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Experimental Investigation on the Performance of Upside Down Solar Desalination Using PCM

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ABSTRACT: India is primarily a water scarcity country with several parts having limited access to water. Desalination is vital and ritual process for obtaining potable water. Desalination is a process of converting saline water into potable water. In this research, technique was highly exploratory and intense on the enhancement cost effective feasible solar desalination model with the help of renewable energy. Prototype is fabricated with the indigenous materials and it works under the principle of upside down coffee maker having a phase change materials to store the thermal energy during daylight and will expel the required amount of energy during nocturnal. The prevailing conventional micro solar basin still has certain limitations that make them inefficient to be used as domestic units. This experimental research highlights certain drawbacks that occur in the evaporation and condensing zones of the vertical solar desalination stills, and expels novel techniques developed to enhance the efficiency of it and introduce the cheapest technique for storing large amount of thermal during day-time. Extensive data collected over a few days are investigated and presented to impart implementing new methodologies for enhancing the efficiency of the of micro scale solar desalination units.

KEYWORDS: DESALINATION, Renewable energy, up-side coffee maker, Solar still, Aluminium powder

I. INTRODUCTION

This project was taken from the Gabriele Diamanti an Italian designer. He has made a solar oven called **Eliodomestico** that can transform salty water into potable water. 5 litres of salty water can be transformed into potable water daily. There is an urgent need of clean, pure and safe drinking water in many countries. Often, water sources are brackish and containing harmful bacteria and therefore cannot be used for drinking. The amount of drinkable water is decreased day by day globally because of scarcity of drinking water. 97 percent of the earth's water mass lies in its oceans [1].

The remaining 3 percent, 5/6 is brackish (slightly salty), leaving a mere 0.5 percent as fresh water. Water scarcity in several parts of the world is matter of concern for human beings. Fresh water supply by trucks and laying long pipelines carrying potable water from far off region is usually not economically feasible. In addition, due to pollution of the rivers and lakes by industrial wastes and large amount of sewages results in contamination of water quality

[2]. Also in coastal areas and deserts potable water for drinking is the main problem. So, there is a need for desalination of brackish water to meet the requirement economically. One of the options used

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to obtain potable water from saline water is to use solar distillation process. Renewable energy sources are attractive, and due to increasing demand for energy there are focusing on using these energies. One of the main parameters in developing the utilization of these energies is storing it in a suitable form [2].

Paraffin wax is considered the most prospective PCM between several materials, because of some of its desirable characteristics

[3]. Paraffin wax has high latent heat of fusion, limited super-cooling, low vapour pressure in the melt. Also, it is chemically stable and can be 100% recyclable. However, it has low thermal conductivity that results in lower heat transfer rates during phase changing (melting/freezing) processes [4]. The thermal conductivity usually can be improved by adding highly conducting materials to the paraffin wax. Desalination is one of the numerous applications of solar radiation energy especially in countries with abundant sunshine and arid regions [5]. The usage of free energy made solar distillation exhibits a considerable economic advantage over other types of water distillation processes. Distillation with solar energy characterized by its simplicity and favourable for small compact water desalting at geographic locations where there is considerable solar radiation [6].Many researchers investigated the methods of enhancing the thermal response of paraffin wax heat storage by incorporating aluminium thermal conductivity promoters of various designs into body of the wax [7].

Aluminium is one of the particles used by many researchers in their experimental investigations. Recently Ho investigated experimentally the active thermo physical properties of PCM prepared by his team, including latent heat of fusion, density, dynamic viscosity, and thermal conductivity

[9]. The experimental tests showed that there is a relative increase in the dynamic viscosity of the paraffin containing alumina particles. Mettawee carried out an experimental study to investigate the influence of aluminium particles on melting and solidification processes of paraffin used in a solar collector

[8]. The results revealed that the time required for charging and discharging operations could be reduced substantially by adding the aluminium particles. Hence, the mean daily efficiency of the solar collector with composite PCM was much higher than that of with pure paraffin [9].

II. EXPERIMENTAL SETUP CONSTRUCTION

Place the main body on the ground in a sunny place, far from shades. Insert the water-collecting bowl, sliding it through the front hole. Insert the condenser lid through the big hole on the top. Place the condenser lid on the bowl, It goes in place like a normal lid on a pot. Place the support for the black boiler (evaporator), simply posing it on the main body. Take the black boiler (evaporator) and the flexible tube. Check the rubber seals are in the right place. Screw one end of the flexible tube on the thread, at the bottom of the evaporator. Insert the evaporator and flexible tube assembly in the main body support. Screw the other end of the flexible tube, on the thread of the condenser lid.

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III. DESIGN

3.1 Top Outer Body

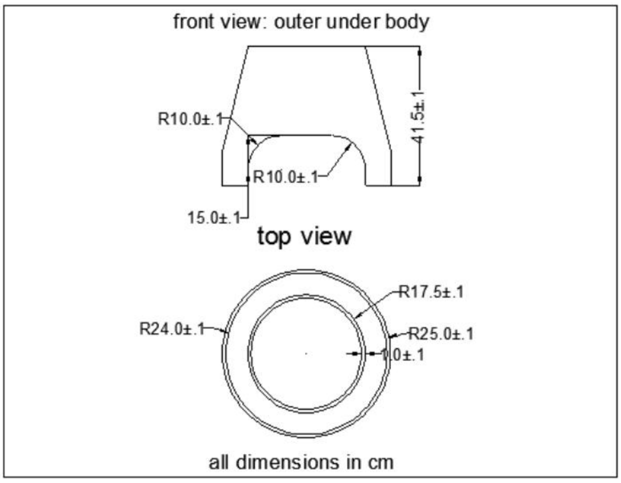

Fig.1. Design diagram of under outer body

3.2 Bottom Outer Body

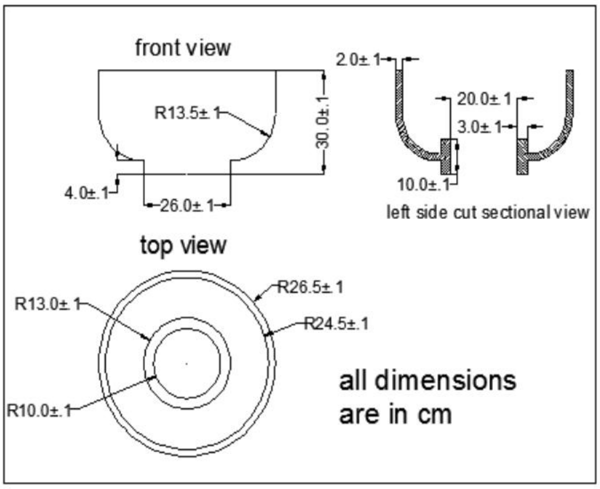

Fig.2. Design diagram of upper outer body

3.3 Evaporator

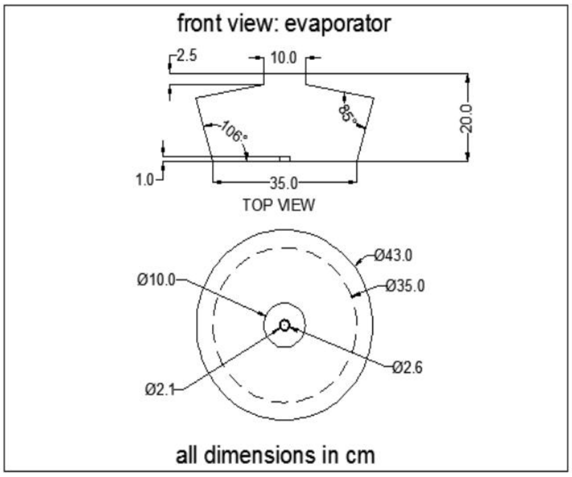

Fig.3. Design diagram of evaporator

3.4 Threaded Pipe

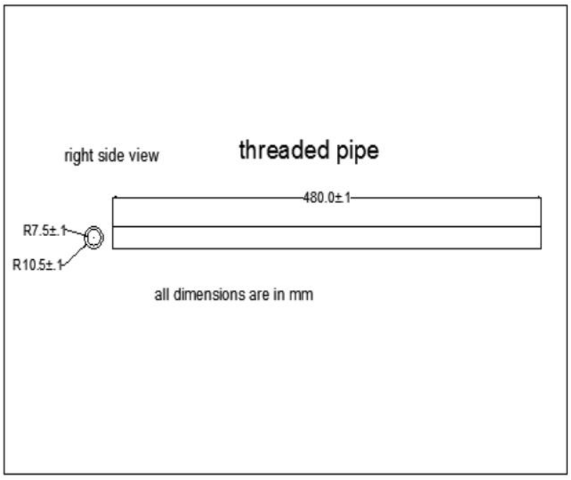

Fig.4. Design diagram of flexible tube

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3.5 Hexagonal Nut

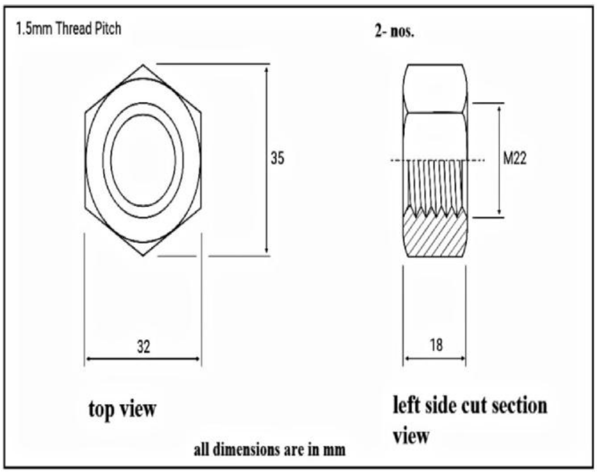

Fig.5. Design of hexagonal nut

3.6 Condenser Lid

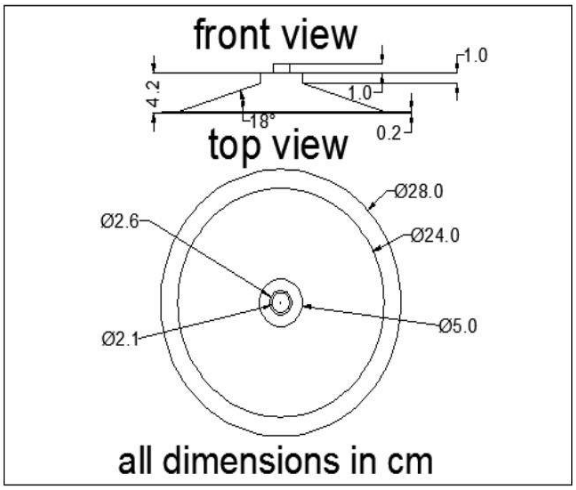

Fig.6. Design diagram of condenser lid

3.7 Collecting Bowl

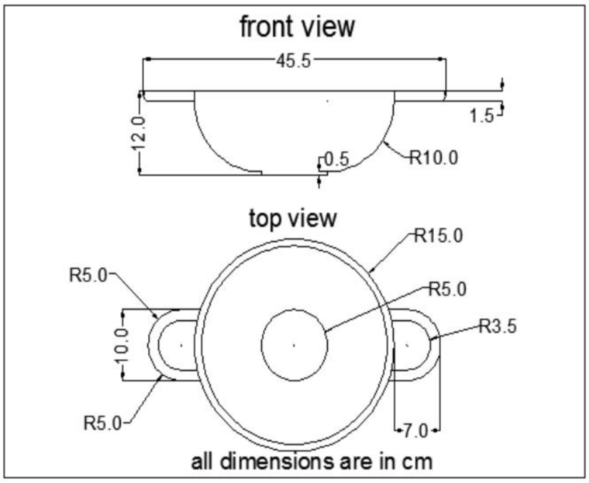

Fig.7. Design diagram of collecting bowl

3.8 Schematic diagram

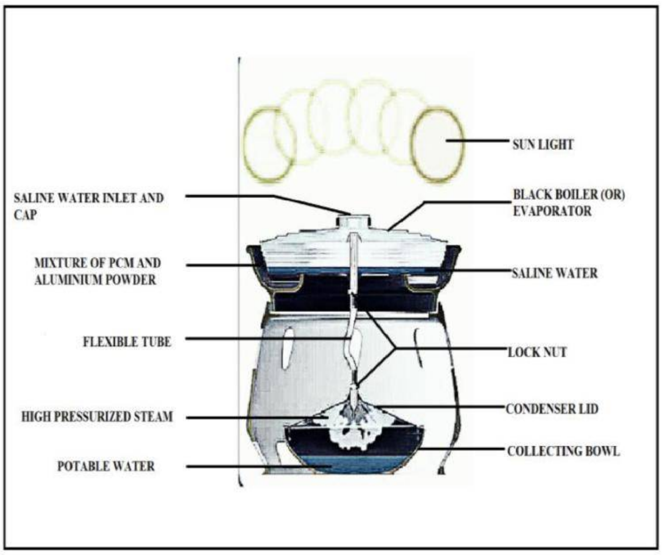

Fig.8. Schematic diagram of the distiller

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Working

Unscrew the filler cap. Pour the saline water in the black boiler (evaporator). Close the cap and tighten it well, after checking if the rubber seal is in its place. This is a soil made stove. It is totally portable. On the upper face of its main body, there is a black boiler. When needed to convert saline water into potable water, this black boiler has to be fitted on the soil made stove. Saline water has to be poured into the black boiler in the morning time. After pouring close the black boiler by tighten the cap of the black boiler has to be tightened and needed to keep the experimental set up under the sun whole day. Under the main body of the experiment set up, there is a portable bowl. The temperature and pressure grows on the black boiler, the high pressurized steam formed in the evaporator. At the same time low pressure acquires on the flexible tube, so the steam collected by flexible tube and it goes downwards through a flexible tube and collects in the lid. In fact, it work like a condenser, It covert the steam into fresh water. Let the experimental setup work for produce potable water until the end of the day.

Raise a bit of the condenser lid, full of freshwater stored in the collecting bowl. At the end of the day, just bring out that collecting bowl which is filled with clean drinkable water (maximum 5 litres) from under the work. That's it. Take the water to drink it. This experimental setup is made for improving productivity of the potable water. With the help of paraffin wax and aluminium powder, the productivity of potable water was increased. Paraffin wax work as a Phase Change Material, The mixture of phase change material and aluminium powder was used to improve the productivity of the potable water. In one solar distiller setup, the sides and the ground base were filled with PCM and aluminium powder. Table 1 lists the used aluminium powder specifications. Aluminium powder mixed with paraffin wax for several times. In each time, half kilogram of PCM was mixed with 5 grams of aluminium powder to preserve 1% rate of mixing. As we used 7.8 kg of PCM in the setup, the used aluminium powder was 78 grams. Aluminium powder selected because it offers components with high thermal and electrical conductivity and due to its reasonable cost. Aluminium powder has excellent conductivity values, both thermal and electrical. Aluminium powder has better thermal conductivity than brass, bronze, and ferrous-based materials significantly. Other significant property advantages associated with aluminium powder include corrosion resistance characteristics.

This will store the thermal energy in day time and dissipate the thermal energy in the evening time. To enhance the productivity of desalination process is by using thermal energy storage systems (sensible and latent heat storage). The latent heat storage system has a significant advantage over sensible heat system, including high energy capacity and almost constant temperature for charging and discharging. To improve the productivity of potable water, here we prepare to use both sensible heat and latent heat thermal energy storage for charging and discharging (aluminum powder and paraffin wax).

Properties of aluminium

After iron, aluminium is now the second most widely used metal in the world. The properties of aluminium include: low density and therefore low weight, high

strength, superior malleability, easy machining, excellent corrosion resistance and good thermal and electrical conductivity are amongst aluminium's most important properties. Aluminium is also very easy to recycle.

Weight

One of the best known properties of aluminium is that it is light, with a density one third that of steel, 2,700 kg/m3. The low density of aluminium accounts for it being lightweight but this does not affect its strength.

Linear expansion

Compared with other metals, aluminium has a relatively large coefficient of linear expansion. This has to be taken into account in some designs.

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Formability

Aluminium's superior malleability is essential for extrusion. With the metal either hot or cold, this property is also exploited in the rolling of strips and foils, as well as in bending and other forming operations.

Conductivity

Aluminium is an excellent conductor of heat and electricity. An aluminium conductor weighs approximately half as much as a copper conductor having the same conductivity.

Table 1: PROPERTIES OF ALUMINIUM POWDER

1	**Melting point**	**660.32 °C**
2	**Density**	**2.70 g/cm^3**
3	**Thermal expansion**	**25 °C**
4	**Thermal conductivity**	**237 W/(m-k)**
5	**Rate of half kg**	**Rs 750**

Properties of paraffin wax

Paraffin wax is an excellent material for storing heat, with a specific heat capacity of 2.14–2.9 J g−1 K−1 (joules per gram

Kelvin) and a heat of fusion of 200–220 J g−1. This property is exploited in modified drywall for home building material: a certain type of wax (with the right melting point) is infused in the drywall during manufacture so that it melts during the day, absorbing heat, and solidifies again at night, releasing the heat. Paraffin wax phase-change cooling coupled with retractable radiators was used to cool the electronics of the Lunar Rover. Wax expands considerably when it melts and this allows its use in wax element thermostats for industrial, domestic and, particularly, automobile purposes.

Appearance

White translucent tasteless odorless solids. A complex combination of hydrocarbons obtained from petroleum fractions.

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Table 2 PROPERTIES OF PARAFFIN WAX

1	Colour	White
2	viscosity	~ 5 mPa.s
3	Phase changeable	Yes
4	Type	odourless , tasteless ,waxy solid
5	Melting Point	45 °C
6	Density	around 900 kg/m^3
7	Soluble	ether ,benzene and esters
8	Rate	Rs 500 per kg

IV. RESULTS AND DISCUSSION

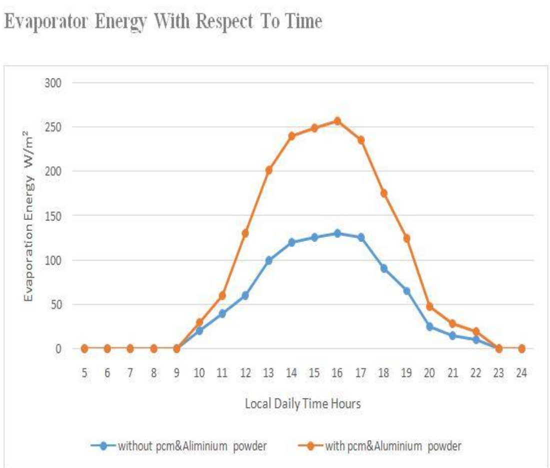

Fig 9. Average Distiller Evaporation Energy with Respect To Time on FEBRUARY 2018

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Fig 9 represents the relationship between evaporation energy and time. It wills undertaken on the period of 5am to 24am.Here with, using of PCM and aluminium powder the evaporation energy attained peak in the time of 16pm.

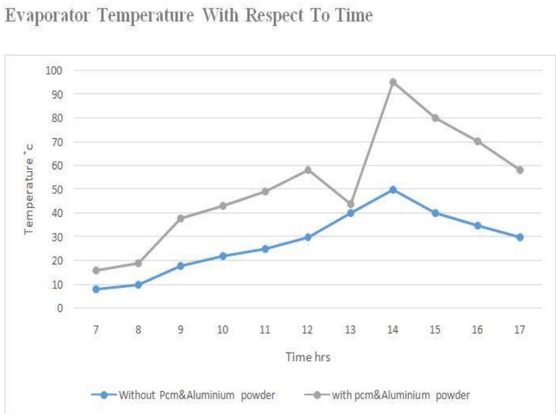

Fig 10. Average Distiller Evaporator Temperature with Respect To Time on FEBRUARY 2018

Fig 10 shows that the evaporator temperature changes with respect to time. Evaporator temperature was increased by using Phase change material and aluminium powder. It will improve the productivity of the potable water. Comparison of with and without using paraffin wax and aluminium powder was shown in fig 9.the temperature raises in the time period of 13pm to 14pm.

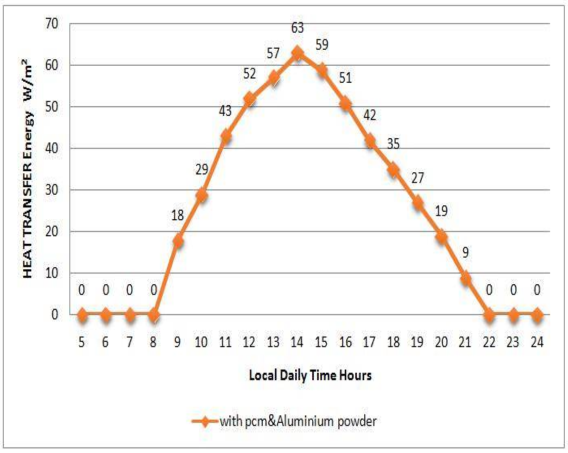

Fig 11. Average Heat Transfer Energy with Respect To Time on FEBRUARY 2018

Heat transfer to the evaporator by using PCM and Aluminium powder with respect to time was show in fig 11. Adding aluminium powder to paraffin wax increased its production time for about three hours after sunset in February 2018.

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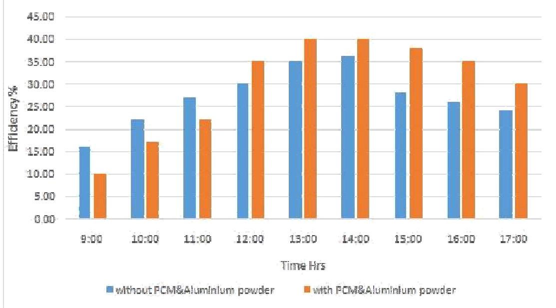

Fig 12. Average Distiller Efficiency with Respect To Time on FEBRUARY

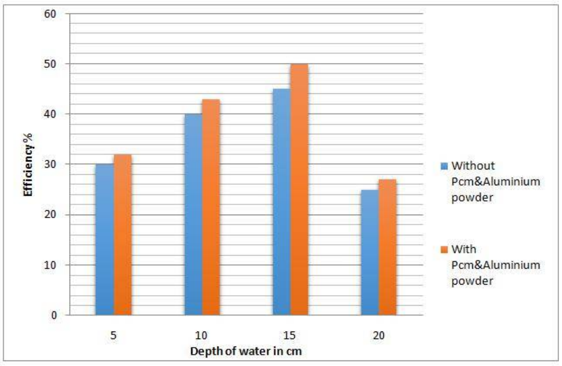

Fig 13. Average Distiller Efficiency with Respect To Depth of Water on FEBRUARY 2018

Fig 12 represents the relationship between efficiency and time. The distiller efficiency was changed with respect to depth of water was shown in fig 13. Both the charts are showing efficiency of solar distiller. The efficiency of distiller get peak in 15cm depth of water. At the same time, 13pm to 14pm the efficiency of solar distiller get increased.

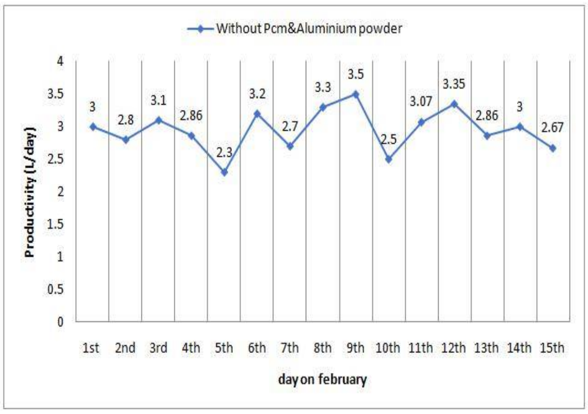

Fig 14. Distiller Productivity with Respect To Days on FEBRUARY 2018

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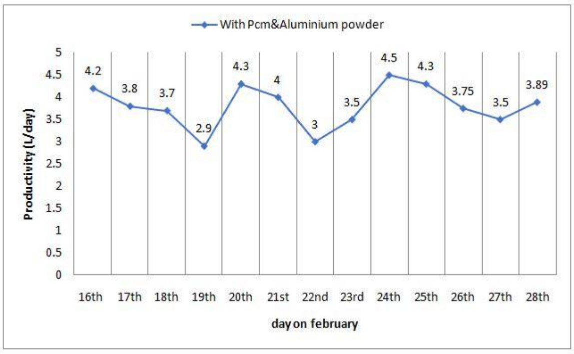

Fig 15. Average Distiller Efficiency with Respect To Time on FEBRUARY 2018

Fig 14 and fig 15 shows that the distiller productivity of water with respect to days. In fig 14, there is no PCM and aluminium was used. So the productivity was done at the sunset. The maximum productivity of potable water in fig 14 is 3.5 litres per day. In fig 15 productivity of water was processed after sunset by using paraffin wax and aluminium powder. This will increase the productivity of potable water after sunset. the maximum potable water was produced by using the combination of paraffin wax and aluminium powder is 4.5 litres per day.

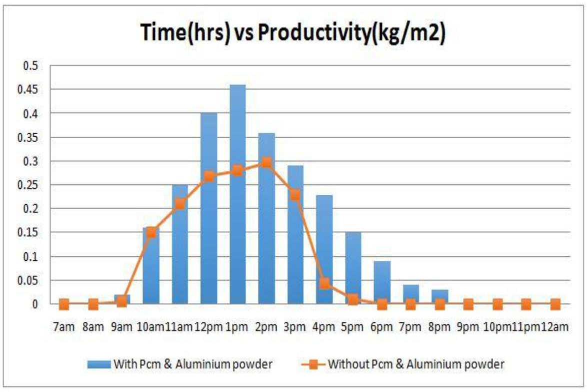

Fig 16. Average Distiller Productivity with Respect To Time on FEBRUARY 2018

Productivity of potable water was get increased with respect to time. The result of the solar distiller was shown in fig 16. In the experimental research still will give 3000ml of water per day. But the solar distiller using PCM and aluminium powder will give around 5000ml per day.

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The productivity level was increased in both cases. Adding additives to PCM increased thermal conductivity; that improved the evaporation and convection energies. Charging and discharging time for aluminium powder and PCM is reduced, compared with other cases, due to better thermal conductivity.

V. CONCLUSION

The work on Upside Down Solar Desalination Using PCM with Aluminium Powder is to increase the productivity of potable water without using electrical energy. Future scope of this project is that to done the desalination and still process in the single experimental setup by using filters. It will increase the productivity percentage of the potable water and hence it can be concluded that the Upside Down Solar Desalination Using PCM with Aluminium Powder will bring great changes and innovation to our life.

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