Performance Evaluation of PCM Lined Evaporator Based Deep Freezer for Storing Icecream

Srinivasa Rao Gampala, Shankar Halavath, Praveen Kumar Veginati, Susmitha Mandadi
Assistant Professors, Dept of Mechanical Engg, Swarna Bharathi Institue of Science and Technology, Khammam

Abstract— Ice cream is one of the most cherished consumer products, but is perishable and hence should be stored and served with utmost care from the stand point of quality. When Ice cream is exposed to temperatures above 10 °F (-12 ^{0}C), it becomes subject to adverse changes in body, texture and flavor characteristics. Typical storage temperature of Ice cream is 0 °F (-18 ^{0}C). The top brand sellers store ice creams in the night in a deep freeze refrigerator with backup power supply. In summer, it becomes all the more challenging with frequent and prolonged power interruptions. Ethylene Glycol based deep freezers are popular and are used extensively with a back up time of around 5 to 8 hours. Phase change materials are looked into for their advantage of less corrosive property and encapsulation feasibility compared to corrosive nature and flooded enclosure design adopted with ethylene glycol systems. In this work, performance of a 100 L deep freeze refrigerator, modified by enclosing evaporator with phase change material is reported. The phase change material (PCM) used in this investigation has a latent heat transformation temperature of -23 ^{o}C. With an identical load using water and pcm material combination of 16 kgs, a steady state temperature of -18 ^{o}C was maintained even when the power supply was interrupted for well over 24 hours. It was also observed that while the pcm lining inside the storage space can be very effective in maintaining required temperatures for a prolonged time, the cool down time will be proportional to the freezing characteristics of the entire mass of pcm. On the contrary the approach to enclose evaporator with pcm can be beneficial in faster cool down of the load.

Index Terms— Deep freezer, PCM enclosed evaporator, Phase change material, Poly Urethane Foam, Vapor Compression Cycle

1 INTRODUCTION

Thermal Energy Storage through Phase Change material is finding wide applications in the field of air conditioning and refrigeration. The specific use of this Thermal Storage has been for Energy Storage during low demand and release of this Energy during peak loads with potential to provide energy savings. Of late, the application of this type of Phase Change materials for domestic refrigeration application to save energy or operate during the power outage has been under active consideration (Pluss polymer presentation) (4, 2010).

Power outages are a common feature especially in summer in developing countries like India due to heavy demand from industries and unmatched power capacity. Hence PCMs are finding newer applications. One such is the ice cream freezers.

Proper handling and storage of ice cream and frozen desserts are essential to help consumers enjoy favorite treat to the fullest. Ice cream being a perishable product, it should be treated carefully. When frozen ice creams are exposed to temperatures above 10°F, they become subject to adverse changes in body, texture and flavor characteristics. All ice cream will be negatively affected if improperly handled or stored and hence improved systems are being developed. Glycol based deep freezers are in the market which can maintain temperature below zero degrees up to 8 hours. However to sustain storage temperature below 0 ^{0}F (-15 ^{0}C) needs a different strategy. This is where enclosing evaporator with a pcm with a freezing temperature of -10 ^{0}F is attempted.

2 MATERIALS

2.1 Phase change material

Phase change material (PCM) melts within a narrow temperature range, and absorbs a large amount of energy while in the transition state, thus minimizing the rise in the environment temperature.

PCM has high heat of fusion, hence while melting and solidifying at a certain temperature, it is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa. PCM with a suitable melting temperature may be used to provide thermal capacity to maintain suitable internal temperature during power failure.

For our investigations we have used PCM HS23N supplied by Pluss Polymers, India. The properties were listed in table 1. The PCM has a freezing point of - 23 0C. The PCM was used in the form of pouches of 300mmx 500 mm in size. Each PCM pouch weighs around 800 gm.

2.2 The experimental system

A deep freezer refrigerator (100 L) was specially fabricated incorporating phase change material pouches wrapped around the evaporator coils. The outer body of the deep freeze refrigerator is made of stainless steel with the dimensions of 20x26x42 inches. The system is a modification of a commercial deep freezer of 100 L capacity with ethylene glycol based encapsulation surrounding the evaporator coil. The conventional systems have back up time of 8 hrs. In the modification, the evaporator was covered with about 20 HS23N pouches (~17

Kg) and finally covered with puf insulation.

The amount of pcm was calculated based on the heat input to the space for the specific storage time interval of expected mass of the load for a typical load of 16 kgs. A 6 kg water and 10 kg pcm, an encapsulation quantity of 17 kgs was used. In a 100 L ice cream vending machine demonstration, using the pcm enclosed evaporator the storage time was 8 hrs.

2.2.1 Performance evaluation

The cool down characteristics of the system with no load and load as well as warm up characteristics were generated. The K type thermocouples were used to record the temperatures at the bottom, top surface and the load. The storage space was filled with 16 kgs of load and evaluated for cool down and warm up characteristics. The power supply was switched off after maintaining steady state for more than a day. The temperature was recorded using K type thermocouple. The data plotted as graph is as shown below.

The graph 1 & 2 show the comparative space temperature with no load and 16 Kg load during cool down of a conventional 100 L deep freezer and modified deep freezer with pcm encapsulation of the evaporator. The graph includes cool down characteristics of a load consisting of mixture of 8 kg water and 8 kg PCM HS23N.

The graph 3 shows warm up characteristics under no load and a load of the modified refrigerator.

2.3 Figures and Tables

Experimental results with PCM panels

SNO	Time(hr)	Tempera-ture(°C)	SNO	Time (hr)	Tem(°C)
1	0	-25	17	16	-9
2	1	-24	18	17	-8
3	2	-23	19	18	-8
4	3	-22	20	19	-8
5	4	-21	21	20	-8
6	5	-20	22	21	-8
7	6	-19	23	22	-8
8	7	-18	24	23	-8
9	8	-17	25	24	-8
10	9	-16	26	25	-7
11	10	-15	27	26	-6
12	11	-14	28	27	-5
13	12	-13	29	28	-4
14	13	-12	30	29	-2
15	14	-11	31	30	0
16	15	-10			

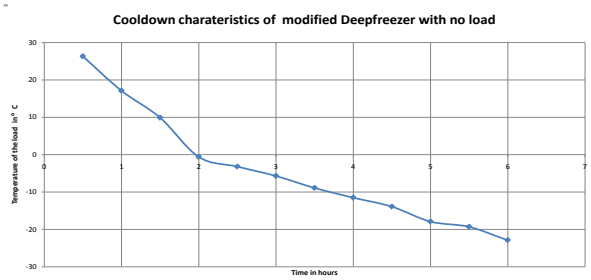


Fig1: Cool down characteristics of modified freezer with no load

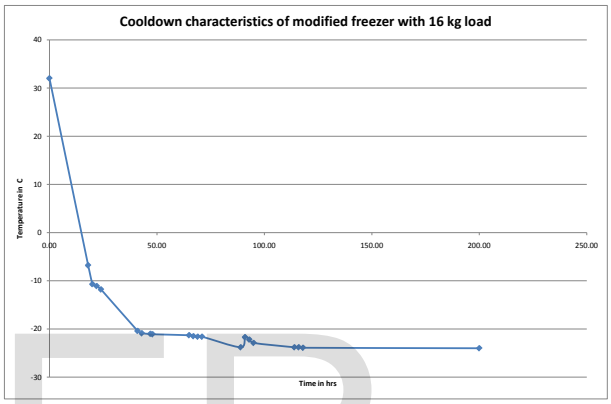
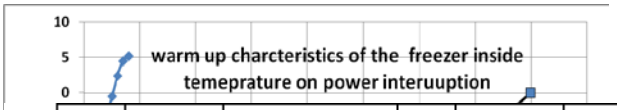


Fig2: Cool down characteristics of modified freezer with 16 Kg load



SNO	Time(hr)	Temperature(°C)	SNO	Time(hr)	Temperature(°C)
1	0	-25	7	6	-3
2	1	-22	8	7	-5
3	2	-19	9	8	-2
4	3	-13	10	9	0
5	4	-9	11	10	3
6	5	-8			

3 Conclusion

The air space temperature near the top was measured and plotted under no load and the load surface temperature was measured when evaluating load conditions. As shown in graph 1&2.

From the graph 1 it can be seen that cool down characteristics of modified deep freezer. It can be clearly seen that cool down char-

acteristics of the modified freeer is around 6 hours and the warm up of an empty system is also around 6 hours. This lag in cool down and warm up could be attributed to pcm enclosing the evaporator while conventional deep freezers warm up in about 2 hours.

How ever the loaded freezer performance is a clear indication of the advantage.

While loaded system takes about 40 hrs to reach -22, then almost steady state maintained for another 40 hrs before cool down to -23 degrees indicating phase change taking place of the PCM that is used as a load. It is also observed that cool down characteristics of the empty space could be cooled to -23 deg in about 6 hrs and the space also warmed up to 5 digress in about 4 hrs. The glycol based deep freezer of the model used for the modification warms up to zero.

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