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An Experimental Investigation of Free Space Cooling by Phase Change Material (PCM)

[1]Ratnakar Kulkarni, [2]Ummid Shaikh and [3]Priyanka Chavan
[1]Faculty of Engineering and Technology, University Malaysia Pahang,
Lebuhraya Tun Razak, 26300, Kuantan, Pahang, Malaysia
[2,3]Pimpri Chinchwad College of Engineering, Nigdi, Pune, India-411044
[1]ratnakulkarni@gmail.com, [2]ummids@gmail.com, 3primechol@gmail.com

Abstract—In free space cooling PCM at suitable melting point is solidified by using night time cold air. During day time room air is passed over the solid PCM which absorbs Latent heat from it and melts. As a result room air gets cooled. In the present work suitable double pipe heat exchanger is designed and manufactured for the experimentation. The inner pipe is made up of copper and outer pipe with acrylic for visualization of phase change. PCM LatestTM29T (hydrated salt)is filled in annular space and atmospheric air is passed through inner tube. Air flow velocity is measured by hot-wire anemometer. 8 RTD sensors are placed at different location, 2 for inlet and outlet temperature and 6 are inserted in the PCM at different radial locations.The real time temperature data is captured by 8 channel Data Acquisition System at an interval of 15 minutes. A 90 W Centrifugal blower with VFD controller is used for passing the air with different velocities. The experimentation consists of passing cold outside air in the copper pipe during late night hours until PCM solidifies and measurement of solidification time. During day time hot room air is passed through tube and melting time and temperature dropof air is measured.It is observed thatabout 90% of PCM solidifies in about 7 hours when the night time ambient temperature is 220C with airvelocity of 12 m/s. During day time melting hoursof PCM are found to be 6.5 hours with inlet average temperature of air to be 340C, with 4m/s velocity and average temperature drop of 0.8 0C is observed.

Index Terms -Free space cooling, Phase change material (PCM).

I. INTRODUCTION

Energy required by the buildings comprises about 40% of worlds total energy consumption, and from that 10-20% of energy is required by HVAC equipment [1,2]. Considerable amount of energy is needed for air-conditioning of buildings. Today demand of fossil fuel is increasing day by day but sources are limited. Use of fossil fuel results in greenhouse gas emission which causes global warming.Earlier researchers were working on cost reduction of energy, but nowadaysresearchers are working on minimizing energy needs like the concept of green building. Green building consumes minimum amount of energy and the energy from renewable energy sources.
Passive cooling is the type of cooling that focusses on heat gain control and heat dissipation in a building with very less energy consumption. In passive cooling free space cooling (nocturnal cooling) is the type which works on diurnal temperature variation. In this system night time cold is stored and it is utilized during day time. For storing cold conditions during night time phase change material is used because of high storage capacity [3]. The concept of free space cooling using PCM is explained below.

Free space cooling with PCM working principle

a) Discharging process (heat absorption): During day time hot air from the room is circulated around solid PCM, which results into melting of PCM as inlet air temperature during day time is more than melting point of PCM. As latent heat of fusion is absorbed from the air by PCM for changing its phase, cooling effect can be achieved at the outlet of storage unit. This cooled air can be circulated in the room [3].

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b) Charging process (heat release): This occurs during the night when the outdoor air temperature is lower than melting point of PCM. Cool outdoor air flows through the PCM and absorbs heat from the liquid PCM. The PCM then begins to solidify at a specific temperature. This process stops when the ambient temperature is almost equal to that of the solid PCM [3]

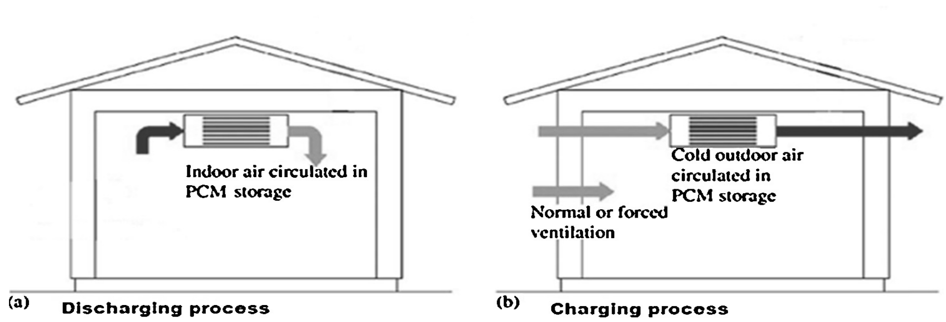

Figure 1 Free space cooling with PCM working concept

II. EXPERIMENTATION

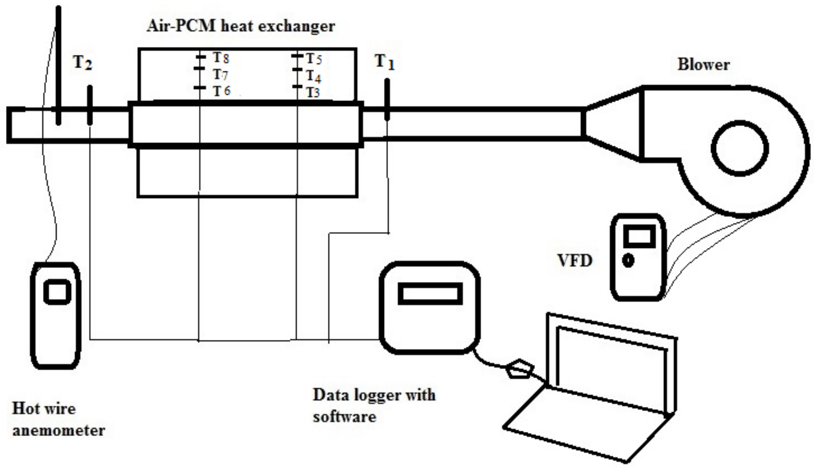

Figure 2 Schematic diagram of experimental set-up

The experimental set-up consists of double pipe heat exchanger. Inner tube of heat exchanger is a copper tube with an ID of 75mm, with an OD of 82mm and length of 400mm. Another tube made up of acrylic material with same length, with an OD of 160mm and thickness of 5mm is used as an outer tube. Heat exchanger is closed with 10 mm acrylic plates and U-biddings are used as gasket to seal the leakage. The Phase change materialLatestTM29T (hydrated salt) with melting point of 290C is then filled in the annular space. The PVC pipe is attached at both ends of the heat exchanger for entry and exit of air. Two RTD sensors(PT-100) are mounted on PVC pipe, one at outlet and another at inlet of heat exchanger. The 6 RTD sensors are placed at two in a group of 3. Each RTD sensor in a group is placed at different radial location. All these RTDs are connected to 8-channel data logger which continuously measures the temperature at the interval of 15 min. A Centrifugal blower of 90W capacity with variable speed drive is used to supply the air through inner copper tube. Hot wire anemometer is used to measure the velocity of supplied air.

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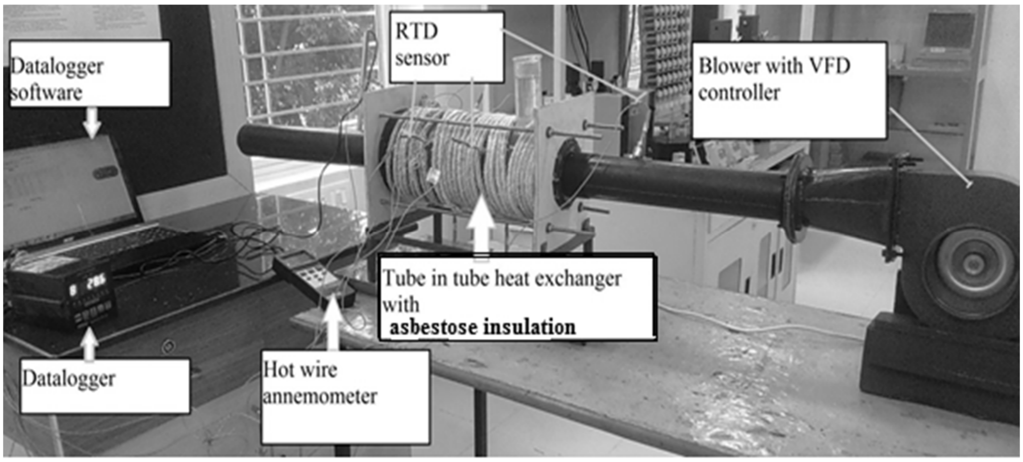

Figure 3 Experimental Set-up

II. RESULTS AND DISCUSSION

The night time experimentation is done for two different air velocities 9m/s and 12m/s, with average inlet temperature of 22 and 24^{0}C and solidification time is measured. It is observed that at lesser temperature and higher flow rate solidification rate is faster. Solidification was faster at the bottom side than the top side of heat exchanger due to phase separation. Because of phase separation salty part get accumulated at bottom and watery part at the upward side. Some crystals are also observed at the inner face of acrylic. TABLE Ishows results obtained during solidification of PCM.

For melting ambient air was passed through the inner pipe with 4 m/s velocity. The average temperature of air was observed to be 34^{0}C.The temperature drop of 0.8^{0}C was observed for about 6.5 hours during melting of PCM in day time.

Table I Results for solidification of PCM

Sr.No	Inlet air temp. (^{0}C)	Air velocity (m/s)	Solidification time (Hours)	Approximate % of solidification
1	22	9	6.05	90%
2	22	12	5.10	90%
3	24	9	6.20	80%
4	24	12	5.30	80%

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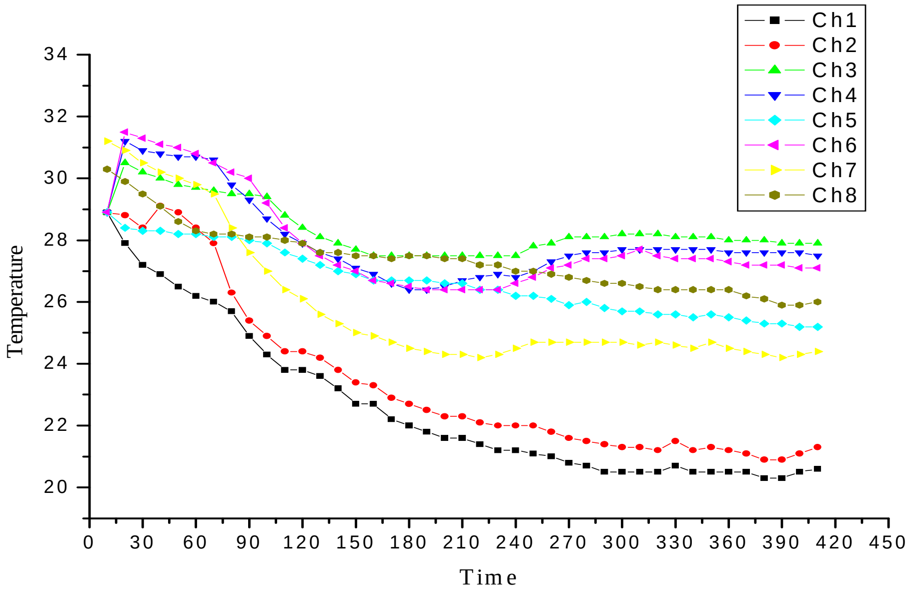

Figure 4 Temperature variation of PCM for 22^{0}C average air temperature and 9m/s velocity during solidification

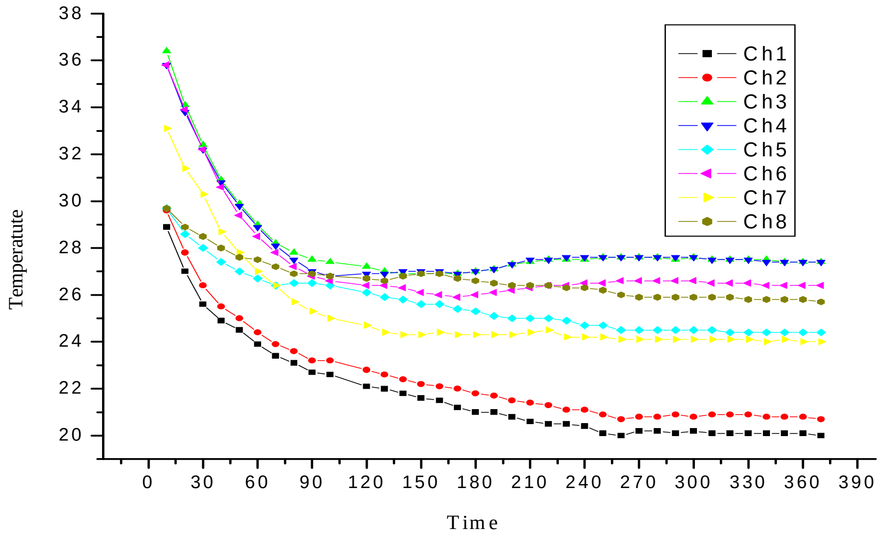

Figure 5 Temperature variation of PCM for 22^{0}C air average temperature and 12 m/s velocity rates during solidification

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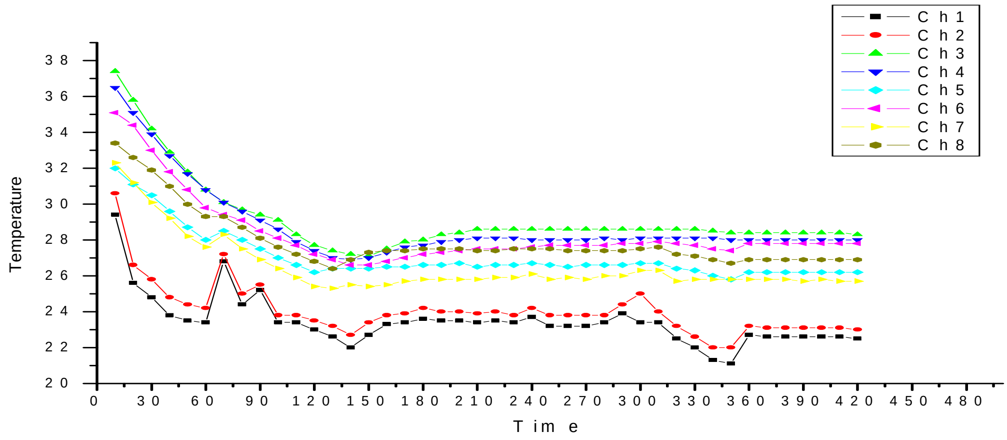

Figure 6 Temperature variation of PCM for 24^{0}C average air temperature and 9 m/s velocity during solidification

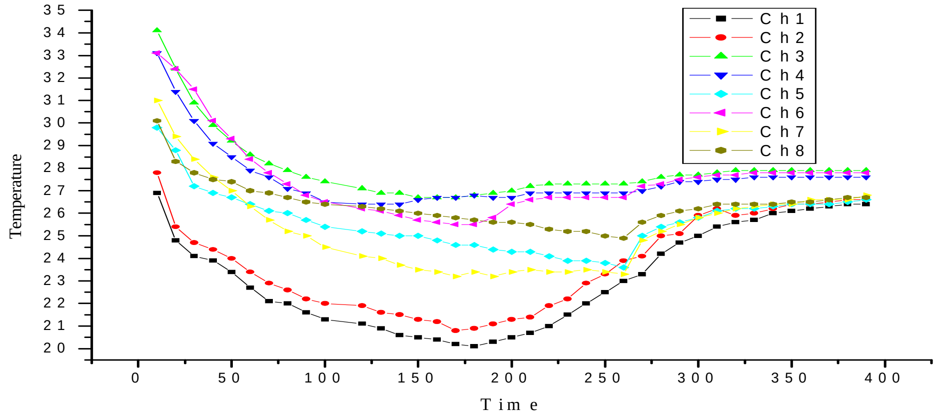

Figure 7 Temperature variation of PCM for 24^{0}C average air temperature and 12 m/s velocity during solidification

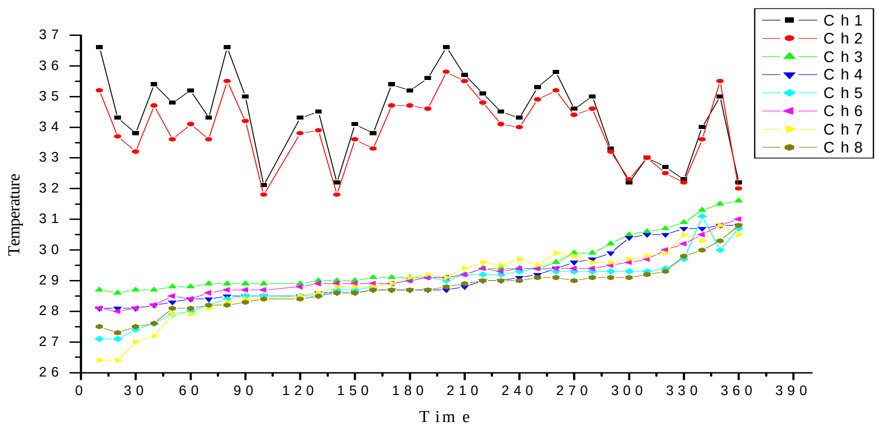

Figure 8 Temperature variation of PCM for 34^{0}C average air temperature and 4 m/s velocity during melting

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III. CONCLUSIONS

It can be concluded that the solidification time depends on air inlet temperature as well as air velocity. As air velocity increases the solidification time reduces. Whereas solidification time varies directly with temperature. Minimum solidification time of 6 hours was observed with air at 22^0C at 12m/s.

During day time the average temperature drop of air is observed to be 0.8^0C with air at 34^0C at 4m/s. The PCM last for 6.5 hours with these inlet conditions. During solidification the PCM undergoes sub cooling initially, which further extends the solidification time.

The vitiation of temperature at different locations of PCM (C3 to C8) may be due to phase separation. As the water separates from salt hydrate concentration difference is created and different solidification temperature is observed in different locations inside the mass of PCM.

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