVR) to be able to increase the pressure and temperature of the working fluid. The process of MVR requires big quantities of high quality energy (electric power), with this, it can be carried out the pumping of heat at an immediate level. The absorption process is named in this way by the characteristic of absorbing gas into a liquid. The process of absorption replace to the MVR with the advantage of using low enthalpy energy. The main disadvantage of the process of absorption is assumed for

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its recurrent characteristic, it requires a long time for the transitory state, in that, the thermodynamic balance settles down in the whole system. Although the coefficient of performance of a heat transformer is lower to the unit, it has the unique ability to elevate the temperature from some type of waste heat to a more useful level with the entrance of additional energy required for the pumps. [Best, 1997].

2. Advanced cycles

A heat transformer is a device that indeed can recover near of 50% from the waste heat and reuse it in some industrial process. The characteristics of a heat transformer are: (1) it can increase the temperature from the waste heat from a first level thermal to a high level, while it consumes a small quantity of work used by pumps, (2) It doesn't have high energy rotational devices to exception of the pumps, which makes that this device has a simple configuration, (3) and this device can reduce a lot of energy consumption and CO_2 emission to the atmosphere.

The mixture water - lithium bromide has been the only mixture commercially used in heat transformers [Yin,2000]. However, this mixture possesses some disadvantages; one of these is the crystallization risk for salt concentrations of solution near to 70%. The mixture water – Carrol™ developed by Carrier Co. almost possesses same characteristics as the water - lithium bromide but has a bigger solubility of about 80% [Reimann,1984]. Best and Rivera [Best, 1997] proposed for first time the use of that mixture in heat transformers and also reported information of thermodynamic design for a single stage heat transformer operating with this mixture. After that, there was research for single stage heat transformers [Sozen, 2007, Rivera, 1998;2001] but there is not research of Double State Heat Transformer reported in Latin America [Jun,1999; Shi, 2001]. Then this is the firs project that report this advanced cycle in the Latin America.

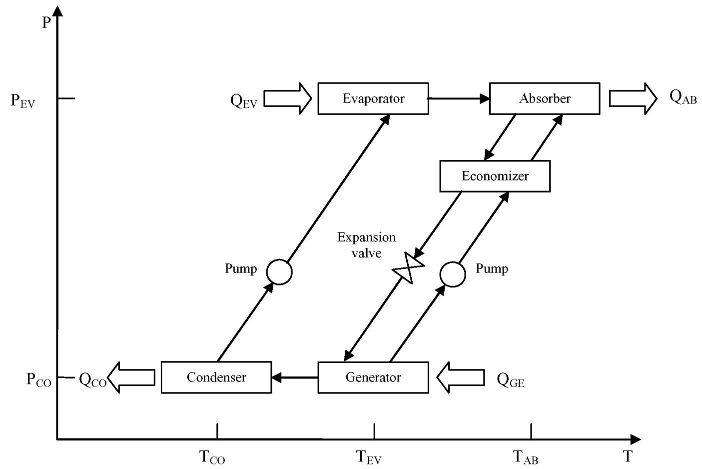


Fig. 1. Schematic Single stage heat transformer

A quantity of waste heat is added to an intermediate temperature to the generator, to evaporate the working fluid of the weak solution in salt. Under these conditions, working fluid in form of vapor leaves the generator and goes to the condenser, where this is condensed and releases a quantity of heat at low temperature. The liquid that leaves the condenser is pumped to the evaporator where this is evaporated by means of a quantity of heat from the waste heat source at intermediate temperature, same level than the generator. After this, the working fluid passes to the absorber where this it is absorbed by the strong solution in salt coming from the generator, it releases a quantity of heat to a higher temperature. Finally, the weak solution in salt returns to the generator, preheating the strong solution in salt in the economizer, beginning again the cycle.

2.1 Main parameters

The most important parameters in design for a thermal transformer are: the relationship of flow, the effectiveness of the economical one, the increment of temperature and the coefficient of performance [Romero, 1996; Abrahamsson,1995].

2.2 Flow ratio

The relationship of flow (FR) it is defined as the reason of mass flow rate that goes from the absorber to the generator among the mass flow of the working fluid

$$FR = \frac{M_{AB}}{M_{WF}} \qquad (1)$$

Of a balance of mass in the absorber or generator, the relationship of flow (FR) it can be written in concentration terms like

$$FR = \frac{X_{GE} - X_{WF}}{X_{GE} - X_{AB}} \qquad (2)$$

2.3 Effectiveness of the economizer

The economizer is used to recover energy internally in the cycle of the heat transformer. The effectiveness of the economizer can be defined as the current heat recovered among the possible maximum heat that could be recovered.

$$EF = \frac{Q_{AB}}{Q_{MAX}} \qquad (3)$$

2.4 Gross Temperature lift

One of the characteristics of the absorption systems is the Gross temperature lift (GTL). This is defined as the difference of values that exists between the temperature of the absorber (where recovers the energy) and that of the evaporator (where the energy is given).

$$GTL = T_{AB} - T_{EV} \qquad (4)$$

2.5 Coefficient of performance

The coefficient of performance (COP) is an important parameter this represents the efficiency of an absorption heat transformer. This it is defined as the heat liberated in the absorber by unit of heat given to the generator and evaporator.

$$COP = \frac{Q_{AB}}{Q_{GE} + Q_{EV}} \quad (5)$$

3. Advanced cycles of heat pump

A single stage heat transformer (SSHT) it can be used to recover heat from industrial waste to intermediate temperatures when final application needs smaller increments of temperature about 30 °C in industrial processes. However, when they are necessary higher increments of temperature they should be consider a double stage heat transformers (DSHT) and double absorption heat transformers (DAHT). A double stage heat transformer consists of two heat transformers of single stage, which can be coupled in three different forms. A double absorption heat transformer is a single stage heat transformer to which has been added a unit of double purpose absorber/evaporator.

4. Double stage heat transformer (DSHT)

The double stage heat transformer (DSHT) basically it consists of two thermal transformers of a stage (SSHT) which can be coupled in three different forms as it is shown in the figure 2. The first option consists on connecting the absorber from the first stage to the evaporator of the second stage in such a way that the heat liberated in the absorber allows the evaporation of the work fluid in the second stage. The second form consists on coupling the absorber from the first stage to the generator of the second stage [Rivera et al, 2001].

$$COP = \frac{Q_{AB2}}{Q_{GE1} + Q_{EV1} + Q_{GE2}} \quad (6)$$

4.1 Experimental setup

The Figure 2 shows the schematic diagram of a DSHT designed to operate with the mixture water – Carrol™. This diagram shows the main components of the system that are the generator, evaporator, condenser, absorber and economizer.

For the construction of the experimental rig were used 10 gasket plate heat exchangers with the same design. These were manufactured at the request of the CIICAP by the Danish company Sondex specialized in the development and production of plate heat exchangers (see Figure 3).

For the installation of the components [Kakaç,2002] of the double stage heat transformer 2 bases of 1.15 X 0.55 m and a height of 1.17 m those were used which are recovered with epoxy painting. In this structure the components were placed as it is shown in the Figure 4 in the superior part it is the condenser and evaporator respectively and in the inferior part they are installed the generator, economizer and absorber.

4.2 Connections

They settled two valves of type floodgate located in the condenser and evaporator of ½ inch of nominal diameter manufactured in stainless steel 316 it settled a valve of type ball of ¼ of inch of nominal diameter manufactured in stainless steel 316 by means of which is carried out hole and for which the hole pump is connected

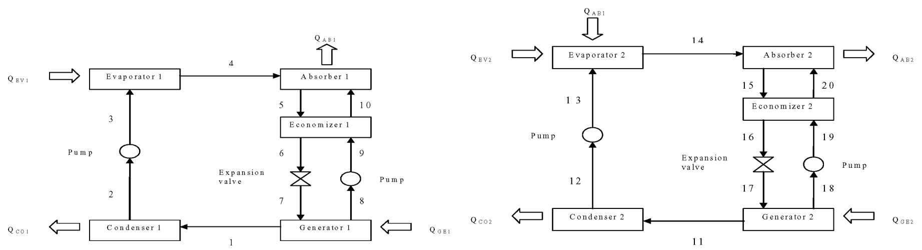


Fig.2 . Schematic diagram of double stage heat transformer (DSHT)

Figure 3. Plate heat exchangers.

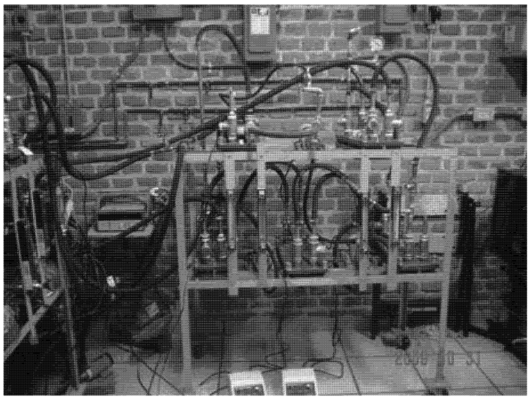
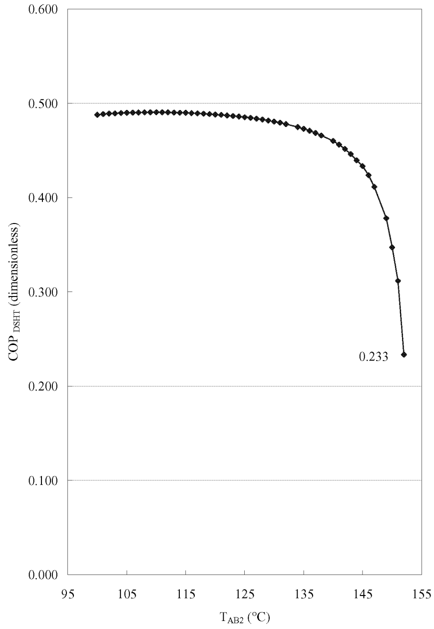


Figure 4. DSHT

To interconnect the components, tubing of stainless steel 316 with nominal diameter of 3/8 was used, to carry out the connections among the components, hose model Parker Push-lok 821-10 was used, which has a temperature range of operation from -40 °C to 100 °C and a working pressure of 250 psi. This hose is formed with interior tube of synthetic rubber, reinforced with a textile braid and a covered with synthetic rubber.

5. Results and Discussion

The DSHT has been simulated using software programmed in the CIICAp of the UAEM. This software has allowed calculating the heats, flows, temperatures and operation pressures of each one of the components of the system. The results obtained with the software have been compared with the values of the literature for SSHT.
The authors consider that there are two forms of comparing a DSHT:
The value of the COP of both systems
The value of the GTL of both systems
In the case of the COP, It can be observe that an increment of the value will be obtained under the extreme conditions for the SSHT.
Recovery of energy at 80 °C in the SSHT the highest temperature is 152 °C, with the COP of 0.233 (dimensionless). It is shown in Fig. 5.
Recovery of energy at 80 °C in the DSHT with first absorption at 120 °C the highest temperature is 170 °C, as it can be seen in figure 6.



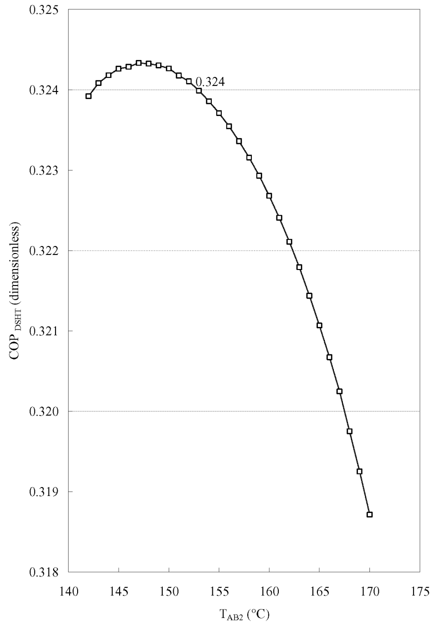


Fig 5. SSHT data.

Fig. 6. DSHT data.

In the case of the GTL:

SSHT has the operating conditions between 20 °C and 72 °C with the highest COP at 110 °C into the absorber.

DSHT has the operating conditions in a smaller range: from 62 °C to 90 °C with the highest COP at 147 °C.

In both comparisons there is a real advantage of the DSHT compared with SSHT. Main results is for the highest temperature of SSHT with recover of 23.3 % of waste energy, meanwhile DSHT at same temperature has the capability to recover 32.4 % of waste energy from 80 °C and deliver at 152 °C.

6. Conclusions

The CIICAp of the Autonomous University of Morelos State (UAEM) has the first Latin-American double stage heat transformer. The construction of the device was carried out all in 316SS. The instrumentation and connectors are installed now. The simulation of the entire system show two main advantages compared with Single Stage Heat Transformers. The DSHT main advantage is the capability for recover more than 30 % compared with the SSHT. The calculated gross temperature lift is 20 °C higher than an SSHT, for recover energy from 80 °C and release to 152°C.

7. Acknowledgment

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