

Pump-less Thermal Storage Systems

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Abstract

One of the biggest consumer of energy is the HVAC industry, catering to the cooling demand of both residential and industrial consumer. At a majority of sites over-sized units are installed to meet the peak load, which is not only economically disadvantageous but invariably leads to wastage of energy. Thermal Storage Systems (TSS) are a solution to such problems. TSS stores cold thermal energy in Phase Change Materials (PCM), during off peak hours and utilizes it during peak load time. Pump-less TSS (PLTSS) has a unique pump-less operation. This article explains this unique operation and discusses the tests performed with PLTSS using different PCMs.

The Need for Thermal Storage Systems (TSS)

A thermal storage system is an innovative way to store thermal energy, either cold or hot, in order to utilize it at a later time. A thermal storage system uses power during off peak periods or night time to store cold thermal energy in a phase change material as latent heat, which is then recovered during the peak load hours. TSS's operation flattens the peak demand and in places where

the night time tariffs are lower, thermal storage system can help make significant savings. Compressor running in night time cooler temperature will work more efficiently. Hence energy stored will be 'greener' [1], [2]. It can also be utilized as a backup to meet cooling loads during power cuts. This in turn eliminates the need for DG sets.

Energy Storage in Phase Change Material (PCM)

Within the context of TSS PCMs are substances which store energy in the form of latent heat. This is particularly attractive because large amounts of energy can be stored without any appreciable rise in temperature. Latent heat storage is 5-14 times more than sensible heat storage in mediums like water and masonry or rock [3]. Latent heat can be stored as solid-liquid, liquid-gas, solid-gas and solid-solid phase change process.

The liquid-gas and solid-gas process has high latent heat but owing to large volumes involved, the systems are complex and difficult to handle. Hence solid-liquid and solid-solid are of particular interest in TSS. [4], [5].

Various PCMs tested in different TSS

around the world include paraffin, non-paraffin organics, fatty acids, salt hydrates, and eutectics of organic and inorganic compounds [6]. Since water freezes at 0°C, for low temperature applications it can be used as energy storage material.

Pump-less TSS (PLTSS)

PLTSS is a unique thermal storage system which is designed to have a pump less operation.

Figure 1 illustrates the working of PLTSS. There are 2 refrigerant circuits connected to PLTSS, each using R-22 as refrigerant.

The red circuit connects the condensing unit to PLTSS. It operates during night or off peak period to freeze the PCM. This process is termed as "charging". The blue circuit illustrates the connection between PLTSS and a flooded evaporator. There are NO expansion valves or capillaries in this circuit. The cycle operates between two processes of evaporation and condensation.

About the Author

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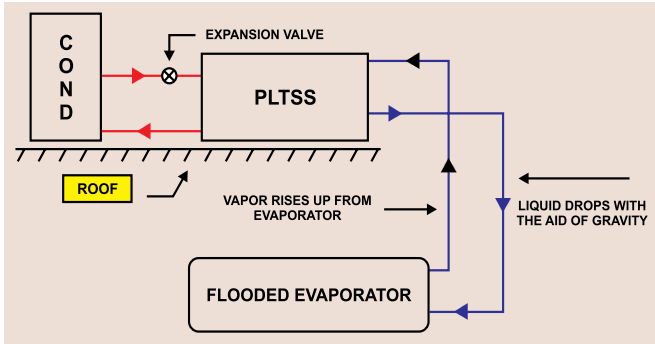


Figure 1: Layout of a system incorporating PLTSS

Refrigerant evaporated rises up into PLTSS where it condenses and rejects heat to PCM. The liquid refrigerant hence formed, aided by gravity drops back into the evaporator. This process of melting PCMs is called “discharging”. During “discharging” the condensing unit is not required and hence remains in the OFF state. The PLTSS unit is installed at an elevated level to use gravity as an aid for the refrigerant flow in the discharging circuit, eliminating any pumping action.

PLTSS is essentially an insulated network of flexible pipes filled with phase change material. Figure 2 shows an assembly of pipes whose network produces the PLTSS module. The outer pipe is corrugated plastic pipe of 2” mean diameter. The plastic expands when the PCM within it changes phase from liquid to solid.

The other two pipes are part of the two refrigerant circuits which have been discussed above—Circuit 1 being part of the discharging process and Circuit 2 that of the charging. R-22 is used in both the circuits.

PLTSS vs Other TSS

a) PLTSS has been essentially developed for localized distribution of cooling effect, as opposed to conventional systems which act as central energy storage sites.

b) It offers a PUMPLESS operation which is not available in

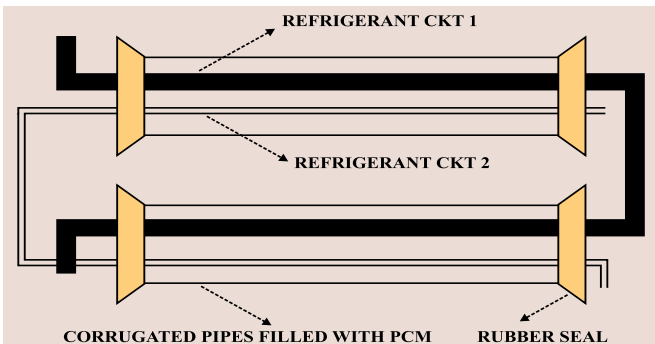


Figure 2: Assembly of pipes whose recurrence produces the entire PLTSS module

any other thermal storage system.

c) Most TSS freeze PCM in a large tank and use it to chill water. This chilled water is then circulated in chilled water units located at different sites. This adds to the cost of piping and other sophisticated controls. PLTSS provides direct cooling to the space using simple refrigerant circuits without any secondary refrigerant. It thus avoids any need of sophisticated controls or complex network of piping.

d) The concept of storing PCM in flexible pipes allows PLTSS to be flexible in its installation. For the same capacity, the size and arrangement of pipes can be modified to fit into different space constraints. Such design flexibility is not available with TSS which freezes PCM in large storage tanks.

PCMs Tested With PLTSS

Originally, PLTSS was developed to work with water as the PCM. However tests have also been conducted with salt hydrates as PCM. The properties of both PCM have been enlisted in Table 1.

Table 1: Properties of water and PCM 25

PCM	Freezing Pt.	Melting Pt.	Latent Heat of fusion	Specific gravity
Water	0°C	0°C	330 kJ/kg	1
PCM 25	19°C	25°C	120 kJ/kg	1.48

With water, low temperature (18°C) in the room was targeted. PCM 25 finds its application in telecom shelters. With PCM 25, it was required to maintain a room temperature of not more than 38°C .

The test rig (Figure 3) was setup and the important parameters were observed. Based on the observation and some preliminary calculations the test results of sample test conducted are tabulated in Table 2.

The capacity of PLTSS system is estimated in TR-Hrs. A system is designed to give the desired cooling for a fixed interval of time. The given unit is designed to provide 0.5 TR of air conditioning for 2 hrs with water as PCM; hence it is a 1TR-Hr unit.

Table 2: Results with water as PCM

DATA	RESULT
Mass of water in PLTSS	39 kg
Charging Time(21°C to -7°C)	195 MINS
Discharging Time	165 MINS
Cumulative capacity	1.17 TR-HRS
Units consumed	2.2 kW hrs
COP	1.87

The test rig (Figure 4) for testing PCM 25 incorporated a 1kW heater to simulate the load conditions. The output of the heater is modulated so that the temperature controlled should not exceed 38°C.

Using similar test rig (that was used in water) for PCM 25, under different loading conditions, results in 71% utilization of energy storage and retrieval capacity of PCM 25, which is in sync with the rated capacity of the product.

Table 3: Results with PCM 25

DATA	RESULT
Mass of PCM 25	63 kg
Charging (28°C- 13.0°C)	80 MINS
Discharging Time (13°C - 26.0°C)	138 MINS
Heat load	1.5 kW-hrs
Capacity	0.43 TR-Hrs
Units consumed	1.0kw hrs
COP	1.5

Applications of PLTSS

PLTSS can be used for localized distribution of cooling. For a large office building, in case of power cuts it is imperative to provide cooling to certain area (e.g. server room or offices/cabins of VIPs). PLTSS can then be integrated with the existing chilled water system of the building. During power cuts the secondary circuit of PLTSS will cool the water (through a heat exchanger) which will then be circulated normally in the room units. This process thus allows reduction in the size of DG sets.

With water or brine as PCM, PLTSS has the potential to combine the benefits of Ice Bank System and Bulk Milk Coolers used in dairy industry. It can store cold thermal energy during off peak hours and discharge the energy through secondary refrigerant circuit directly into the direct expansion type evaporators. The “discharging circuit” of PLTSS, working on principles of evaporation and condensation will allow larger heat transfer as compared to chilled water circulation. Augmentation of heat transfer through chilled water circulation would require pumping of additional volume of chilled water, which causes a rise in pumping work. With PLTSS large quantities of milk can be cooled in relatively short time without any additional pumping work.



Figure 3: Test rig of PLTSS with water as PCM



Figure 4: Test Rig of PLTSS with PCM 25

The successful tests with high freezing temperature phase change material (PCM 25) indicate that the system can be used in telecom shelters as backups, for cooling. PLTSS avoids any pumping of water during its operation. This absence of pumping of water is of particular interest to shelters, since the operation eliminates any water leakage into the shelter. This safeguards the sensitive instruments within the shelter.

Limitation of PLTSS

By the virtue of its operation, installation of PLTSS would require certain minimum elevation above the room unit or the evaporator as shown in Figure 1. In some cases there could be difficulty in installation of such a system. However in critical situation a small refrigerant pump can be used.

The refrigerant pipe sizing in the secondary circuit requires careful consideration while designing the system. This consideration becomes even more significant when the friction losses increase. In any case the pipe sizing will be comparable to an equivalent capacity chilled water system.

The salt hydrates used as PCM do not melt congruently. They melt into saturated aqueous phase and solid phase. Due to density differences, the solid phase settles out and collects at the bottom of the container. During solidifying, the solid phase does not combine with the saturated solution to form the original salt-hydrate. Another important problem is their poor nucleating properties resulting in supercooling of the liquid salt hydrate prior to solidification [7]. This phenomenon was observed by testing the capacity of PLTSS by freezing PCM 25 at different temperatures (from the rated 19°C, to 8°C). Therefore, thickening agents or nucleating agents are generally needed when salt hydrates are used as PCMs.

Conclusions

A simple layout and a flexible design allow PLTSS to be custom made for the desired applications. It comes in compact units which can be directly installed at the site where the cooling is desired. It eliminates large chilling units and other proprietary items.

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The test results further indicate that the design works well not only with water but with other PCMs as well.

The test apparatus has been set up with standard parts and not with an aim to optimize the results. The tests conducted are qualitative in nature and not quantitative. The tests are an attempt to determine how well the assembly responds and up to what extent are the expectations met in terms of designed system capacity. Hence there is a lot of scope in optimizing the setup, subject to further R&D.

References

- [1] ADM Associates Inc Sacramento CA, *Final Report November 2006, Evaluation of Demonstration Project for Ice Bear® Thermal Ice Storage System, For Demand Shifting.*
- [2] Pyeongchan Ihma , *“Development of a thermal energy storage model for EnergyPlus”*, Journal of Energy and Buildings 36 (2004) 807–814
- [3] Hale, D.V., Hoover, M.J., and O’Neill M.J., 1971, *“Phase change*

materials”, Hand Book, Marshal Space Flight Center, Alabama.

- [4] Someshower Dutt SHARMA, *“Phase Change Materials for Low Temperature Solar Thermal Applications”*, Mie Univ., Vol. 29, pp. 31-64 (2004)
- [5] Wang, X., Lu, E., Lin, W., Liu, T., Shi, Z., Tang, R. and Wang, C., 2000. *“Heat storage performance of the binary systems neopentyl glycol/pentaerythritol and neopentyl glycol/trihydroxy menthyl-aminomethane as solid phase change materials,”* Energy Conservation and Management, 41, 129-134.
- [6] M.Yamaha-*“Study of the Thermal Characteristic of the PCM for Buildings use”*. Takasago Thermal Engineering Co. Ltd., Tokyo Japan.
- [7] Wen-Shing Lee, *“Latent Heat Storage in a Two-Phase Thermosyphon Solar Water Heater”*

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