

# Experimental Study of a 600 W Seasonal Solar Heat Storage Reactor for the Heating of Buildings

Samuel HENNAUT<sup>1</sup>, Elisabeth DAVIN<sup>1</sup>, Romain BAIWIR<sup>1</sup>, Laurent COLLARD<sup>1</sup>  
and Philippe ANDRE<sup>1</sup>

<sup>1</sup> BEMS, SPHERES Research Unit, Université de Liège, Arlon (Belgium)

## Abstract

A prototype of sorption-based solar heat storage is tested. It integrates a vibrating circular reactor designed for batch operation with around 2 kg of composite (Silica Gel with 40 % of CaCl<sub>2</sub>). The global performance of the system and of each component is evaluated during adsorption and desorption. The influence of different parameters of the system is measured through a parametric variation: temperatures, flow rates, adsorbent mass and granulometry, air humidity and reactor insulation. The prototype is connected to the experimental building allowing to make semi-virtual experimentations in controlled conditions. In conditions considered as realistic, the reactor average heat flow is around 600 W of which 250 W are transferred to the heating loop. The efficiency of a cycle desorption/adsorption is around 13% for a water uptake between 12 and 40%. Parameters identified as crucial are the adsorbent granulometry, the low temperature heat source temperature and location, the load return temperature and the hot source temperature and flow rate.

*Keywords: thermal storage, adsorption, silica gel and CaCl<sub>2</sub> composite, fluidized bed reactor*

---

## 1. Introduction

Today, energy storage is commonly admitted as a necessary solution to improve the utilization of renewable energy. For heating applications with solar thermal collectors, an efficient seasonal storage would allow reaching high solar fraction. Sorption-based heat storage is generally cited as promising solution for seasonal efficient long term storage, due to the expected energy density and the absence of “chemical losses” during the storage period. However this technology is not yet mature and it needs still a lot of research and development. Sorption systems are also known as complex technologies, because it relies on chemical reactor, which must, most of the time, be connected to some auxiliary components in order to improve the system efficiency.

This paper presents experimental performance evaluation of such a system. The influence of the related components is specifically analyzed. A 600 W adsorption reactor, for the seasonal storage of solar heat, was tested between June 2016 and January 2018, in conditions corresponding to the space heating of a residential building. This reactor is integrated in a closed air loop including a humidifier, and several heat exchangers: a recovery heat exchanger and others connected to the hot source, to the load and to a low temperature heat source. The prototype is built to allow opening the loop to use fresh air during desorption.

This paper will firstly describe the tested system, then principle and the objectives of the experimental campaign are presented. Finally, main results are analysed with a focus on the performance in standard test conditions.

## 2. Description of the system

The general basic scheme of the system is illustrated on Figure 1 and its integration in the laboratory is shown on Figure 2. Main components are described in this section.

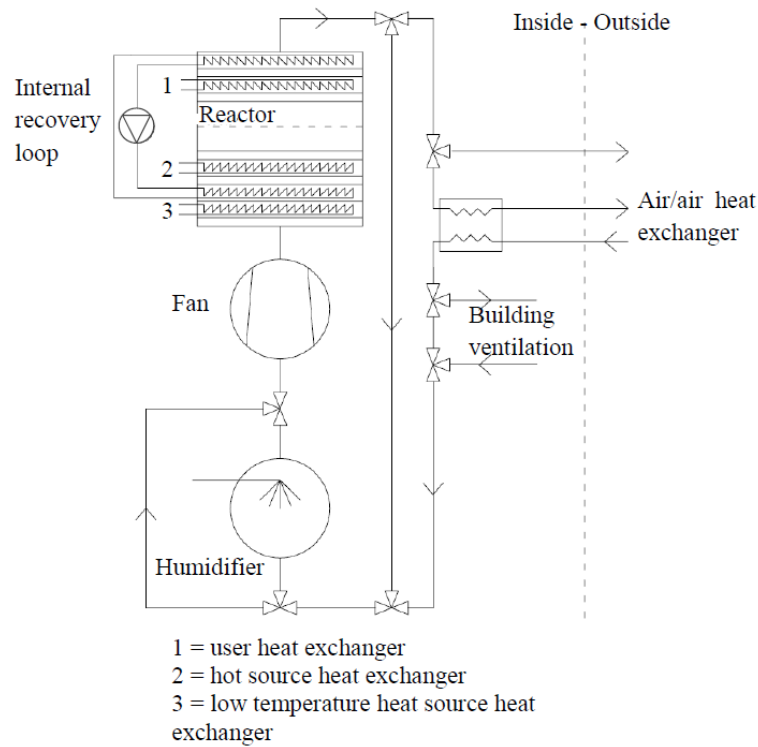


Figure 1 – System general basic scheme

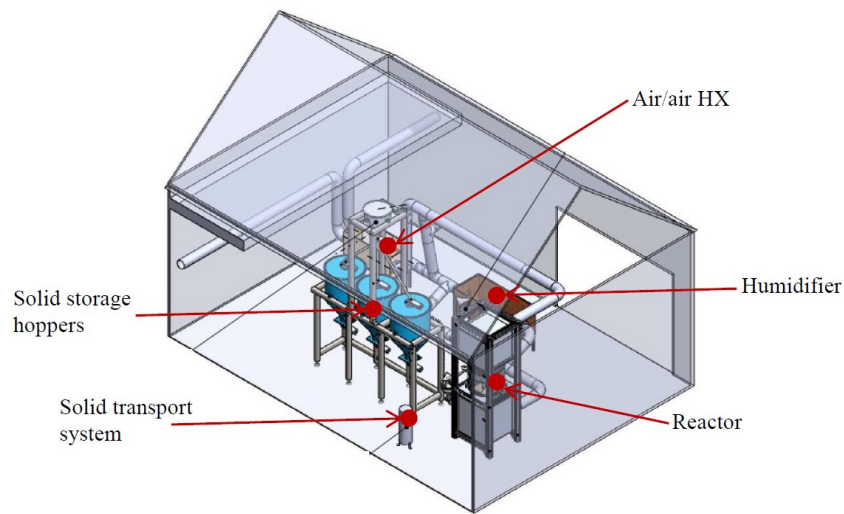


Figure 2 – Implantation of the prototype in the laboratory (3D view)

## 2.1 Description of the reactor

The main component of the tested system is the circular reactor where the sorption reaction takes place. It's a separate reactor (the adsorbent is not stored in the reactor) designed for batch operation with around 2 kg of dehydrated adsorbent: it is introduced in the reactor where it is hydrated or dehydrated according to its initial state and to the conditions (temperature and humidity) of the air flow crossing the reactor. The adsorbent rests on a sieve that allows air to pass from the bottom to the top of the reactor. The flow rate is adjusted to cause fluidization of the bed (Figure 3). During the reaction, the adsorbent circulates on the sieve along a spiral trajectory from the centre to the edge, thanks to vibrations of the reactor generated by unbalanced motor. Once at the edge, the adsorbent is returned to the centre of the reactor by a ramp. When the desired hydration level of the adsorbent is reached, it is removed from the reactor and stored in hermetic hoppers. Then, a new quantity of solid can be introduced in the reactor for a new reaction.

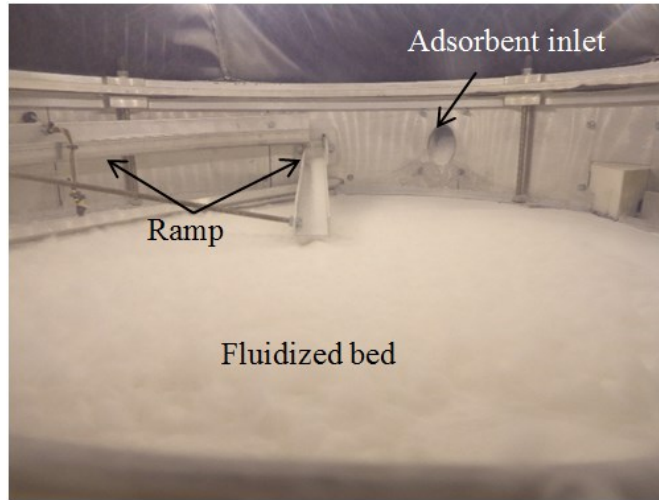


Figure 3 – Inside the reactor during adsorption (D'Hondt, 2016)

## 2.2 Reagent couple

The following results were obtained using a composite adsorbent made of silica gel and  $\text{CaCl}_2$ . It contains slightly more than 40% of  $\text{CaCl}_2$ . The bulk density of dry adsorbent is almost  $700 \text{ kg/m}^3$ . The adsorbate is water vapour. Two “versions” of the composite were tested in the reactor. These 2 versions were produced according to the same protocol, but using 2 Silica Gel from different suppliers which differ mainly in the granulometry. In this document, the composite is also equally called, solid, or adsorbent.

## 2.3 Air/water heat exchangers

This reactor is surrounded by 5 air/water heat exchangers (HXs). In fact, each HX is composed of 3 air/water HXs in series. The reactor and the HXs are integrated in the same closed volume without duct in between.

At the top, the first heat exchanger above the reactor is used to transfer the heat from the air flow (coming from the reactor during adsorption) to the water loop from the building heating system (water tank or heat emitter). In the following, it will be called “User HX”. Above the User HX, there is the upper HX of the internal heat recovery loop. This internal heat recovery loop is called “Internal HX” below. It consists of two air/water HX connected by a water loop and a pump circulating water between both HX. The upper HX of the Internal HX (called “Upper HX”) recover the heat remaining in the air after the user HX and transfer it to the lower HX of the Internal HX, below the reactor, by the water loop.

At the bottom, the first HX below the reactor is used to transfer the heat from the hot source (from the solar loop or from a tank) to the air flow supplied to the reactor during desorption. In the following, it will be called “Hot Source HX”. Below the Hot Source HX, there is the lower HX of the Internal HX (called “Lower HX”). It transfers the heat coming from the upper HX to the air flow before the Hot Source HX. The air flow is then preheated, reducing the contribution of the hot spring (in desorption), or increasing temperature at the reactor inlet (in adsorption). Below the Lower HX, there is the last air/water HX connected to a low temperature heat source (LTHS). In the following, it is called “LTHS HX”. This HX can be used during adsorption to preheat the air flow between the humidifier and the Internal HX, thanks to the LTHS source.

## 2.4 Fan

The fan is integrated below the LTHS HX and flow the air through the reactor, the HXs and the other components connected to them in the air loop. Different air loops are described below. The air flow supplied by the fan is evenly distributed on the LTHS HX area, thanks to a repartition sieve placed before the HXs. The maximum power of the fan is 81 W.

## 2.5 Humidifier

The humidification is realized thanks to an evaporative cooling media (Figure 4 a) that maximize the evaporation of water thanks to its large surface area of contact between air and water (D'Hondt, 2016). The honeycomb panel, made of impregnated cellulose, is humidified by water pumped to its top (D'Hondt, 2016). The water flowing down the panel is collected in a small tank where it can be pumped again to the top. The evaporative panel and the pump are integrated in an insulated box of wood (Figure 4 b).

The circulation loop existing in the humidifier can also be used to integrate a heat exchanger connected to the LTHS. The objective of this combination of the humidifier and the LTHS is to enhance the efficiency of the LTHS in comparison to its integration by the air/water HX.

The humidifier allows humidifying the air flow before the reactor during adsorption, if the air runs in closed loop. It can also be used with open air loop to increase the humidity before the reactor during adsorption.



Figure 4 – (a) Evaporative cooling media; (b) Insulated box of wood integrating the evaporative panel. (D'Hondt, 2016).

## 2.7 Air loops

All components described above are connected by insulated air ducts (4 cm of mineral wool). The diameter of ducts is 200 mm. The system was designed to be adjustable and allow the configuration of different air loops. The objective was being able to realize tests in different conditions. Dampers strategically placed in air pipes allow imposing the desired path to the air flow. Both configurations (one for adsorption and the other for desorption) used to produce following results are:

- “Adsorption closed loop” configuration (Figure 5a): the air circulates in a closed circuit. The air must absolutely be humidified to compensate the humidity adsorbed in the reactor. The reaction heat is provided to the load thanks to the User HX and the Internal HX is used. In order to compensate the temperature decrease during humidification, a LTHS can be connected to the LTHS HX or to the humidifier. This configuration has also a duct and specific dampers to by-pass the humidifier, for example when the adsorbent reached the desired hydration level.
- “Desorption open loop” configuration (Figure 5b): the outside air by-pass the humidifier, is preheated by the Internal HX (Lower HX) and then is heated by the Hot Source HX before it's supplied to the reactor for desorption. After the reactor, the air goes through the Upper HX to preheat the inlet air, before it's exhausted.

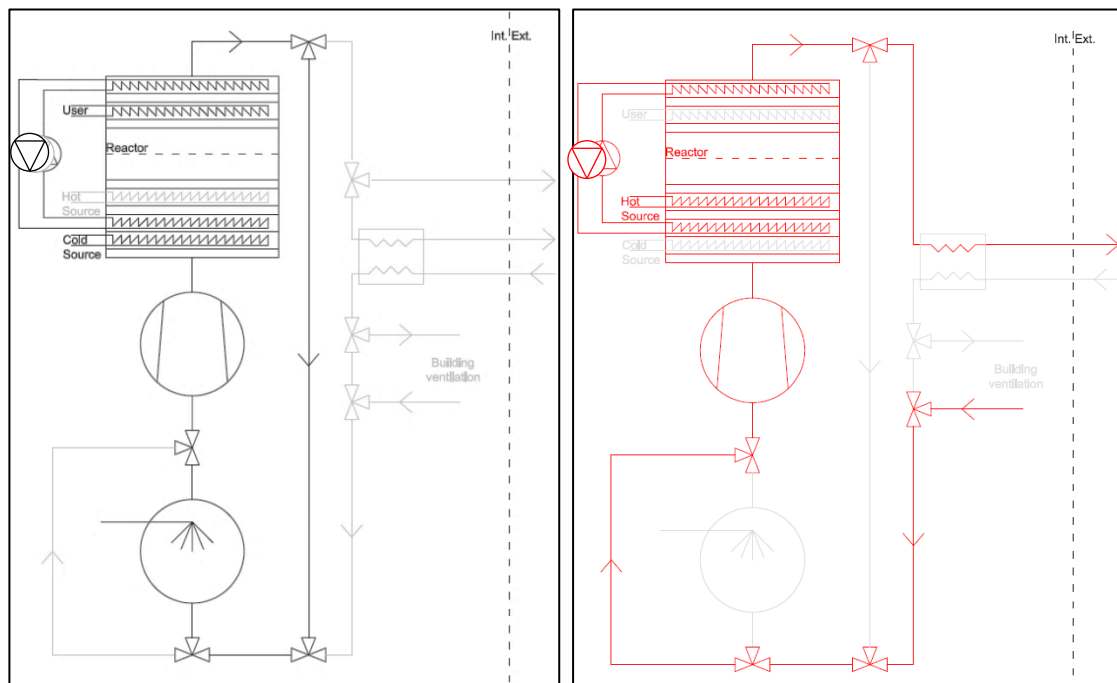


Figure 5 – (a) “Closed air loop” configuration for adsorption; (b) “Open air loop” configuration for desorption

### 3. Experimental campaign

The experimental campaign was divided in 3 phases corresponding to 3 objectives: The first and major objective was to test the influence of each component of the system through a parametric variation. For this purpose, most tests were realized in controlled conditions, in order to compare more easily the different configurations tested, and obtain reproducible experiments. To determine the influence of each parameter correctly, all parameters should remain as constant as possible during the test. Then, tests were done to analyse the influence of the adsorbent aging on thermal behaviour, by reproducing 15 cycles of adsorption/desorption on the same adsorbent volume. Finally, some tests were realised in realistic conditions or, at least, closer to reality than totally controlled conditions. The results presented below concern only closed-loop adsorptions and open-loop desorption, realised in controlled conditions.

#### 3.1 Experimental protocol in controlled conditions

In order to control as much as possible the boundary conditions and the parameters of the system, the principle of emulation (semi-virtual experimentation) is used for the various components connected to prototype: heating storage/distribution and LTHS for adsorption or hot source (solar) and inlet air for desorption. The main objective is to impose a constant temperature at the inlet of the heat exchangers or a constant humidity ratio at the air inlet of the system. A specific attention is also paid to flows control even if this aspect is trickier.

The experimental protocol is mainly divided in 2 parts:

- The preparation of the experiment, which mainly includes stabilization of experimental conditions. The preparation phase is considered finished when the prototype (air loop) and its inlets reach a “nearly steady state”. This period is also used to prepare the adsorbent: the composite hydration rate is measured by dehydration at 150°C in order to introduce always the same quantity of solid (measure at 150°C) in the reactor.
- The proceedings of the experiment. For adsorption, it is necessary to realize 2 tests in a row, to harmonize initial conditions and produce reproducible results. The stopping criterion is the hydration of the solid computed by the data acquisition program (moisture balance of the reactor). However this computation is not perfect, so in adsorption as 2 tests are realized in a row, the results of the first test is used to adapt the reaction duration of the second test. During desorption, the humidity ratio difference between the inlet and outlet of the reactor is also a good indicator to identify the end of the reaction. The objective is to reach 12% in desorption and 40 % in adsorption.

After preliminary tests on the system, some conditions were identified as “standard conditions” and used as reference for comparison. Parametric variations were constructed around these standard conditions. For adsorption, the configuration of test number 51 was selected as reference and for desorption the test number 60 was chosen. Standard test conditions are detailed in Table 1. Parameters presented in this table were the main ones studied in the parametric variation, in controlled conditions, in addition to the Silica Gel granulometry.

Table 1 – Standard test conditions & parameters studied

Parameter	Adsorption (#51)	Desorption (#60)
Water uptake	Between 12 and 40 %	
Mass of solid in reactor	2.15 kg of anhydrous (at 150 °C) SMG1_2	
Air flow rate	250 m <sup>3</sup> /h	
Water flow rates	1.2 L/min	
Reactor insulation	Not insulated	
User HX inlet temperature	25°C	/
Hot source HX inlet temperature	/	85°C
LTHS inlet temperature	8°C	/
LTHS location	in humidifier	
Inlet air humidity ratio	/	8 g/kg

### 3.2 Instrumentation of the prototype

The prototype was monitored continuously during experiments. Temperature sensors are installed before and after each component and at the boundaries of the prototype. The flow rate is measured in each water loop and in the air loop. Humidity sensors are located before and after components influencing the air moisture (reactor, and humidifier) but also at the air inlet and outlet.

## 4. Results and discussion

All graphical representations and computations presented in this section (unless otherwise specified) correspond to measurements realized on the prototype between the solid introduction into the reactor and the opening of the reactor evacuation valve.

For adsorptions, these results are only relative to the second batch realized in row (less than 15 minutes after the first), unless otherwise specified. For desorption, sometimes, experiments were longer than necessary. In fact, it seems that it would sometimes have been possible to stop the test several minutes earlier without excessively influencing the amount of solid adsorbed at the end. All tests are analyzed as is, but for some tests, the treatment of results is also proposed for a shorter version of the test. The criteria used to determine the new end of the test is that the heat flow provided to the reactor decrease below 450 W for a hot source temperature of 85 °C.

### 4.1 Adsorption: standard test conditions

Figures 6 to 9 concern test number 51, realised with standard conditions for adsorption (only second batch). On Figure 6, main heat flows of prototype are illustrated. The average power supplied by the reactor is about 600 W, of which about 250W are supplied to the user loop. The adsorption duration is 47 minutes. On this basis, an energy density of 153 kWh/m<sup>3</sup> is computed, considering the reactor production. It drops to 65 kWh/m<sup>3</sup> if we consider the energy recovered by the user loop. These densities are computed per m<sup>3</sup> of solid, considering a bulk density of 700 kg/m<sup>3</sup>. The system efficiency in adsorption, defined as the ratio between the energy provided by the reactor and the energy supplied to the user loop is 42 %. The energy removed from the humidifier (P.Wat.Hum), around 100 W, almost balances the gains due to the humidifier circulation pump (around 72 W). We can thus consider this test configuration corresponds to a situation without low temperature heat source.

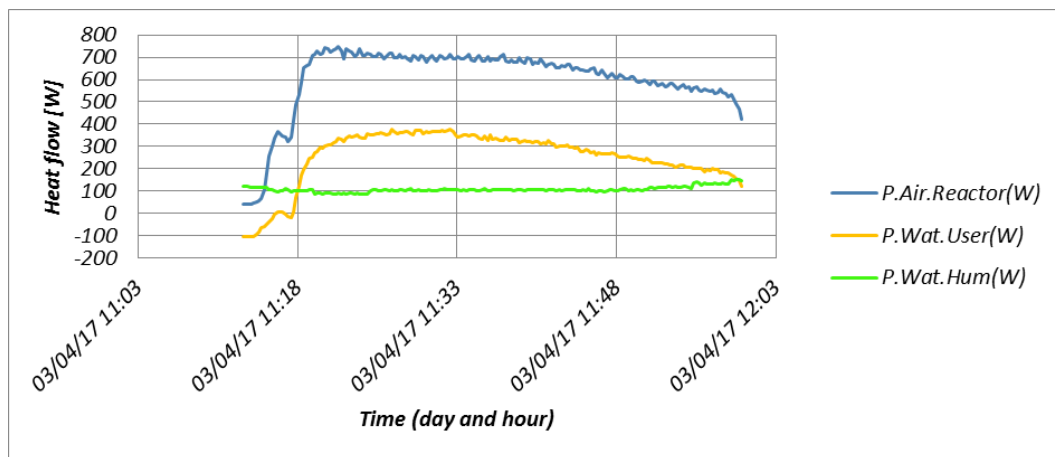


Figure 6 – Test # 51 – Heat flows in standard adsorption conditions: Heat flow supplied by the reactor (P.Air.Reactor), heat flow supplied to the user water loop (P.Wat.User), Heat flow removed from the humidifier (P.Wat.Hum).

Regarding temperatures (Figure 7), the user HX inlet temperature (T26) is imposed constant at 25 °C. The return temperature (T27) supplied to the user loop has a mean value of 27.8 °C during the test with a maximum reaching 29°C. At reactor boundaries, the average temperatures vary from 21.7 °C at the inlet (TavgIn – maximum 22.4 °C) to 29°C at the outlet (TavgOut – maximum 30.8 °C). We also observe that the temperature of the air at the humidifier outlet (T19) never drop below 9.8 °C (average temp. 10.6 °C). This makes the use of a geothermal source for LTHS in the LTHS HX impossible.

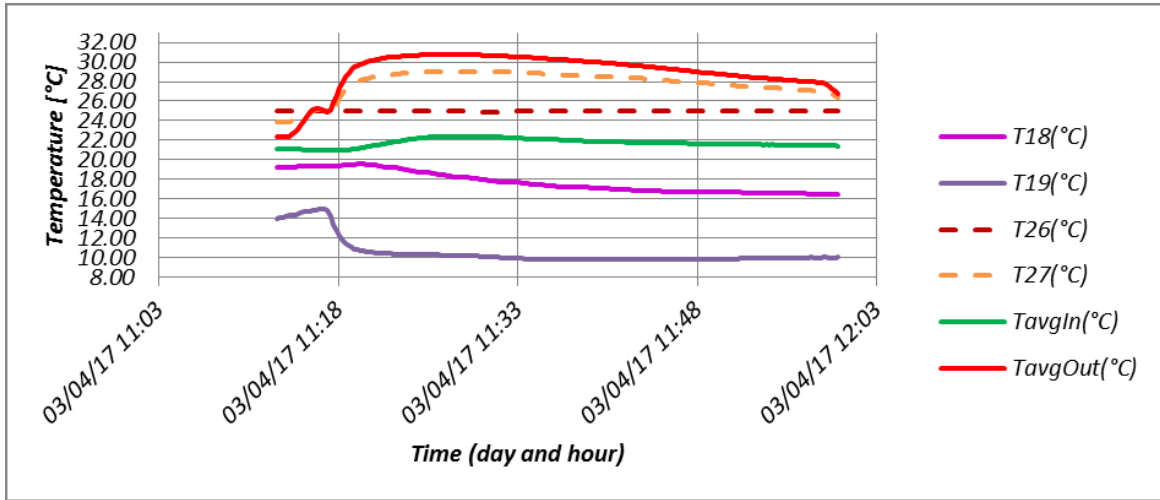


Figure 7 – Test # 51 – Temperatures in standard adsorption conditions: Average temperatures at the reactor inlet (TavgIn) and outlet (TavgOut), Temperature of water at the user heat exchanger inlet (T26) and outlet (T27), Temperature of air at humidifier inlet (T18) and outlet (T19).

On the humidity ratio side (Figure 8), the reactor inlet humidity (AH2) is around 7 g/kg, quite fairly constant over time. The reactor outlet humidity (AH1) varies from almost 3.5 g/kg at the beginning to 5 g/kg at the end. The difference between inlet and outlet decreases during the test and the gap at the end shows the solid is far from the equilibrium when the reaction is stopped. The decrease of solid humidification rate during the test is due the reduction of the deviation from the equilibrium when the water uptake of the solid increases. This also explains that both temperature and heat flows, on the user and reactor side, decrease a bit during the test.

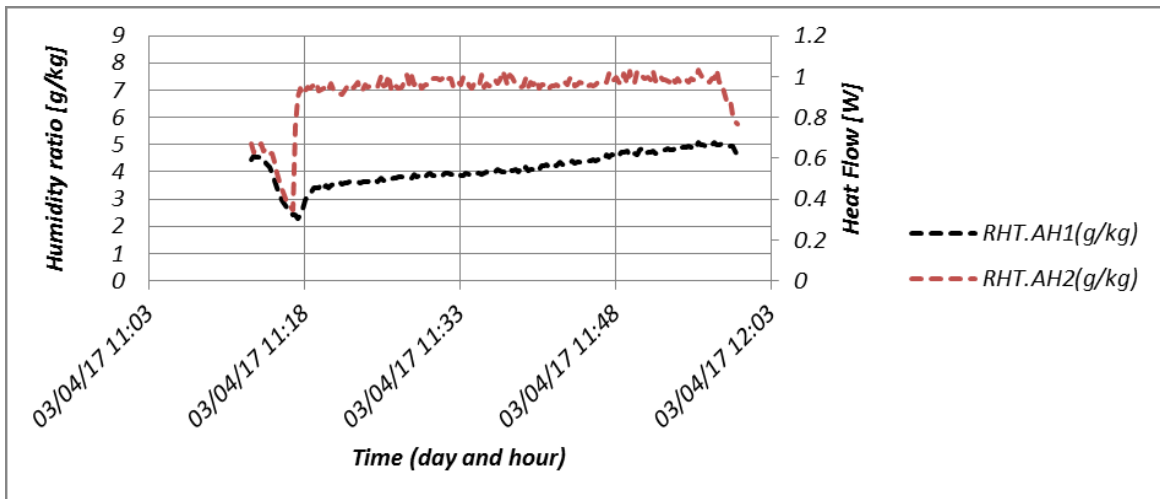


Figure 8 – Test # 51 – Humidity ratio in standard adsorption conditions at the inlet (RHT.AH2) and outlet (RHT.AH1) of the reactor.

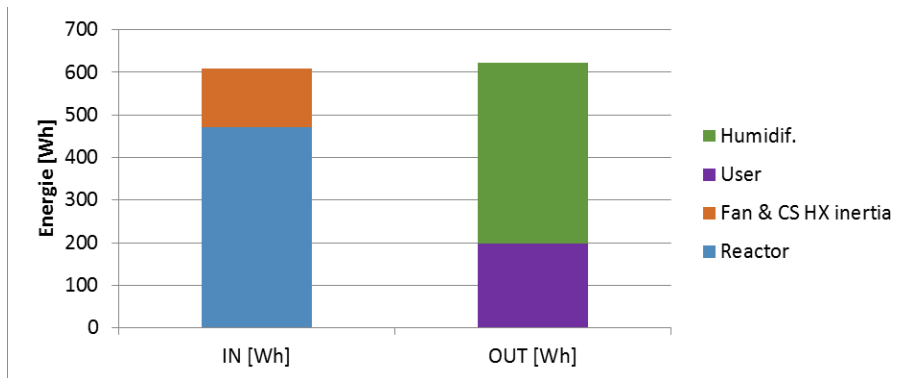


Figure 9 – Test # 51 – Energy balance of the system in standard adsorption conditions

The energy balance of the system along test number 51 is illustrated on Figure 9. We can observe that the major part of the hydration reaction of the solid is used to compensate the energy necessary for the humidification of the air. On the input side of the energy balance, we observe that other heat sources than the reaction heat represent around 20% of the energy supplied to the system. Other sources are mainly, the fan, the energy stored in the LTHS

HX before the beginning of the reaction (due to reactor warm up) before reaction and the energy gained by the air through pipe walls (between the reactor and the humidifier).

#### 4.2 Adsorption: main results of parametric variations

In adsorption, the first parameter identified as important, was quite surprising, and not initially integrated in the experimental campaign. Anyway, the granulometry of the silica gel appeared as a crucial parameter to allow a correct behaviour of the solid in the reactor and reaching desired adsorbed mass at the end of the reaction, without crust formation or solid aggregation. Behind the hydration level, there is of course the question of the energy density. With the exception of the aggregation problem, both composites have the same thermal behaviour.

The temperature of the LTHS and, maybe more interesting, the location of this source were identified as very important questions. Firstly, it was shown that a geothermal LTHS was too cold to be valorised in this closed air loop after the humidification. Secondly, it appears that the position of the LTHS in the air loop was crucial when the source temperature increases. Figure 10 shows that the combination of the LTHS and the humidifier (compared to the connection at the LTHS) makes the prototype efficiency rising by 3 % for a LTHS at 10°C, but the improvement reach 13 % for a LTHS at 20°C (the heat flow to the load increase by 80 %. 20°C is not a conventional temperature for a free LTHS, but this temperature level (up to 30°C) was tested, in order to estimate the potential for the valorisation of industrial heat losses or geothermal solar heat storage at the end of the heating period. However, we see that with a 30°C LTHS the average heating supply temperature reach only 35,6 °C, which is for example not enough for DHW production.

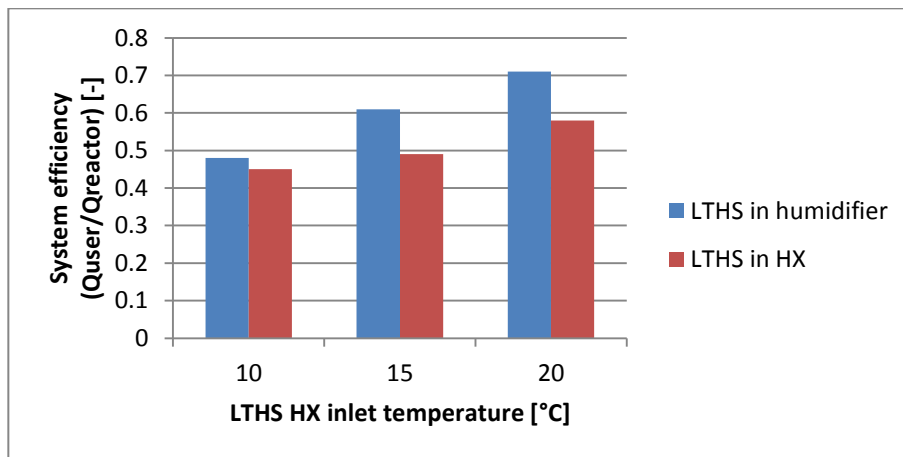


Figure 10 – Influence of the LTHS temperature and location

Another important parameter in adsorption is the load return temperature. So, the efficiency of the heat emitters is very important to allow working at low temperature and to have a good efficiency of the prototype. Figure 11 shows that the efficiency is divided by more than 2 when passing from 25 to 30°C at the inlet of the user HX.

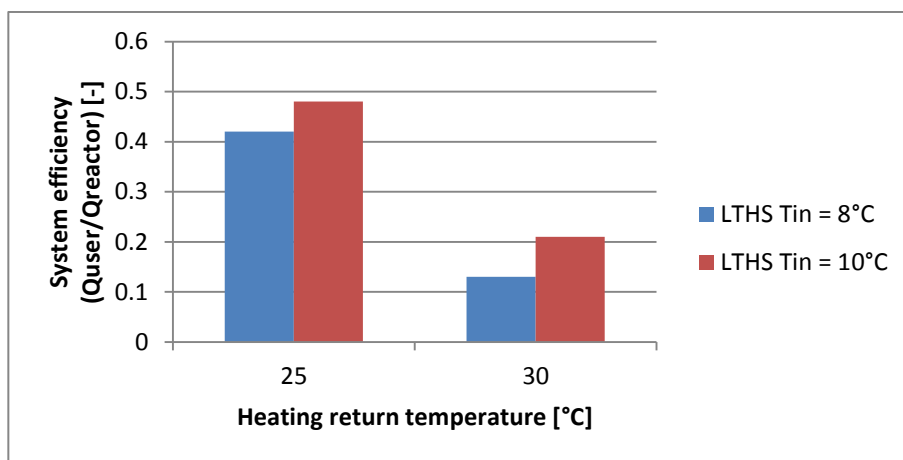


Figure 11 – Influence of the heating return temperature (temperature at the inlet of the user HX) for 2 LTHS.

Concerning air flow rate, we observe that the heat flow supplied by the reactor increase proportionally with the flow rate. It is the same for the user heat flow. The duration of the reaction is reduced if the flow rate becomes greater. However, the difference in terms of efficiency and energy density are not significant.



### 4.3 Desorption: standard test conditions

Figure 12 to 15 concern test number 60, realised with standard conditions for desorption (only 1 batch).

Figure 12, shows main heat flows in the system. The average heat flow provided by the hot source (P.Wat.Solar) is about 2.39 kW, of which 1.35 kW are provided to the reactor (P.Air.Reactor). The desorption lasts 37 minutes. According to these measurements, the energy density necessary for desorption corresponds to 277 kWh/m<sup>3</sup> (computed at reactor boundary) or 481 kWh/m<sup>3</sup> (computed at hot source boundary). This Figure also highlights that the average energy lost in the air leaving the open loop (P.Air.Out) is close to 0.9 kW. The system efficiency in desorption, defined as the ratio between mean powers from the reactor and from the hot source is around 56 %, which means nearly 45 % of losses. The heat flow measured on the reactor also includes the thermal losses through the reactor walls. A hypothesis is that these losses correspond almost to the heat flow supplied to the reactor at the beginning and at the end of the test (around 450 W). We see that the efficiency of desorption (ratio between energy used and energy provided) decreases as the desorption progress. 26 minutes after the beginning of the reaction, the losses become greater than the energy absorbed in the reactor.

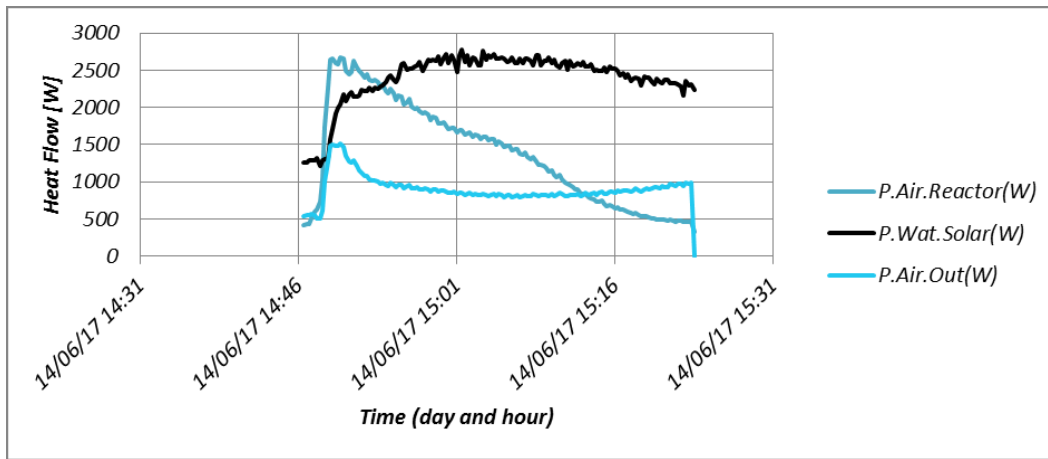


Figure 12 – Test # 60 – Heat flows in standard desorption conditions: Heat flow supplied by hot source (P.Wat.Solar), heat flow supplied to the reactor (P.Air.reactor), Heat flow lost due to temperature rise of the air between system inlet and outlet (open loop).

Regarding temperatures (Figure 13), the hot source inlet temperature (T24) is imposed constant at 85 °C. The inlet average temperature of the air in the open loop (T18) is 22.4°C and the outlet temperature (T16) is always above 30°C. At reactor boundaries, the average temperatures vary from 79.3 °C at the inlet (TavgIn – maximum 83.3 °C) to 62.3°C at the outlet (TavgOut – maximum 73.3 °C).

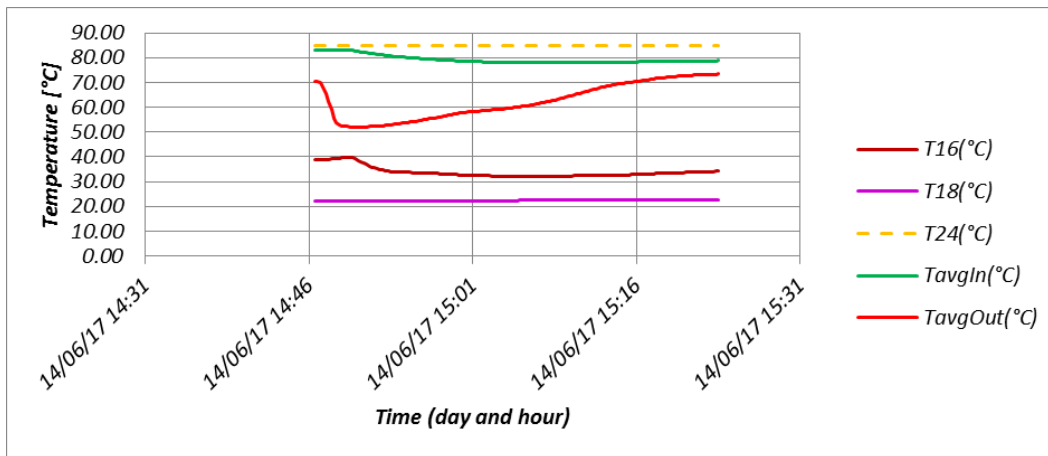


Figure 13 – Test # 60 – Temperatures in standard desorption conditions: Average temperatures at the reactor inlet (TavgIn) and outlet (TavgOut), Temperature of air at open loop inlet (T18) and outlet (T16), temperature of water supplied by the hot source (T24).

Concerning humidity ratio (Figure 14), 7.7 g/kg in average are imposed at the reactor inlet (AH2), even if the control of this input is not perfect, on account of the technology used. The humidity at the outlet varies between 16 g/kg a few minutes after the introduction of the solid in the reactor and 8g/kg at the beginning and at the end of the test (average 11.5 g/kg). The fact that the humidity at the outlet of the reactor equals the inlet value means the solid is close to the equilibrium when the reaction is stopped. The outlet curve meets the inlet curve a few minutes before the evacuation of the solid, which means that the reaction duration can maybe be a bit reduced. This is interesting

on account of the low efficiency of the system at the end of the desorption.

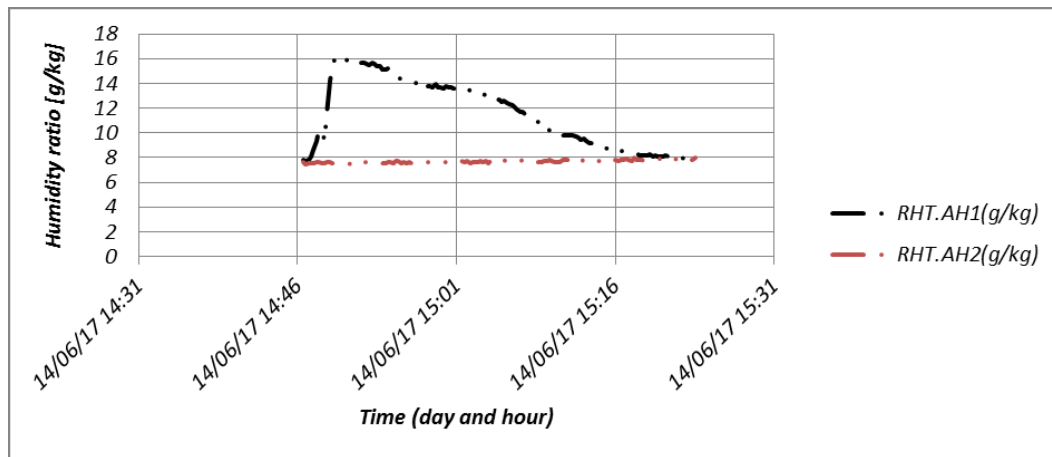


Figure 14 – Test # 60 – Humidity ratio in standard desorption conditions at the inlet (RHT.AH2) and outlet (RHT.AH1) of the reactor.

The energy balance of the system along test number 60 is illustrated on Figure 15. We can observe that the major part of the energy provided by the hot source is used for the dehydration of the solid, but around 40 % are lost in the air released at the outlet of the open air loop. Some specific action should probably be done to improve the utilisation of this energy. With a temperature above 30°C, this temperature can maybe be used to preheat the DHW during summer.

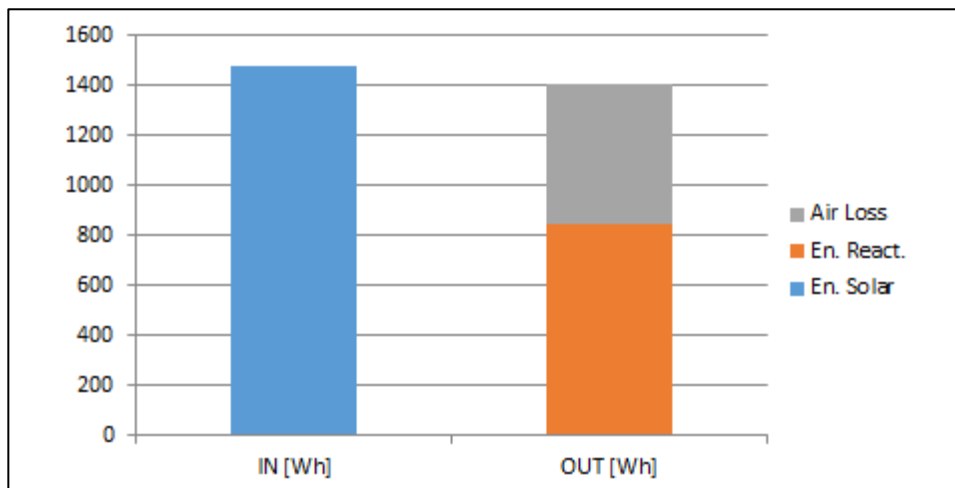


Figure 15 – Test # 60 – Energy balance of the system in standard desorption conditions

#### 4.4 Desorption: main results of parametric variations

Figure 16 shows that increasing the hot source temperature between 65 and 85°C allows improving the efficiency of the system in desorption.

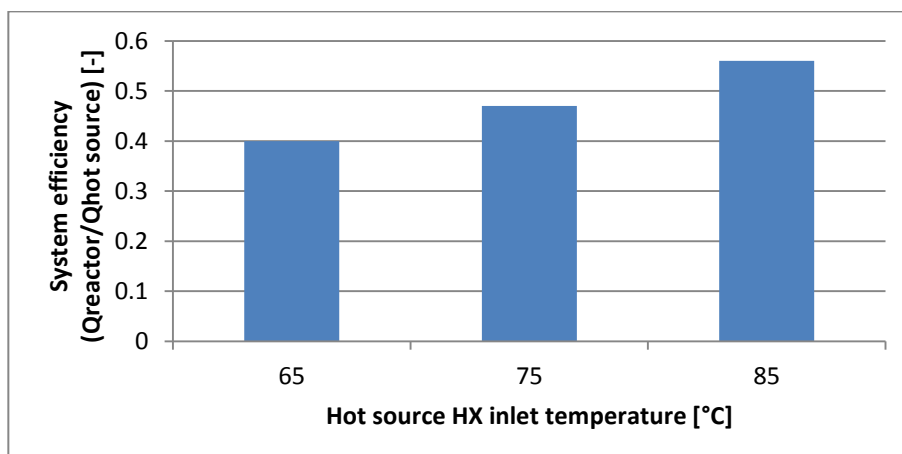


Figure 16 – Influence of the hot source temperature

The improvement is mainly due to the reduction of the reaction duration. The reaction is more than 2 times longer at 65 °C compared to 85°C. The higher temperature at the reactor inlet increases the difference with the thermodynamic equilibrium, which speed up the reaction. The heat flow provided by the solar loop increases with the temperature, as the heat flow lost at the loop outlet or the heat flow provided to the reactor, but the reduction of the duration has a better impact on the efficiency.

The control of water flow rate in the hot source loop to have the same heat capacity on both sides of the air/ water exchanger was also highlighted as an important parameter. Increase the flow rate has nearly the same influence in terms of efficiency and energy density than decrease it. Increase the air flow rate will mainly increase the hot source heat flow, but without clear increasing of the reactor heat flow (so this energy is lost). On the opposite, reduce the flow rate will reduce the reactor heat flow and thus increase the time of the reaction, and the attached losses.

#### 4.5 Influence of reactor insulation

There is no significant influence of the insulation of the reactor on the system performance. It can be explained by the poor quality of the insulation, with no consideration of the airtightness. Indeed, 2 major technical constraints make the insulation of the reactor very complicated. Firstly, the insulation can't be glue on the reactor wall without perturbations of the vibrations. Secondly, unbalanced motors need to be out of the insulation because they can't resist to higher temperatures reached in desorption, this create large spaces not insulated around motors. Moreover, the important instrumentation of the prototype creates a lot of paths for hot air in the insulation.

#### 4.6 Cycle efficiency in standard conditions

The efficiency of the cycle desorption/adsorption computed with test number 51 and 60 is presented on Figure 17. This cycle varies the water uptake of the solid between 13 and 41 %. The efficiency of this cycle for the system in standard conditions is around 13.5 %. 481 kWh are supplied by the hot source for the desorption of the solid and 65 kWh are recovered by the user loop. If we compute the efficiency of the reactor (ratio between the energy provided to the reactor for desorption and the energy recovered from adsorption at reactor boundary) it reaches 55 %.

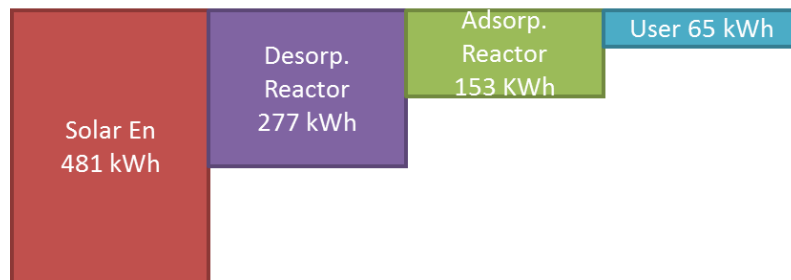


Figure 17 – Energy balance of a complete cycle desorption/adsorption (based on tests #51 and 60).

## 5. Conclusion and outlook

This experimental campaign allowed testing the system, prove the concept is working and submit it to a wide range of conditions. This kind of “experimental parametric variation” allowed identifying most important parameters of the system, i.e. those to which special attention should be paid in future developments.

The experimental campaign shows the concept is working during a quite large period, but it also highlighted weakness of the prototype and especially robustness and conception problems. Therefore, the robustness of the prototype and the automation must be improved to make it usable without any operator. Regarding the automation, the main challenge is to find a reliable stopping criterion of reaction, in order to maximize the energy density without solid aggregation.

More generally, the inefficiency of the reactor insulation in adsorption and desorption was observed. This is certainly a crucial point to increase the reactor efficiency. The reflexion about the insulation should certainly be integrated in the conception of future prototypes. More generally, the reduction of other losses would to improve the quite low system efficiency constitute a priority in future development. As a consequence, the cycle efficiency is also quite low. Its improvement could also rely on the increasing of the recovery heat exchanger efficiency.

Even if the concept of this reactor is already nearly out of date at the end of the experimental campaign, some future investigations would remain interesting: i.e. study deeply the connection off the prototype to the building ventilation without any additional ventilation.

## 6. Acknowledgements

This research was conducted in the SOTHERCO project (FP7 – Grant agreement n°295775) with following partners: Be-Sol (Coordinator, Belgium), UMons (Belgium), AIT (Austria), UVSQ (France), CEA/INES (France), ULB (Belgium), ULiège (Belgium), CLIPSOL (France). The prototype was mainly developed, built and installed in the laboratory by Be-Sol (Gilbert Descy, Michel Beeckmans, Alexandre Descy, Léon Chalon, Ludovic Polomé).

## 7. References

D'Hondt, M. (2016). *Expérimentation d'un stockage solaire thermo-chimique*. (Master en Sciences et Gestion de l'Environnement Master Thesis), Université de Liège, Arlon.