International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 09, RTMSE-2026

Impact Ethylene Glycol and Water Mixture on The Holding Time of Stored Products in Refrigerated Space

(RTMSE-26_07)

Rajinder Kumar
Mechanical Engineering Department
Panipat Institute of Engineering and Technology
Samalkha, India.
rajinderror86@gmail.com

Vishal Dabra
Mechanical Engineering Department
Panipat Institute of Engineering and Technology
Samalkha, India.

Ranjan Chaudhary
Mechanical Engineering Department
Panipat Institute of Engineering and Technology
Samalkha, India.

***Abstract*—To maintain the quality of perishable products, it is essential to store and transport them at low temperatures. Typically, chilled and frozen products are kept between -18 to 15 ºC. This work aims to maintain low temperatures in the refrigerated space for a long-time duration, during power failure. There is continuous heat gain from the surroundings through insulated walls due to temperature differences. An experimental setup was fabricated using a conventional refrigeration system (Vapor Compression Refrigeration) and a layer of PCM inside the refrigerated space. In this research, results are obtained experimentally by providing a PCM-filled cavity around the refrigerated space. There is continuous heat gain from the outside environment through insulated walls due to temperature differences. Additionally, intermittent door openings can introduce warm and humid air into the refrigerated storage space, leading to additional heat gain. The mixture of ethylene and water is used as PCM. During experimentation percentage of the Ethylene glycol in the Ethylene glycol–water mixture is varied. It is observed that a 40% ethylene glycol and 60% water mixture showed the best results as enhancement of the duration for the low temperature inside the cooling space by 325 min.**

Keywords*—: *TES, PCM, Holding time, Energy Consumption

I. INTRODUCTION

TES can be a viable solution to fulfill the demand for energy in the refrigeration sector [1, 2]. It is a passive way of refrigeration. Heat energy can be stored in a material and can be used whenever a power failure occurs. TES is possible by three methods: sensible, latent, and chemical heat storage methods [3, 6]. In the sensible heat storage method, heat is stored by rising temperature without transforming the phase of the material. The sensible heat accumulated by a material is given as follows:-

$$Q_{Sensible}=\int_{T1}^{T2} Cp.\,dT$$

PCMs are widely employed for TES because they possess high energy density, which makes them advantageous for TES in systems [16]. The PCM must have a phase transition temperature within the storage temperature range [5]. For the given temperature rise (ΔT=T2-T1) heat accumulated in a PCM is computed as follows:-

$$Q_{Latent} = \int_{T1}^{Tpc} Cp,s.\,dT + \Delta Hpc + \int_{Tpc}^{T2} Cp,l.\,dT$$

In the Chemical heat storage method, heat is accumulated by a reversible thermo-chemical reaction. It can be represented as:-

X + HEAT ↔ Y + Z

In the first phase, the charging phase, due to heat absorption (Endothermic reaction) chemical X is transformed into two new chemicals Y and Z. Simultaneously these two obtained chemicals are kept in two separate vessels. In the second phase, the discharging phase, chemical Y reacts with chemical Z to transform back into the initial chemical X while librating the storage heat (Exothermic reaction).

The appreciable values of heat storage density and power capacity during the charging and discharging phase are the vital characteristics of any storage system, which results in the superiority of the Latent Heat energy storage method compared to the Sensible Heat Storage method [7, 8]. Although the Chemical Heat storage method provides the highest energy storage density, it is still at an early stage in terms of research and development. In Latent Heat Storage, PCM is used, which is a substance with a high latent heat of fusion. By melting and solidifying at a certain temperature, PCM is capable of storing and liberating huge amounts of heat energy [10, 11]. Latent heat storage in PCMs can be attained through solid-liquid, solid-vapor, and liquid-vapor phase transitions [13]. However, solid-liquid phase transition is primarily used for PCMs, as liquid-vapor phase transition is not feasible due to the huge volume or high-pressure requirement for material storage in their vapor phase [9, 14]. PCM is preferred for its chemical stability, low cost, non-

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 09, RTMSE-2026

toxicity, non-corrosiveness, large latent heat per unit mass, non-flammability, and non-explosiveness [4, 12]. In our experiments, water (H2O) and ethylene glycol mixture is used as the PCM, which possesses most of these desirable properties.

II.EXPERIMENTAL SET-UP

In this experimental setup, the main components are a cold chamber operating on the Vapor Compression Refrigeration (VCR) System and a Data Acquisition System (DAS). A cavity surrounds the storage space, which can be filled with PCM. This cavity is covered by polyurethane foam (PUF) insulation on the outer side. The evaporative coil is located inside the PCM cavity and is coiled around the chamber for stored items, as shown in Figure 1.

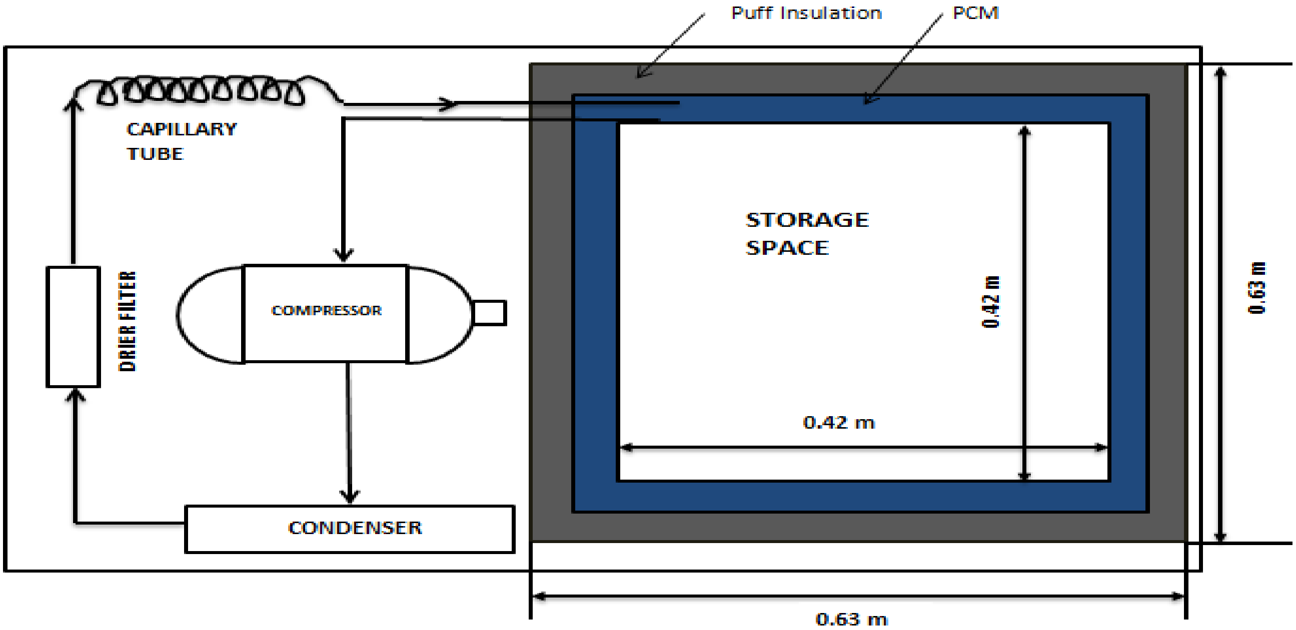

Fig.1 Cold Storage Chamber

The experimentation is conducted first without filling any PCM in the cavity and then after filling the cavity with PCM. The effects of TES were evaluated in terms of holding time and additional energy consumption. Holding time is defined as the time taken by the stored item to reach a temperature at which the deterioration of its quality is assumed to begin [15]. An Arduino-based Data Acquisition System (DAS) was used to measure and record the atmospheric and chamber temperatures.

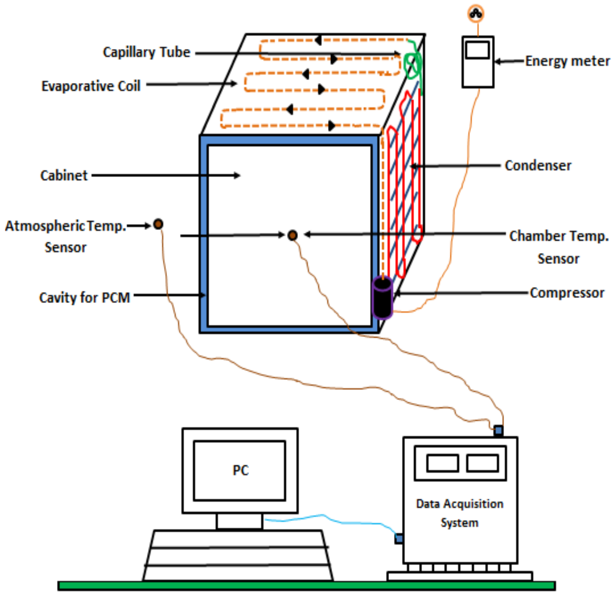

Fig.2 Data Acquisition System

III. RESULTS AND DISCUSSIONS

A. Experiment without PCM

In this experiment, the cavity was not filled with any PCM, and only air was present in the cavity. The temperature of the chamber was reduced to -10 °C, and then the refrigerator was turned off. The refrigerator consumed 2.13 kWh of electricity. The time was then recorded until the chamber temperature rose to 0 °C. The holding time of the water stored in the chamber was recorded as 385 minutes. The variation in atmospheric and chamber temperatures over time is presented in Table 1 and Fig. 2.

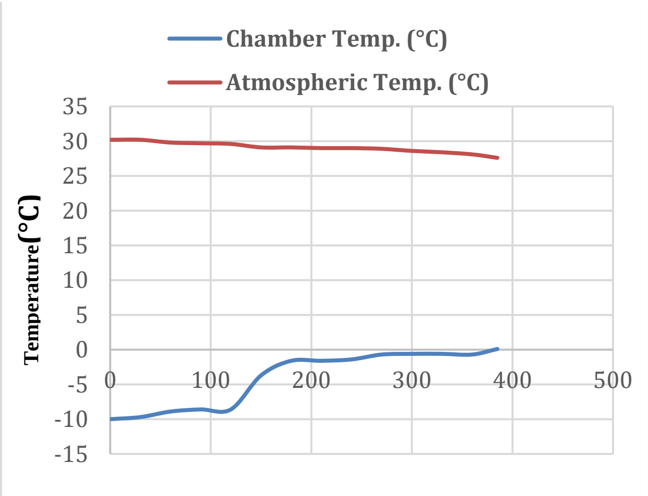

Fig. 2. Holding Time Without PCM

Table No.1. Holding Time Without PCM

Sr. No.	Time (Min)	Chamber Temp. (°C)	Atmospheric Temp. (°C)
1	0	-10	30.2
2	30	-9.7	30.2
3	60	-8.9	29.8
4	90	-8.6	29.7
5	120	-8.6	29.6
6	150	-3.7	29.1
7	180	-1.6	29.1
8	210	-1.6	29
9	240	-1.4	29
10	270	-0.7	28.9
11	300	-0.6	28.6
12	330	-0.6	28.4
13	360	-0.7	28.1
14	385	0.1	27.6

A. Experimentation Using Water as PCM

In this experiment, the cavity was filled with PCM. Similar to the previous experiment, the temperature of the chamber wasreduced to -10 °C, and then the refrigerator was turned off. The refrigerator consumed 4.98 kWh of electricity. The time was recorded until the chamber temperature rose to 0 °C. The holding time of the water stored in the chamber was recorded as 710 minutes. The variation in atmospheric and chamber temperatures over time is presented in Table 2 and Fig. 2.

Sr.No.	Time (Min.)	Chamber Temp. (°C)	Atmospheric Temp. (°C)
1	0	-10.6	28.4
2	30	-10.6	28.3
3	60	-10.3	28.6
4	90	-10.1	29.1
5	120	-9.7	29.5
6	150	-9.4	29.8
7	180	-9.2	29.7
8	210	-8.9	29.8
9	240	-8.5	30.2
10	270	-8.1	30.5
11	300	-7.8	30.9
12	330	-7.2	31.3
13	360	-6.7	31.7
14	390	-5.9	31.8
15	420	-5.3	31.7
16	450	-4.5	32.1
17	480	-3.6	32.4
18	510	-2.3	32.6
19	540	-1.5	32.9
20	570	-1.1	33.2
21	600	-0.9	33.6
22	630	-0.6	33.9
23	660	-0.4	34.1
24	690	-0.1	34.3
25	710	0.5	34.8

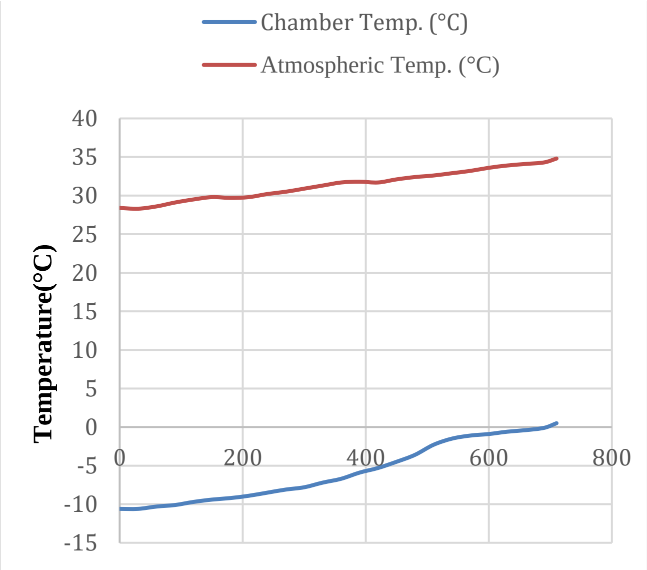

Fig. 2. Holding Time Without PCM

IV. CONCLUSION

Based on the recorded data, it can be concluded that the PCM improves the holding time, our primary concern, from 385 minutes to 710 minutes. This increase in holding time will help preserve the quality of the stored product for a longer period. Additionally, since the cavity is filled with PCM, the cooling capacity also increases, leading to higher electricity consumption, which increases from 2.13 kWh to 4.98 kWh.

NOMENCLATURE

PCM Phase Change Material

TES Thermal Energy Storage

REFERENCES

[1] Donhowe D.P., R.W. Hartel, "Recrystallization of ice during bulk storage of ice Cream International," Dairy Journal 6, (1996) 1209-1221.
[2] Ngapo T.M., I.H. Barbare, J. Reynolds, "R.F. Mawson, Freezing rate and frozen storage effects on the ultra structure of samples of pork," Meat science 53, (1999) 159-168.
[3] Phimolsiripol Y., "Shelf Life Determination of Frozen Bread Dough Stored under Fluctuating Temperature Conditions," Kasetsart Journal (Nat. Sci.) 43, (2009) 187-197.
[4] Leducq D., P. Schalbart, F. Trinquet, G. Alvarez, B. Verlinden, P. Verboven, S. Van Der Sluis, E. Wessink, F. Jay, M. Pirani,“ Thermal energy storage : a key technology for the food cold chain,”23rd IIR International Congress of Refrigeration, Prague, Czech Republic, Aug 2011.
[5] Zalba B., JoseM. Marin, Luisa F. Cabeza, Harald Mehling, "Review on thermal energy storage with phase change: materials, heat transfer analysis and applications," Applied Thermal Engineering 23, (2003) 251-283.
[6] Farid M.M., Amar M. Khudhair, Siddique Ali K. Razack, Said Al-Hallaj, "A review on phase change energy storage: materials and applications," Energy Conversion and Management 45, (2004) 1597-1615.
[7] Sharma A., V.V. Tyagi, C.R. Chen, D. Buddhi, "Review on thermal energy storage with phase change materials and applications," Renewable and Sustainable Energy Reviews 13, (2009) 318-345.
[8] Oró E., A. de Gracia, A. Castell, M.M. Farid, L.F. Cabeza, "Review on phase change materials (PCMs) for cold thermal energy storage applications," Applied Energy 99, (2012) 513-533.
[9] Ravikumar M., Dr. Pss. Srinivasan, "Phase change material as a thermal energy storage material for cooling of building." Journal of Theoretical and Applied Information Technology, (2008).
[10] Oró E., M.M. Farid, L.F. Cabeza, "Improving thermal performance of freezer using phase change material," International journal of refrigeration 35, (2012) 984-991.
[11] Oró E.,C. Barrenche, M.M. Farid, L.F. Cabeza, "Experimental study on the selection of phase change material for low temperature application," Renewable Energy 57, (2013) 130-136.
[12] Ahmed M.M., J. Kannakumar, P. Mallikaarjuna Reddy, "Design and fabrication of cold storage using phase change material," International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, (2013) 4277-4286.
[13] Groulx D., W. Ogoh, "Solid-liquid phase change simulation applied to a cylindrical latent heat energy storage system," Excerpt from the Proceedings of the COMSOL Conference 2009 Boston.
[14] Bhatt V.D., K. Gohil., A. Mishra, "Thermal energy storage capacity of some phase changing materials and ionic liquids," International Journal of Chemtech Research Vol.2, (2013) No.3, 1771-1779.
[15] Khan M.I.H., H.M.M. Afroz, "Diminution of temperature fluctuation inside the cabin of a household refrigerator using phase change material," International Journal of Recent advances in Mechanical Engineering (IJMECH) Vol.3, No.1, (2014) 43-52.
[16] Saini D.K., M. Chandershekara, “ Fabrication and investigation of stearic acid based thermal battery with water to enhance the heat transfer rate,’’ Journal of Energy Storage Vol. 81, (2024), 110333.