# Experimental and Theoretical Analysis of Thermal Energy Storage with Magnesium Chloride as the TCM

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**Abstract:** Thermal energy storage is essential for various applications. Periodic or intermittent heat sources like solar energy and process waste heat etc can be of good use when they are stored efficiently. Thermo chemical storage materials, in this aspect, provide much higher storage capacities per mass or volume compared to sensible or latent heat storage. Moreover, thermo chemical storage materials can store the heat for infinite time without insulation and are regarded as a key technology for heat transport and long term storage. In this paper theoretical and experimental analysis of thermal energy storage performance of Magnesium Chloride has been done. Making of an efficient, compact and practical reactor was the core idea of the work. The paper also presents the results obtained by testing the thermo chemical storage reactor under various conditions.

## Introduction

Thermo-chemical storage is an indirect way to store heat. The heat is not stored directly as sensible or latent heat but by way of a physico-chemical process like adsorption or absorption that consumes heat in charging mode and releases heat in discharging mode. For chemical storage, heat is required in an endothermic process to split compounds into several products. For a cyclic process, the products of the reaction or sorption process have to be reconverted to the original compound in an exothermic reaction, where heat can be utilized for the load. The exothermic reaction is generally at a lower temperature than that of the endothermic reaction. Many compounds result in products that can be stored over long periods without significant energy losses, making long term heat storage possible.

A thermochemical TES cycle, like other types of TES, includes three main processes: Charging: Thermal energy is absorbed from an energy resource and used for dissociation of the thermochemical material. This process is endothermic.

Storing: Products of the charging process are separately stored.

Discharging: Stored materials are combined and the stored energy is recovered via an exothermic process. The most important advantages of thermochemical TES systems over other types of TES are low heat loss during the storing period, rendering thermochemical TES systems especially suitable for long-term energy storage, and the potential for more compact energy storage since thermochemical materials have higher energy densities relative to PCMs and sensible storage media.

## Theoretical Analysis

In theoretical investigation the system consists of a working fluid and a thermochemical material. Energy from an energy resource (e.g. solar energy collected via a solar thermal collector) is transferred to a working fluid. This thermal energy provides the necessary energy for dissociation of the thermochemical material. After a storing period, energy released from synthesis of thermochemical material is absorbed by the working fluid for heating purposes (e.g. domestic hot water heating, space heating).

The assumptions are

1. Chemical reactions within the reactor occur at constant pressure.
2. Work interactions into and out of the control volume are neglected, implying that pump, compressor and fan work terms are neglected, as kinetic and potential energy terms are neglected.
3. In the charging process, the initial temperature of the thermochemical material is assumed to be that of the reference environment.
4. There are no energy losses during the storing period and thermochemical materials are stored at the reference-environment temperature.

### Energy balance for charging

Energy input – Energy output = Energy accumulated

$$Q_{in} = m_{wf}C_{pwf} (T_1 – T_2)$$

$Q_{in}$ is the Net energy input
m is the mass of working fluid
Cp is the specific heat of working fluid
$T_1$ and $T_2$ are the initial and final temperatures of the working fluid.

The charging process includes three steps. The first step is preheating the thermochemical material from its initial temperature to the dissociation temperature. The second step is the thermochemical reaction in which the energy of the thermochemical material increases by an amount equivalent to the enthalpy of reaction. The third step involves cooling after the reaction from the reaction temperature to the reference-environment temperature, which is the temperature at which it is assumed the thermochemical materials are stored
The energy balance becomes
$m_{wf}C_{pwf} (T_1 – T_2) - Q_L = \Delta H$
Where $Q_L$ is the net eat loss and ΔH is the change in enthalpy during charging.

The energy efficiency of the charging process is the ratio of energy gained by the thermochemical material to the net energy input.

$$\eta_c = \Delta H/ m_{wf}C_{pwf} (T_1 – T_2)$$

**Storing process**

Assuming no or negligible energy loss during storing then the energy accumulated is equal to energy stored. According to this assumption the energy efficiency of the storing process equal to unity.

**Discharging Process**

Considering the energy accumulation is negative for an exothermic reaction the energy balance for discharging becomes,

-[Energy recovered + Heat loss] = Energy accumulated

And energy efficiency for discharging is the ratio of energy recovered to the energy released in the reactor.

$$\eta_d = m_{wf}C_{pwf} (T_2 – T_1)/ \Delta H_d$$

$\Delta H_d$ is the energy released in the reactor or enthalpy of formation.

First $MgCl_2.6H_2O$ has been taken for the analysis, this material has to preheat upto $77^0$C to initiate the reaction. During the first reaction two water molecules escapes from the bond.

$$MgCl_2.6H_2O \rightarrow MgCl_2 . 4H_2O + 2H_2O$$

This reaction takes place at $77^0$C and we can easily achieve this temperature by a conventional solar collector. The energy efficiency for charging process has been found (86% approx.). The theoretical energy density of this material is found to be 1.03 $GJ/m^3$.

**Experimental Analysis**

Figure. 1 Experimental setup.

The experimental analysis includes only the charging and discharging behaviour of the selected TCM. The temperatures are measured by thermocouples and the humidity was measured by a digital hygrometer. The hot air is supplied by a hot air gun which can adjust both the temperature and flow rate.

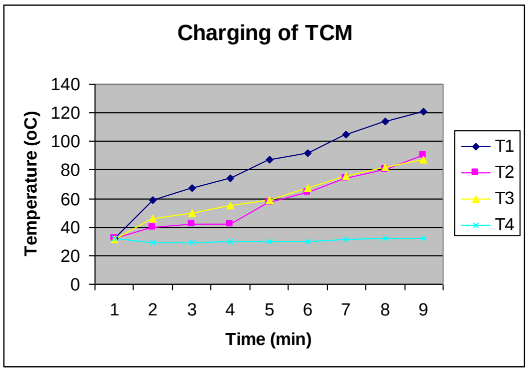


Figure 2: Charging process in open reactor

Figure 2 shows the charging process of the TCM in an open reactor ie. The reactor is open to the atmosphere. The temperature of the material during charging increases up to a maximum of $120^0$C at the bottom of the reactor, but at the top side there is no considerable increase in temperature of the material. This is because of the top layer of the material continuously reacting with the moisture content of the atmosphere at the temperature just above the ambient temperature.

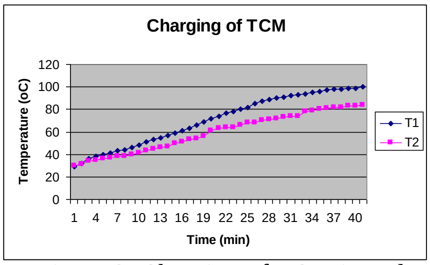

Figure 3: Charging of TCM in a closed reactor

The charging of the TCM in a closed reactor shows (Figure 3) the rise of the temperature in the outermost layer of the material. From this it is clear that the charging process is more efficient in closed reactors.

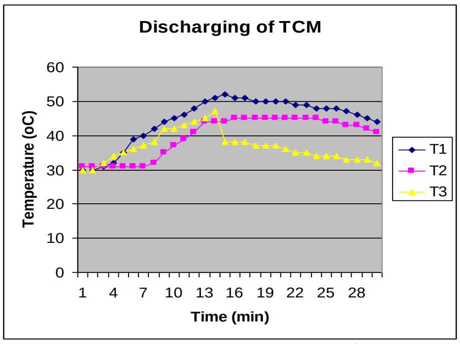

Figure 4: Discharging of TCM

The discharging of TCM was analysed by supplying cold air by a blower, the inlet temperature was $30^0$C and the experiment duration was 30 minutes. The maximum temperature obtained was $54^0$C after 13 minutes then the temperature gradually decreases. The efficiency loss may due to the leakage of air into the reactor.

## Conclusion

A theoretical investigation is done about the energy storage density of $MgCl_2.6H_2O$ and the hydration reaction of $MgCl_2.4H_2O$. The heat liberated during the hydration reaction depends on the vapor pressure of the humid air flowing through the material and it also varies along with the temperature. This is due to the fact that the adsorbance capacity is varies with factors above mentioned. The heat that could be recovered is lesser than the heat that was supplied. So there is a requirement for optimizing the parameters that affect the heat liberation so as to obtain the maximum possible.

- Analytical investigation shows the suitability of solar energy for charging the TCM
- Experimental analysis gives an insight to the factors affecting the charging and discharging process.
- Investigation of the role of various factors in the performance of a TCM is very important.

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