ISSN (Print): 0974-6846
ISSN (Online): 0974-5645
Indian Journal of Science and Technology, *Vol 11(28), DOI: 10.17485/ijst/2018/v11i28/130797, July 2018*

Experimental Study on Optimised Composition of Water based Nitrate Salt Solution for Sensible Heat Storage

Sumit Kumar Jangra and Gyanendra Singh Goindi

Department of Mechanical Engineering, Chandigarh University, Mohali - 140413, Punjab, India; sumitj6@gmail.com, hod.me@cumail.com

Abstract

Objective: To find out factors like specific heat, heat capacity and heat loss. **Method/Analysis:** Sodium nitrate (NaNO3) is mixed in water with different weight quantity like 100g, 200g, 300g last 600g and potassium nitrate (KNO_3) is mixed in water with weight quantity 100g, 200g, 300g and 400g. **Findings:** Total heat holding storage is more in $NaNO_3$ than KNO_3, but KNO_3 has better energy holding capacity. But KNO_3 is reached saturation point in 1 litter water while $NaNO_3$ went up 600g without reaching saturation. **Novelty/Improvement:** Results shows big molecule has low heat capacity and more Total heat or energy holding storage.

Keywords: Energy Holding Capacity (EHC), Potassium Nitrate (KNO_3), Sodium Nitrate ($NaNO_3$), Sustainable Development, Thermal Capacity (TC), Thermal Storage Fluid System

1. Introduction

Storage of thermal energy is more imperative in many engineering applications. As known, among the real-world problems convoluted in solar energy systems is the need for an actual means by which the spare heat collected during eras of bright sunshine can be stored, well-maintained and later released for consumption during the night or further periods. Similar problems ascend for waste heat recovery systems where the unwanted heat availability and employment periods are different. Heat storage can also be useful in most types of buildings where heating needs are substantial and electricity rates consent heat storage to be cheap with other forms of heating. There are various types of commercially existing systems, and numerous new enlargements in the technology are taking place. Therefore, the scope of this paper is to appraisal sensible heat storage methods for space and water heating applications. Nowadays most of the researcher focus on molten salt storage. This is good but its only we can use in high grade thermal energy. Some of previously done researcher as follows.

One of the researcher using PCM for lowering the heating and cooling demand as required. Its finding of this review is consolidation of the PCM based thermal storage systems have great potential to replace energy expended systems and delivers the efficient energy unadventurous system[1]. In this research nitrate salt-water is the candidate of storing heat. Some of them using river send for making appropriate for high temperature thermal energy storage in Concentrated Solar Power Plants and it observed 1087° and 1041 J/kg/K average heat capacity and this is used for high grade thermal storage[2]. This paper represented low grade thermal energy storage. One of researcher conduct experiment with two-pass solar air collector with thermal storage[3].

The application of low grade thermal energy with the use of adsorption system are simply thermodynamic system based on heat exchanger[4]. They try to improved present thermodynamic system[4]. The valuation of thermal properties of various PCMs, methods of heat transfer enrichment and design conformations of heat storage facilities like solar passive and active space heating[5]. Results were not as expected. One of researcher performed experiment for thermal stability of eutectic mixture ($LiNO_3$-$NaNO_3$-KNO_3) of nitrates[6]. They only try to calculate some property like melting point and solidification point. And one evaluates the melting point and thermal stability of conventional salt systems. And evaluate the physical and chemical properties by Differential Scanning Calorimetry (DSC)[7]. They didn't express the applications. One of the research conduct by two molten solar salt ($NaNO_3$ and KNO_3) and HitecXL (ternary salt $Ca(NO_3)_2$, $NaNO_3$ and KNO_3) for reducing electricity cost[8]. This research is good but its costly and not use for low grade thermal energy storage system. Few researches presented by thermodynamic cycles like Organic Rankine Cycle (ORC). In which important candidate is Refrigerant and turbines[9]. This is also costly process. Solar pond is also part of thermal energy storage system one of Istanbul university conduct research on solar pond. In which they conduct three-zones names the upper convective zone, the non-convective zone and the lower convective zone all zones are solved analytically and numerically[10]. The result attained by Analysis not experimental. One of researcher used a steam accumulators and molten salts for Thermal Energy Storage system for conducting electricity and they comparison TES calculation with different types of Rankine cycles[11]. This process concentrates on high grade thermal energy with molten salt.

This experiment performed to check salt-water mixture is feasible to low grade heat energy system. In which salt is added with base water in different mass quantity to notice change in various thermos-physical properties. If this is possible then this system is implying all low-grade heat storage system like car radiators, centralised Air-conditioning etc.

2. Experimental Setup and Methodology

Figure 1 shows the experimental setup for thermal energy capacity. Apparatus of this experiment is two concentric Aluminium vessel of 2 mm thickness each with 230-watt heating coil is fitted in a lid of aluminium vessel. End of heating coil cover with silicon for avoid electricity to the system and for temperature measurement using K-type thermocouple probe is fitted inside entering via lid. For showing salt-water mixture process like fault (if any), boiling etc. small window made up of acrylic sheet.

In the experiment salt were added in equal quantities start with 100gm till salt reach their saturation point. This mixture heated gradually at its boiling point. Time was noted down for every 1-degree temp ride till boiling point.

Figure 1. Experimental Setup.

For check Energy holding capacity calculation changed the lid of this container without any attachment. Main vessel same as before after this case too time was noted down for every single degree of temp drop.

3. Results

The objective of this experimental study is to find water-based nitrate salt mixture use as a Low-grade thermal storage system. Main factors based on this experiment is following:

- Specific Heat Capacity, 'Cp'
- Energy Holding Capacity
- Heat Loss (Q_{loss})

3.1 Specific Heat Capacity, 'Cp'

Specific heat is defined as any system is the amount of heat required to raise one per degree Celsius temperature. The Temp vs. Specific Heat graph for water, $NaNO_3$ & KNO_3. Variation in the value of Cp can be easily & distinctively seen. Fluid system was heated gradually from 50°C till its boiling point. Values of time were noted for 1 degree of temp rise & Specific Heat Cp were calculated using following formula:

$$Q = m \times C_p \times \Delta T$$

$$C_p = \frac{Q}{m \times \Delta T}$$

When compared for 100gm addition of salts in 1 Lit of water KNO_3 has more value of Cp than $NaNO_3$ & water has the maximum Cp. But, its $NaNO_3$+ Water which has the maximum boiling point & water with the least. Difference in boiling points of two salt mixture for 100gm addition is very less.

For next 3 levels of experiment with 200gm, 300gm & 400gm addition of salts in water results were more distinctive & clear. Results indicate that in every case $NaNO_3$ has more Cp, more boiling points & without a doubt more heat input capacity or Heat Capacity shown in Figure 2. Also, Cp of $NaNO_3$ is always less than that of water in every case, which in fact only improves the situation since it's easy to provide more energy in less time & overall heat capacity increment is seen by rise in boiling point. Moreover, KNO_3 reached its saturation point at 400 gm & 30°C, but $NaNO_3$ didn't reach saturation at even 600gm addition. Further addition of $NaNO_3$ beyond 600gm wasn't done, but the system didn't reach its saturation.

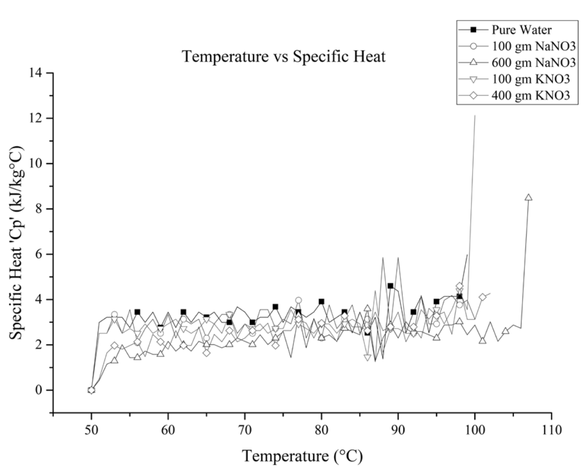

Figure 2. Shows the Temperature vs. specific heat graph.

3.2 Energy Holding Capacity

One more important factor which effects overall efficiency of Thermal Energy Storage System is its ability to hold the energy given into it. A good Thermal Energy Storage System is the one which can hold energy for longer duration of time as a function of drop in temp.

For testing the test fluid was poured in the equipment & K-Type digital thermocouple was utilised for noting temp decrement. Results indicate that rate of cooling is more for $NaNO_3$ than KNO_3 implying, that $NaNO_3$ lacks in energy holding capacity. As the size & atomic weight of molecule increases its holding capacity is increased shown in Figure 3.

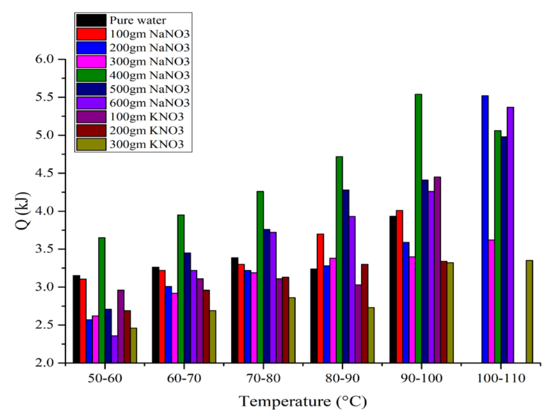

Figure 3. Shows the Temperature vs. Heat capacity graph.

3.3 Heat Loss

Heat loss is a measure of the total transfer of heat through the Aluminium of an aluminium vessel from inside to the outside, either from conduction, convection, radiation, or any combination of the these. Figure 4 shows the result of heat loss during cooling of nitrate salt solution. As environmental condition this is the very impressive result as estimated. As experimental result 100, 300 gm $NaNO_3$ is good as comparison KNO_3 and water due to the large molecular size as KNO_3 that's why sodium nitrate cooling time is more than others.

Energy loss equation:

$$Q_{loss} = \frac{\left(T_f - T_{atm}\right)}{\left(68.86686775\right)}$$

$$T_f = \textit{final temperature when cooling start}$$

$$T_{atm} = \textit{atmospheric or outer temp during experiment}$$

$$Q_{loss} = \text{Heat Loss}$$

4. Conclusions

This study investigated the feasibility of a mixture of (Nitrate salt + Water) as a possible Thermal Energy Storage system for low grade waste heat recovery. Two different types of salts utilized for experiments were $NaNO_3$ & KNO_3. Reason for selecting these two was their low cost & huge difference between their atomic size. Based on performed experiments following conclusions can be drawn out:

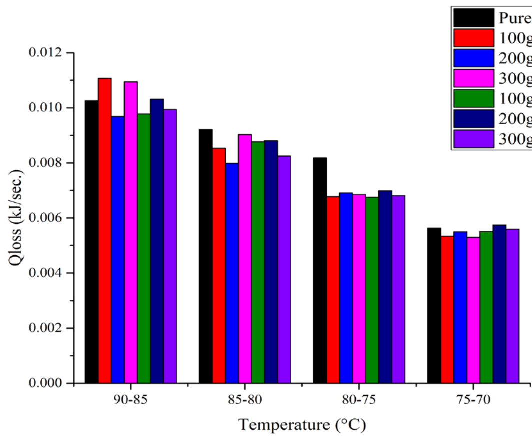

Figure 4. Shows the temperature vs. heat loss graph.

- This nitrate salt-water-based mixture is feasible in thermal energy system.
- As the atomic size of salt increases specific heat of mixture decreases & overall energy storage capacity decreases. But temp increment of system is faster.
- Every nitrate salt-water mixture specific heat capacity lower than pure water.
- As for energy holding capacity KNO_3 has shown better results than $NaNO_3$. Its reason only atomic weight of this molecule. As basic concept increases molecule size and weight then its continuous motion decreases and it provide better holding capacity.

After successful experimentation this is the proof such a system is feasible and has able to increase thermal storage capacity. And its proving if molecule is small it has more heat transfer rate.

5. References

1. Jaykumar PH, Darji HP, Qureshi NM. Phase Change Material with Thermal Energy Storage System and its Applications: A Systematic Review. Indian Journal of Science and Technology. 2017; 10(13):1-10. https://doi.org/10.17485/ijst/2017/v10i13/112365.
2. Lalitha RP, Salim S, Vaishnu B, Vijaya C. Study on Characterization of River Sand as Heat Storage Medium. Indian Journal of Science and Technology. 2016; 9(30):1-10. https://doi.org/10.17485/ijst/2016/v9i30/99010.
3. Mishra PS, Shrivastava V. Experimental Investigation of One Glass Cover and Three Absorber Plates Two-Pass Solar Air Collector with Thermal Storage. Indian Journal of Science and Technology. 2017; 10(19):1-10. https://doi.org/10.17485/ijst/2017/v10i6/86164 https://doi.org/10.17485/ijst/2017/v10i19/112984 https://doi.org/10.17485/ijst/2017/v10i24/110791 https://doi.org/10.17485/ijst/2017/v10i19/113836 https://doi.org/10.17485/ijst/2017/v10i29/112447 https://doi.org/10.17485/ijst/2017/v10i31/113854.
4. Wang RZ, Xia ZZ, Wang LW. Heat transfer design in adsorption refrigeration systems for efficient use of low-grade thermal energy. Energy. 2011; 36(9):5425-39. https://doi.org/10.1016/j.energy.2011.07.008.
5. Murat K, Khamid M. Solar energy storage using phase change materials. Renewable and Sustainable Energy Reviews. 2007; 11:1913-65. https://doi.org/10.1016/j.rser.2006.05.005.
6. Rene IO, William E. LiNO3–NaNO3–KNO3 salt for thermal energy storage: Thermal stability evaluation in different atmospheres. Thermochimica Acta. 2013; 560:34-42. https://doi.org/10.1016/j.tca.2013.02.029.
7. Viillada C, Bolivar F, Jaramillo F. Thermal evaluation of molten salts for solar thermal energy storage. International Conference on Renewable Energies and Power Quality (ICREPQ’14). Cordoba (Spain). 2014; 1(12):1-5. https://doi.org/10.24084/repqj12.431.
8. Kearny D, Herrmann U, Nava P. Assessment of a Molten Salt Heat Transfer Fluid in a Parabolic Trough Solar Field. Journal of Solar Energy Engineering. 2003; 125(2):1-7. https://doi.org/10.1115/1.1565087.
9. Hung TC, Wang SK. A study of organic working fluids on system efficiency of an ORC using low-grade energy sources. Energy. 2010; 35(3):1403-11. https://doi.org/10.1016/j.energy.2009.11.025.
10. Kurta HS, Haliceb F, Binarkc AK. Solar pond conception - experimental and theoretical studies. Energy Conversion & Management. 2000; 41:939-51. https://doi.org/10.1016/S0196-8904(99)00147-8.
11. Roubaud GE, Osorio DP, Prieto C. Review of commercial thermal energy storage in concentrated solar power plants: Steam vs. molten salts. Renewable and Sustainable Energy Reviews. 2017; 80:133-48. https://doi.org/10.1016/j.rser.2017.05.084.