Laboratory instrumentation and object oriented design for working fluid control in an "absorption heat pump" using Water / Carrol

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***Abstract*— In this work the flow control in a single stage absorption heat pump (SSAHP) is shown, in particular case for the water – Carrol ™ absorption pair, and the operating conditions of the system are calculated. The dimensionless tendencies of powers are shown as a function of the final temperature of revaluation from waste energy. The used software is described for the temperature sensors calibration, as well as the software for in - line calculations of powers and mass flows into the thermodynamic cycle. Finally, a correlation for working fluid control into the Laboratory absorption heat pump is shown.**

Index Terms— absorption heat pump, thermodynamic cycle, operation conditions, water – Carrol™

I. Introduction

AN absorption heat pump of single stage (SSAHP) is a thermal device that is used in the industries for the recovery of waste heat for energy uses to higher temperature of the original source [1]. The operating of a SSAHP is based on heat and mass simultaneous transfer by absorption of a working fluid into an absorbent, with the consequent exothermic reaction that promotes increment of pressure and temperature in the fluids, this reaction is used to revalue thermal energy from a TEV temperature and recovered it at higher value: T_{AB}.

On the performance of a SSAHP, there are five basic components, two auxiliary systems and heat recovery system. This system has: vapor generator, a condenser, an evaporator, an absorber and an economizer [2], the auxiliary systems are a heating system and a cooling system [3] and the system of heat recovery consists of a heat exchanger coupled to the absorber, as schematized in the figure 1.

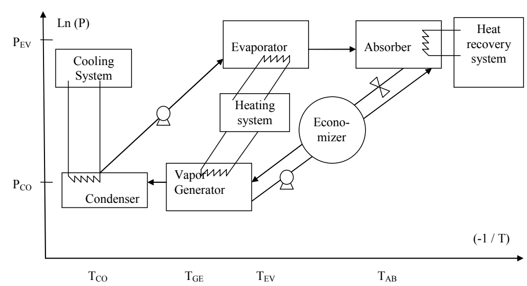

Figure 1. Schematic single stage absorption heat pump (SSAHP) for energy revaluation.

In a SSAHP, there are 32 variables to be able the operating of this cycle under steady state conditions. In the starting of this system, five critical parameters exist: Pressure, Temperature, Concentration of the absorbent, flow of working fluid and evaporation power.

The operating in a SSAHP had carried out in the "Ingeniería Térmica Aplicada" Laboratory (LITA) of CIIICAP – UAEM, in this operation we have been calculated and simulated in a personal computer with a previously validated model for the operation of a pilot plant [4].

The control that is carried out of the critical variables has been done in manual mode, with technical support to operate in permanent state. It is meritorious to mention that the starting of the system implies a transitory state of 5 hours for the control of the 32 variables. This transitory state was monitoring with a personal computer connected to a data logger with the software Benchlink©. [5]

II. Control challenges

In order to control the system, a variables correlation model

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has been used for the mixture water - Carrol. In this "working fluid - absorbent" (WFA) pair, the aqueous Carrol is the absorbent and the water (in phase vapor) is the working fluid.

With the used pattern [6] the operating conditions and the influence of the flow of the working fluid have been determined to fix the permanent state conditions.

We have determined the following methodology for the control of this pilot plant:

Modeling of absorption SSAHP system;
Simulation of water / Carrol as WFA pair;
Identification of Supporting with Benchlink © software
Developed data acquisition system with thermocouple,
Calibration for each made component. Some part of the calibration is shown in the figure 3.
Test of circuit with working fluid;
Object Oriented Design,
Test and validation of pattern – controller,
All this into the CIICAP – UAEM laboratory.

III. Results

Using the validated pattern, theoretical operation conditions has been determined to future real operating conditions in the pilot system at thermal applied engineering laboratory (LITA). These conditions are shown in the chart 1.

All conditions for the system was simulated with powers of 0.9 kW + / - 0.02 each component. With these conditions, it has been able to determine the ratio between the powers of generator and evaporator, as function of the revalorization temperature TAB. This behavior is shown in the figure 2.

T_{GE}	T_{CO}	T_{EV}	T_{AB}	P_{CO}	P_{EV}	X_{AB}	X_{GE}
ºC	ºC	ºC	ºC	kPa	kPa	%w	%w
69.9	16.1	71.3	90.0	1.83	32.9	49.1	73.8
69.9	16.1	71.3	91.0	1.83	32.9	50.0	73.8
69.9	16.1	71.3	92.0	1.83	32.9	50.9	73.8
69.9	16.1	71.3	93.0	1.83	32.9	51.7	73.8
69.9	16.1	71.3	94.0	1.83	32.9	52.4	73.8
69.9	16.1	71.3	95.0	1.83	32.9	53.1	73.8
69.9	16.1	71.3	96.0	1.83	32.9	53.8	73.8
69.9	16.1	71.3	97.0	1.83	32.9	54.5	73.8
69.9	16.1	71.3	98.0	1.83	32.9	55.1	73.8
69.9	16.1	71.3	99.0	1.83	32.9	55.7	73.8
69.9	16.1	71.3	100.0	1.83	32.9	56.3	73.8
69.9	16.1	71.3	101.0	1.83	32.9	56.9	73.8
69.9	16.1	71.3	102.0	1.83	32.9	57.5	73.8
69.9	16.1	71.3	103.0	1.83	32.9	58.0	73.8
69.9	16.1	71.3	104.0	1.83	32.9	58.6	73.8
69.9	16.1	71.3	105.0	1.83	32.9	59.1	73.8
69.9	16.1	71.3	106.0	1.83	32.9	59.6	73.8
69.9	16.1	71.3	107.0	1.83	32.9	60.2	73.8
69.9	16.1	71.3	108.0	1.83	32.9	60.7	73.8
69.9	16.1	71.3	109.0	1.83	32.9	61.2	73.8
69.9	16.1	71.3	110.0	1.83	32.9	61.7	73.8

Chart 1. Simulated conditions for pilot system in LITA.

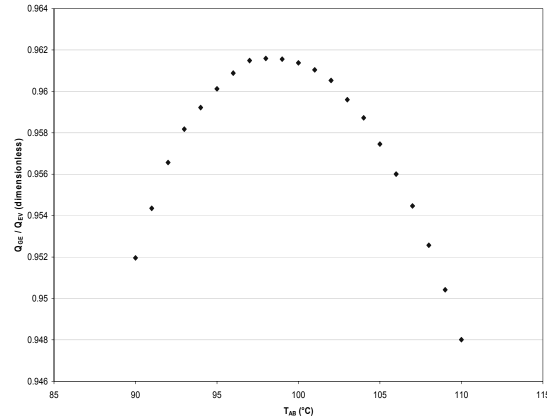

Figure 2. Ratio of powers in generator and evaporator as a function of revalorization temperature.

IV. Data Acquisition

Supporting with Benchlink © software we have developed data acquisition system with thermocouple, whose previous calibration for each component has made. Some part of the calibration is shown in the figure 3.

V. Flow control

To carry out the flow control toward the system we have programmed the calculation of the powers of the components in the HP-VEE © of Agilent Co. software. The calculation has been complicated because it requires to be carried out readings in real time for each temperature, to manipulate the data involved in each component to be able the calculation by energy balance considering thermodynamic first law, to define thermal load in each component.

Some part of the program is shown in the figure 4. This program has prepared with a different color each component in order to avoid the interaction of mistaken thermocouples.

Channel			Measurement	Scaling (Mx+B)				Comment
ID	Scan	Name	Function	Scale	Gain(M)	Offset(B)	Label	
201	☑	Sol HEX LBr out gen	Temp (type T)	☑	0.9986	0.0634	C	LiBr que sale del generador y entra al SOL HEX
202	☑	HEX2 H20 out c-H e-C	Temp (type T)	☑	0.998	0.2631	C	(cond) H20 pura caliente (enf) H20 pura fria que sale del HEX2
203	☑	HEX2 -HW in	Temp (type T)	☑	0.9866	1.1342	C	Agua del medio de enfriamiento que entra al HEX2
204	☑	Sol HEX LBr out abs	Temp (type T)	☑	0.9986	0.0127	C	LiBr que sale del absorbedor y entra al SOL HEX
205	☑	HEX2 W out c-H e-C	Temp (type T)	☑	0.9995	0.121	C	(cond) Agua del medio de enf (enf) agua de enf que sale del HEX2
206	☑	HEX2 H20v in	Temp (type T)	☑	1.0008	0.1652	C	H20 vapor que entra al COND AUX o al HEX2 (cond)
207	☑	Sol HEX LBr in abs	Temp (type T)	☑	0.9994	0.1031	C	LiBr que sale del SOL HEX hacia el absorbedor
208	☑	Cond Aux -HW out	Temp (type T)	☑	0.9986	0.0964	C	Agua del medio de enfriamiento que sale del COND AUX
209	☑	Generador LiBr out	Temp (type T)	☑	0.9994	0.1328	C	LiBr concentrado que sale del GENERADOR
210	☑	Cond Aux H20 out	Temp (type T)	☑	1.0117	0.2205	C	H20 pura caliente que sale del COND AUX
211	☑	Cond Aux -HW in	Temp (type T)	☑	0.9987	0.2907	C	Agua del medio de enfriamiento que entra al COND AUX
212	☑	HEX1 -HW in	Temp (type T)	☑	0.9994	0.0598	C	Agua del sistema de calentamiento que entra al HEX1
213	☐		DC volts	☐	1.0	0.0	VDC	
214	☐		DC volts	☐	1.0	0.0	VDC	
215	☐		DC volts	☐	1.0	0.0	VDC	
216	☐		DC volts	☐	1.0	0.0	VDC	
217	☐		DC volts	☐	1.0	0.0	VDC	
218	☐		DC volts	☐	1.0	0.0	VDC	
219	☐		DC volts	☐	1.0	0.0	VDC	
220	☑	Presión Barométrica	DC volts	☑	1.0	609.74	mmHg	Presión barométrica
221	☐		DC current	☐	1.0	0.0	ADC	
222	☐		DC current	☐	1.0	0.0	ADC	

Figure 3. Gain and offset for thermocouples in the system.