# The Result Analysis of low temperature Refrigeration System with &without PCM

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***Abstract:*** *As the innovation is creating in the field of refrigeration and cooling, striking solace and saving are accomplished. Keeping up with the necessary low temperature and the expense is low. The principle point is to improve and broaden the self life. The low temperature is acquired generally by fume pressure refrigeration cycle, yet it has its own impediments in creating low temperature. Thus for low temperature creation different pressure double fume cycle is utilized. The idea is that the cooling delivered in first cycle evaporator is utilized to cool the condenser of second cycle, which lessens the cooling limit in condenser and empowers to create exceptionally low temperature for different cold stockpiling applications. Further the low temperature side cooling is given to a Phase Change Material (PCM) and the cooling is put away in PCM, this cooling is supported as long as 20 hours without activity of cycle, accordingly keeping up with the low temperature of the items even without persistent power supply. In this undertaking a parallel fume cycle is intended to create a temperature of $-20^0 C$.*

***Keywords:*** *Cascade, Phase Change Material, Refrigeration*

## I.    Introduction

Course refrigeration framework is a low temperature refrigeration framework and is utilized for exceptionally low temperature range about (- 40C to -130C).At such low temperature basic Vapor Compression Refrigeration Cycle (VCRS) isn't effective because of extremely high pressure proportion that further prompts high release issue and low volumetric efficiencies Whereas, course refrigeration is much productive for such conditions. Course refrigeration cycle is only just a mix of two VCRS cycles named as low and high temperature circuit that are consolidated together by a course condenser. This course condenser unit go about as evaporator for low temperature circuit and condenser for high temperature circuit, the low temperature circuit utilizes low bubbling refrigerants, for example, R23, R744 and so forth and high temperature utilizes high edge of boiling over refrigerants, for example, R717, R290, R404A, R1270, R507A and so on.

### Principle of cascade refrigeration system.

To condense refrigerants that are capable of achieving ultra-low temperatures that would not be able to condense at room temperature. This is achieved by using a low temperature evaporator of one system as the condenser the other, condensing and sub cooling the liquid before entering the metering device.

### Two Stage Cascade Systems:

A two-stage cascade refrigeration system uses two types of compressor devices, they run individually with different refrigerants, connected among them so that evaporator of first cycle used for cooling of second cycle condenser (i.e. the evaporator with the first unit cools the condenser of the second unit). In practice, an alternative approach using a common capacitor with a booster circuit to provide two separate temperature limits of the evaporator
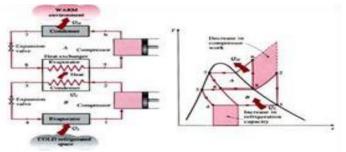


**Fig:1** Cascade system

### Cascade Refrigeration System Description

The cascade refrigeration cycle is a combination of two vapour compression cycles which utilizes two different refrigerants. The primary refrigerant flows from low temperature circuit evaporator to low stage compressor and condensed in cascade condenser which also acts as evaporator for high temperature circuit. The heat rejected from condenser of low temperature circuit is extracted by evaporator of high temperature circuit containing secondary refrigerant then, this secondary refrigerant gets compressed in high stage compressor and finally condensed to outer atmosphere. The desired refrigerating effect is occurred from evaporator of low temperature circuit. The temperature difference in cascade condenser is an important design parameter that decides the COP of the entire refrigeration system.
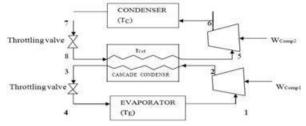
**Fig 2:** systematic cascade refrigeration cycle with evaporator, condenser and cascade condenser

### Advantages of cascade systems

☐   In cascade system using different refrigerants, so,

that it is possible to select a refrigerant that is best suited for that different temperature range. In the manner of Very high or very low pressures can be avoided foe extend.

□ In this system migration of lubricating oil from one
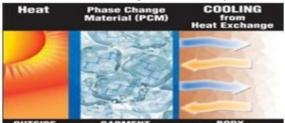


compressor to the other compressor is prevented.

□ The saving of energy is more because the system allows use of refrigerants that have suitable temperaturelimits characteristics for each of the higher-temperature side and the lower-temperature side.

□ It allows especially for stable ultra-low-temperature operation.

□ Repair and maintenance is easy.

## II.    Motivation for Present Work

1.  As the innovation is creating in the field of refrigeration and cooling, noteworthy solace and saving are accomplished. Keeping up with the necessary low temperature for the normal food we take will definitely diminish the expense, as this interaction should be possible when the accessibility is bounty and the expense is low.For the most part they are two methods for keeping up with the low temperature in the evaporator curl.
2.  To bring down the pressure from condenser outlet to expansion outlet as very low.
3.  To increase the heat rejection capacity in condenser at constant pressure.

**From case 1:**

□ If we decrease the pressure to very low from



condenser to expansion valve, it leads to there is a problem of flow of refrigerant in evaporator coil.(i.e. the refrigerant will not flow at vacuum pressure .so, that we should above atmospheric pressure from expansion outlet to evaporator outlet.

In typical course refrigeration framework the hotness exchanger is utilized for the exchange of hotness from low temperature cycle condenser to high temperature cycle evaporator. In heat exchanger the hotness move rate is exceptionally delayed for an extensive stretch

of time, it impacts on the exhibition of the framework as follows,

□ Decline in evaporator temperature.
□ Decline in refrigeration impact.
□ Absence of proceeds with supply of cooling water.
□ Slow hear move rate.
□ It will happen extensive stretch of time for getting lower temperature.

To conquer the above issues we are presenting another plan for course refrigeration framework; a siphon is presented between high temperature cycle evaporator and low temperature cycle condenser. Further the low temperature side cooling is given to a Phase Change Material (PCM) and the cooling is put away in PCM, this cooling is supported as long as 20 hours without activity of cycle, subsequently keeping up with the low temperature of the items even without nonstop power supply.

In this venture a twofold fume cycle is intended to deliver a temperature of – 20 $^0$C.

## III.    Phase Change Materials

The idea to use phase change materials (PCM) for the purpose of storing thermal energy is to make use of the latent heat of a phase change, usually between the solid and the liquid state. Since a phase change involves a large amount of latent energy at small temperature changes, PCMs are used for temperature stabilization and for storing heat with large energy densities in combination with rather small temperature changes. The successful usage of PCMs is on one hand a question of a high energy storage density, but on the other hand it is very important to be able to charge and discharge the energy storage with a thermal power, thatis suitable for the desired application. One major drawback of latent thermal energy storage is the low thermal conductivity of the materials used as PCMs, which limits the power that can be extracted from the thermal energy storage. A phase change material is defined as (PCM) is a substance with a high heat of fusion process in which, melting and solidifying at a certain temperature, and is capable of storing and releasing large amounts of heat energy. The Heat is absorbed or released when the material changes from solid state to liquid state and vice versa; thus, PCMs are classified as latent heat of storage (LHS) units system.

**Fig 3:** Phase change transformation.

**Selection Criteria Thermo dynamic properties.**
The phase change material should possess:

1.  In the desired operating temperature range Melting temperature should be available.
2.  They have high latent heat of fusion per unit volume.
3.  They should posses' High specific heat, high density and high thermal conductivity properties.

4. And they possess Small volume changes on phase transformation and small vapour pressure at operatingtemperatures to reduce the containment problem.
5. High congruent melting.

**Kinetic properties**
1. They should possess High nucleation rate for the avoid of super cooling of the liquid phase.
2. Process high rate of crystal growth, so that the system can meet demands of heat recovery from the storagesystem.

**Chemical properties**
1. Should maintain the Chemical stability.
2. Process Complete reversible freeze/melt cycle
3. It should have No degradation after a large number of freeze/melt cycle.
4. Process Non-corrosiveness, non-toxic, non-flammable and non-explosive materials.

**Economic properties**
1. Less cost
2. Plenty availability

**Ethylene Glycol**
    (IUPAC name: ethane-1, 2-diol) is an organic compound initially they have been used as a raw materialin the manufacture of polyester fibers and fabric industry, and polyethylene terephthalate resins (PET) used in bottling process. A small per cent is used in industrial applications like antifreeze formulations and other industrial products. It process odorless, colorless, syrupy, sweet-tasting liquid properties. Ethylene glycol is initially toxic, with children has been particularly at risk because of its sweet taste, and it became common to add bitter flavoring to consumer antifreezes containing it. Ethylene glycol is produced from ethylene (ethane), via the intermediate ethylene oxide. Ethylene oxide reacts with the water to produce ethylene glycol accordingto the below chemical action.

$$C_2H_4O + H_2O \rightarrow HO–CH_2CH_2–OH$$

**IV.        Objective Of Present Work**

● The goals of the presentation improvement of the course refrigeration framework by utilizing the stage change material (PCM) are given beneath,

● To create the exploratory set up by adjusting the course refrigeration framework as presenting the siphon in the spot of hotness exchanger with PCM based fridge.

● To cut down the framework up to **– 20 $^0$C**

● To lessen power utilization.

● To hold cooling impact for significant stretch of time without power supply.

● To look at the exhibition of single stage cycle with twofold cycle. To notice the framework with PCM and without PCM.

**Design And Experimental Studies**

Experimental study on a system helps to evaluate its performance experimentally under varying operating conditions. Comparing this performance with that of the theoretical studies help in understanding the acceptability limits. In this line, the performance of the designed cascade refrigeration system is studiedexperimentally.

    Test rig is cascade refrigeration system. Figure 6.1 shows the schematic diagram of the experimental setup. This test rig mainly consists of compressors, condenser, expansion devices, cascade condenser, evaporator, water pump and PCM.
This cascade refrigeration system is generally divided as two vapour cycles. These two vapour cycles are run byindividually, the cycles are
1) Higher temperature cycle
2) Lower temperature cycle

*Higher temperature cycle*
□ In high temperature cycle, the high-pressure gas from compressor flows through an oil separator where thecompressor lubricant oil and refrigerant are separated and oil is fed back to the compressor.
□ The high pressure refrigerant from the compressor entering into the air cooled condenser.
□ The condenser is cooled by fan which is run by compressor1.in condenser high pressure vapour refrigerantis converted into high pressure liquid refrigerant due to latent heat of evaporation.
□ This high pressure liquid refrigerant is entering into the expansion device, in expansion device throttlingprocess will takes place the pressure is reduced as condenser to evaporator pressure.
□ The low pressure liquid refrigerant is entering into the evaporator, where the liquid refrigerant takes theheat from the refrigerated space and converted into vapour



**Fig 4:** Working model of Cascade system

Refrigerant due to latent heat of evaporation, and this vapour refrigerant is entering into the compressor, andthen the cycle is repeated.

**Lower temperature cycle**
□ The working process of lower temperature cycle is same as higher temperature cycle, but the differences are as follows.
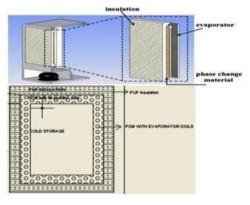
□ The lower temperature condenser is cooled by the higher temperature evaporator; which is achieved by keeping the pump between the higher temperature evaporator and lower temperature condenser.

□ The pump can supply the refrigerated water which is generated by higher temperature cycle to the lower temperature cycle condenser, where the heat transfer takes places from refrigerant which is flowing in the coils to the cooling water, and this cooling water is converted into hot water ,this hot water is again supplied to the higher temperature cycle evaporator by using pump.so ,in this way the cold and hot water is supplied in between high temperature cycle evaporator and lower temperature condenser by using pump.

### PCM



□ In this system the ethylene glycol is used as a phase change materiel.

□ The PCM is incorporated between lower temperature evaporator coil and refrigerated space.

□ Initially the PCM is in liquid state, the refrigerant which is flowing in lower temperature evaporator givescooling to the PCM.

The PCM can stores this cooling for a long period of time and extract the heat from the refrigerated space. Temperatures at various locations were measured using digital thermo meter. Various locations at which temperature was measured are shown in Table 1.



### Different pressures
□ Discharge pressure of compressor
□ Suction pressure of compressor
□ Pressure at the outlet of condenser
□ Pressure at the capillary tube outlet Specifications of the Components:

The design details of the model are as follows:
Mass of refrigerant (R134a) (m) = 250grm.
In both cycle

### Compressor details Used in both cycles
We use Reciprocating piston type compressor.
□ Phase 1
□ Speed= 2850 R.P.M
□ Volts= 160/250
□ Temperature = 40˚C

□ Cycles = 50 Hz
□ Current = 4 A.M.

### Higher temp cycle (In Second Cycle)
□ A tank of GI Sheet capacity 15 Litres surrounded by PUF insulation

### Expander details
In first cycle
□ Diameter of capillary tube = 0.040 inch.
□ Length of capillary tube = 10ft.

In Second Cycle
□ Diameter of capillary tube = 0.036 inch.
Length of capillary tube =10FT Water Circulation Pump
We use centrifugal impeller type water circulation pump.
□ Capacity= 1/4H.P.
□ Head = 9M
□ Volts = 230V AC
□ Current = 0.6 AMP
□ Cycles = 50Hz Evaporator

In First Cycle
It is in the form of a tank of GI sheet of capacity 15 LitresLength of the evaporator coil = 25ft.
Diameter of the evaporating coil = 1/4 inch

In Second cycle
□ It is surrounded by PUF insulation in Ethylene Glycol solution mixed with water (1:3)
□ Capacity of cold storage 25 Liters.
□ Length of the evaporator coil = 30ft.
□ Diameter of the evaporating coil = 1/4 inch

To improve temperature stability during power loss in cold storage, the dimensions of vertical cabin as follows
□ 0.2794m H x 0.2794mWx0.325m D (11"x11"x11") and a storage volume of 25.7 L was used.
□ The PCM with Anodized aluminum panels (a ethylene glycol solution with a melting point of -20°C)

**Fig 6:** Schematic diagram showing incorporation of PCM and Insulation.
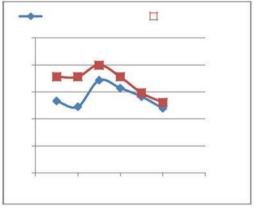
The evaporator coil and phase change material (PCM) are placed in one panel, the PCM will absorbs the energy from evaporator coil cools and stores this energy by changing its phase. During

power cuts or off peak time the pcm will releases its energy and cools and maintains the cold cabin at constant required temperature.

## V. Experimentation

The whole framework was pressure tried utilizing nitrogen gas compressing to 30 bar. The framework was left at that strain for a time of 24 hours. Framework was cleared utilizing a vacuum siphon. By adjusting triple vacuum strategy it was guaranteed that the non-condensable gases present in the CASCADE framework were eliminated. Vacuum was held for 24 hours lastly assessed amount of R134a in fluid structure was surged into the framework and guaranteed that air pocket isn't found in the sight glass while framework is at consistent state working condition**.**

**Experimental Procedure**

➢ Experimental procedure, which is carried out during the experiment, is given below:

1) Initially the first cycle is run till the evaporator temp becomes 0ºC, and then stopped were placed against the walls of the cold storage in the arrangement shown in Figure. The PCM is in an aluminium panels with a dimensions of 0.0254mx0.33xm0.38m (t×w×h) contained 3 liters of ethylene glycol and 12 liters of water as a PCM is occupying a volume of 4.735 L was used for experimental investigation. The PCM panels were placed vertically against the entire walls of the cold storage to minimize the amount of usable storage space lost as shown in Figure 1. The poly urethane foam is used for This PCM panels of dimensions 0.05mx0.43mx0.43m (txwxh). This foam materiel will reduce the heat transfer from outside to inside the cabin as shown



in figure.

2) Now simultaneously the second cycle and water circulation pump is started.
3) Circulation of water continuously cools the condenser of second cycle and hence performance increases.
4) All the Temperature, Pressure and timings are recorded with the help digital thermometers, Pressure gauges and stop watches respectively.
5) The second cycle is to be stopped after the temperature of cold storage reaches around -20ºC.
6) Without pcm, the time for temperature decrement in cold storage for every degree

centigrade is recorded, till the temperature reaches 0ºC.

7) With pcm, the time for temperature decrement in cold storage for every degree centigrade is recorded, till the temperature reaches 0ºC
8) Calculations are made for Refrigeration Effect, work done &COP for the binary cycle and single cycle.

## VI.Results And Discussion

After conducting experimentation the readings are noted and tabulated as follows. Table 2: Noted readings

**CALCULATION OF COP**
Without PCM panel:
COP= $Q_C$ / W Where,
W = Amount of power supplied.
$Q_C$ = Heat removed from the cold reservoir.
$Q_C$ = $mc_p$ dt
m= amount of water stored, i.e.0.5 kg
$C_p$ =Specific heat of water, i.e 4.2 kj/kg – $^0$c dt = Ti-Tf
Ti = Initial temperature of water, i.e.20 $^0$c
Tf = Final temperature of Water, i.e. .5 $^0$ c
Heat rejected Qc = $mC_p$ dt
$\qquad$ = 0.5×4.2×(20-5)

Therefore, power consumed = 230×1.5×0.857 = 295.665W
C.O.P = Heat removed from cold cabin/power consumed By compressor=1.33
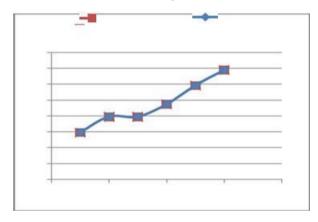
From the graph 1, for the case without PCM: it is evident that the COP is decreasing by increasing the load from 0.5 k to 1kg, and again the COP is increasing by increasing the load to 1.5 kg after that the COP is decreasing gradually by increasing the load. The Max COP obtained is 1.713 and is obtained at 1.5 Kg load. Also from the graph for the case with PCM: it is evident that COP is not changing by increasing the load from to 1kg, and again the COP is increasing by increasing the load to 1.5 kg after that the COP is decreasing up to a certain load. Finally from the graph with PCM panel, the maximum COP is found to be 1.994 and is obtained at at1.5Kg load. It is clear from the graph that COP with PCM is superior to COP without PCM at all tested loads. Especially it is observed that performance at lower loads COP with PCM is far higher than COP without PCM.
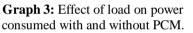
Graph 3 shows that power consumed is increasing with increase of load as expected. Also it shows that power consumed is same in both the cases either with PCM or without PCM. Using PCM does not affecting the power consumed, so only initial cost is the additional amount to be bared whereas the running cost is same even after using PCM.
The graph 4 shows the relation between the Time Vs Temperature with and without PCM panel for cascade system. From the graph for the case without PCM: it

is evident that the temperature is decreasing slowly with respect to time up to a temperature of -10 $^0$ C which takes a time of 3.6 hours, after that for fall of temperature from - 10 $^0$C to 0 $^0$C it takes a time of only 1.9 hours. Finally without PCM panel in cascade refrigeration systemfor getting a temperature from -20 $^0$C to 0 $^0$C, it takes totally a time of 5.5 hours the case with PCM: it is evident that the temperature is decreasing almost uniformly with respect to time from a temperature of -20 $^0$ C to 0 $^0$C . Finally in cascade refrigeration system with PCM panel, for getting a temperature from -20 $^0$C to 0 $^0$C, it takes totally a time of 14.5 hours. With this by using PCM panel we retain the cooling effect for a long period of time. The retained time using PCM is 2.63 times than that the retained time without using PCM.



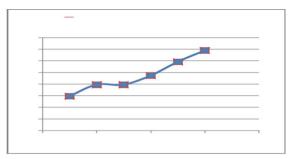**Graph 3:** Effect of load on power consumed with and without PCM.

The graph 4 shows the relation between the Time Vs Temperature with and without PCM panel for cascade system. From the graph for the case without PCM: it is evident that the temperature is decreasing slowly with respect to time up to a temperature of -10 $^0$ C which takes a time of 3.6 hours, after that for fall of temperature from - 10 $^0$C to 0 $^0$C it takes a time of only 1.9 hours. Finally without PCM panel in cascade refrigeration system for getting a temperature from -20 $^0$C to 0 $^0$C, it takes totally a time of 5.5 hours

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Calculations for Cascade (Binary) Cycle:

[1]. Cabeza, L.F., Mehling, H., Hiebler, S., Ziegler, F. (2002). Heat transfer enhancement in water when

From p-h Diagram
- □ h1=430 KJ / Kg
- □ h2a=470 KJ / Kg
- □ ha=420 KJ / Kg
- □ hb=450 KJ / Kg

### VII. Conclusion

After conducting tests on designed cold storage plant of cascade refrigeration system with and without phase change material(PCM), following conclusions are drawn.

- □ From the experimentation it is observed that in Cascade (Binary) refrigeration system the refrigeration effect can be increased by 27.7% as compared to single system for producing -20$^0$C in the cold storage.
- □ By using cascade system the actual work can be reduced by 33.3% as compared single system for producing -200C in the cold storage.
- □ Experimental results show that the coefficient of performance (COP) of cascade refrigeration system is higher than single refrigeration system.
- □ Experimental results shows that for fall of temperature from -200C to 00C without phase change material, takes 5.5 hours' time whereas the same by using phase change material it takes 14.5 hours' time. So with phase change material (PCM) panels at the walls of a cold storage, temperature can be retained for long period of time.
- □ Reduction of a temperature in a cascade cold storage plant using PCM panels has observed that reduction of 10C approximately for every one hour.
- □ Max COP of the refrigeration system using PCM is 16.4% higher than that of maximum COP of the system without PCM.
- □ Moderate load of 1.5Kg yields optimum performance of refrigeration system.

It is understood that present day due to intermittent power supply and power crisis it has become compulsory to have continuous cooling to the frozen items. It is also observed from the system that during power cut this method is cheapest when compared to all other alternate power source systems.

### VIII. References

used as PCM in thermal energy storage. Applied Thermal Engineering, vol. 22, p. 1141-1151.

[2]. Butala, V., Stritih, U. (2009). Experimental investigation of PCM cold storage. Energy and Buildings, vol. 41, no. 3, p. 354-359. [3]. Vakilaltojjar, S.M., and Saman, W. (2001). Analysis and modelling of a phase change storage system for air conditioning applications. Appl. Thermal Eng., 21, 249-263.

[4]. Omer, S.A., Riffat, S.B., and Ma, X. (2001). Experimental investigation of a thermoelectric refrigeration system employing a phase change material integrated with thermal diode (thermosyphons). Appl. Thermal Eng., 21, 1265-1271.

[5]. Riffat, S.B., Omer, S.A., and Ma, X. (2001). A novel thermoelectric refrigeration system employing heat pipes and a phase change material: an experimental investigation, Renew. Energy, 23, 313-323. Refrigerated Warehouse using PCM ethylene , Air Conditioning and Refrigeration Journal, China, April-June 2001.

[6]. Gupta, P., "Cooling Tower Impact Blade Modification on Energy Consumption", A Conditioning and Refrigeration Journal, New Delhi, October-December 2001.

[7]. Stulz Gmb, H., "Comfort Air Precision or Conditioning", Air Conditioning and Refrigeration Journal, Germany, January-March 2002.

[8]. GeorgeSze, Lek Siang Hwa., " HVAC hospital Design: A Challenge for Energy Recovery and Reliability System ", Air Conditioning and Refrigeration Journal. Singapore, July-September 2002.

[9]. Effect of phase change material on performance of a house hold refrigerator, MD Imran Hossaen Khan & Hassan M.M Afroz

[10]. B. Zalba, J.M. Marı´n, L.F. Cabeza, H. Mehling, Free-cooling of buildings with phase change materials, International Journal of Refrigeration.