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Thermal Analysis of Clay Pot in Pot Refrigerator

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Abstract: *Cooling through evaporation is an ancient effective method of lowering temperature. The simple clay pot refrigerator is ideally suited for preserving vegetarian food and water in hot and dry climates. The refrigeration takes place by evaporation through the porous pot material. The present work includes experimental analysis of a clay pot in pot by varying height of water in the inner pot, by varying water level in the annulus of two pots and by subjecting the pot in pot refrigerator for free and forced convection. Results obtained from experimental analysis shows that Temperature T1 is highest when inner pot is filled with 5.5litres of water and lowest when it is filled with 1.5 litres of water. Temperature T1 decreases by increasing water level in the annulus of two pots and rate of cooling is lowest when pot in pot refrigerator is subjected to free convection and highest when it is subjected to forced convection.*

Keywords: *Evaporation, Free and forced convection, Porous, Refrigeration, Temperature*

I. Introduction

Cooling through evaporation is an ancient and effective method of lowering temperature. Both plants and animals use this method to lower their temperature. Trees, through the method of Eva transpiration remain cooler than their environment. [5]

The principle underlying evaporative cooling is conversion of sensible heat to latent heat. The warm and dry outdoor air is forced through porous wall or wetted pads that are replenished with water from cooler's reservoir. Due to low humidity of the incoming air some of the water gets evaporated. Some of the sensible heat of the air is transferred to water and become latent by evaporating some of water. The latent heat follows the water vapor and diffuses into the air. Evaporation causes a drop in the dry-bulb temperature and a rise in the relative humidity of the air. [1]- [7]

Evaporation cooling is dependent on the condition of the air and it is necessary to determine the weather condition that may be encountered to properly evaluate the possible effectiveness of evaporative cooler. On the other hand, the amount of water vapor that can be taken up and held by the air is not constant: it depends on two factors: the first is the temperature of the air, which determines the potential of the air to take up and hold vapor. The second involves the availability of water: if little or no water is present, the air will be unable to take up very much amount of water. [5]

In rural areas of India, vegetarian food is often preserved in a clay pot refrigerator. The cooling space is smaller clay pot inserted within a larger clay pot. The annular space between the two pots is filled with sand are occupied by water. Convective and radiative heat transfer from hot and dry surrounding evaporates this water and brings about cooling of space in the inner pot where food is kept. This slows both the respiratory process and activities of micro-organism which are destructive activity during storage of food. The mathematical model of pot in pot refrigerator using Reynolds flow model is presented by A.W. Date. [1]

An evaporative cooler is made up of a porous material that is fed with water. Hot dry air is drawn over the material. The water evaporates into the air raising the humidity and at the same time reducing the temperature of the air. [5]

The different type of evaporative cooler designs under review includes pot-in-pot, cabinet, statics, and charcoal cooling chamber. The gap between them is either filled with jute, damp cloth, or sand .Water is linked to the cooler at the top, thus keeping chamber cooled. [5]

In the literature cited above it was found that experimental analysis has not carried out by varying load in the inner pot, by varying proportion of sand and water in the annulus of two pots and also it was found that experimental analysis has not been carried out on pot in pot under forced and free convection environment.

In the present study experimental investigation is carried out by varying height of the water in the inner pot, by varying ratio of sand to water and by varying wind speed in the range of 0 to 4.4 m/s.

II. Description Of Clay Pot In Pot Refrigerator

The clay pot refrigerator is designed with locally available material that is clay which is excavated from a nearby stream and before casting of its structure it was mixed thoroughly with water to increase its plasticity. The clay was chosen because of its low conductivity of heat and porosity. It is very cheap and abundantly available. The pots are cylindrical in shape and are made by using wheel. The top and bottom surface of pot in pot refrigerator are insulated using thermo Cole. Pot in pot refrigerator having dimension of larger pot 32cm in diameter, 31cm in height and thickness of wall 0.6cm and smaller pot having dimension 16cm in diameter, 31cm in height and thickness of wall is 0.6cm is used for the analysis. The top and bottom surface of pot in pot refrigerator are insulated using thermo Cole. The cooling space is a smaller pot inserted within a larger pot. The annular space between the two pots is filled with sand and sand particles are of the size between 300 microns to 600 microns which is sieved by using sieve shaker motorized.

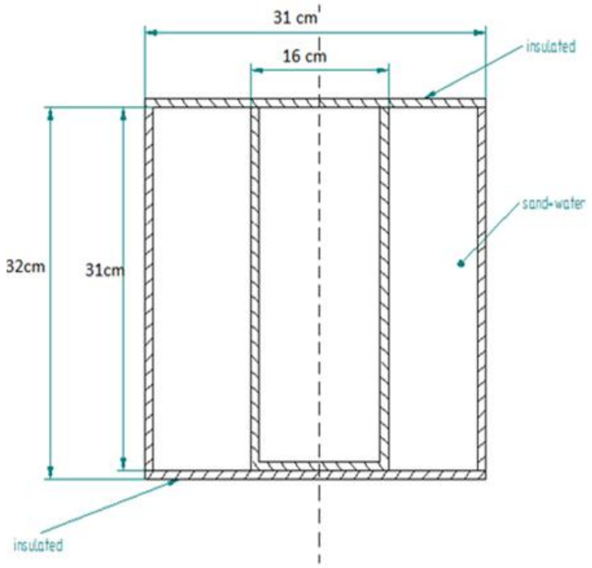

Fig 1: Schematic clay pot in pot

Fig 2: A prototyped developed clay pot in pot

III. Expérimental Setup

Fig 3 shows the experimental setup of a pot in pot refrigerator which is kept for natural convection .It consist of two pots where smaller pot is inserted into the larger pot, thermocouples (T1, T2, T3 and T4), 4 channel scanner, GPRS RTU, AC adaptor, and a power supply. Thermocouple T1 with a reading accuracy 1°C from 0 to 100°C and % F.S. error +/- 0.6 % F.S is used to measure the temperature at the center of the inner pot, T2 is used to measure inner wall temperature of the inner pot, T3 is used to measure temperature of sand and water that is filled between inner and outer pot and T4 is used to measure the temperature of outer wall of the outer pot. 4 channel scanner with reading accuracy ±0.1% of FS ±1 Count scans and display the temperature which is sensed by the thermocouple. It consists of a voltmeter which converts small voltage variation into temperature. Serial Communication with RS 485 is also provided for the scanner through which data of temperature are sent to GPRS RTU.

GPRS connected Remote Terminal Unit which has been used in experiment monitors the analog inputs like temperature from various sensors and also does all the signal processing and digitizes the signal. The collected data using GPRS RTU are sent to cloud through secured protocol using GPRS technology; we can view and download sensor wise analytic and graphs on centralized monitoring system using desktops, laptops, mobiles etc. anywhere and anytime. Experiments are conducted and data's are collected by varying quantity of water in the inner pot and by varying proportion of sand and water that is filled between the inner and outer pot. Dry bulb and wet bulb temperature of the atmosphere at regular interval of time is measured by using psychrometer having 20°F to 120°F measuring range.

Fig 4 shows the experimental setup of a pot in pot which is kept for forced convection. The experimental setup is similar to natural convection but in this case experiment is conducted and data's are collected by varying velocity of air which is blown by the fan kept at a distance of 1.5 meter from the pot in pot. Velocity of the wind is measured by using digital vane type anemometer with a reading accuracy of ± (2% +1d).

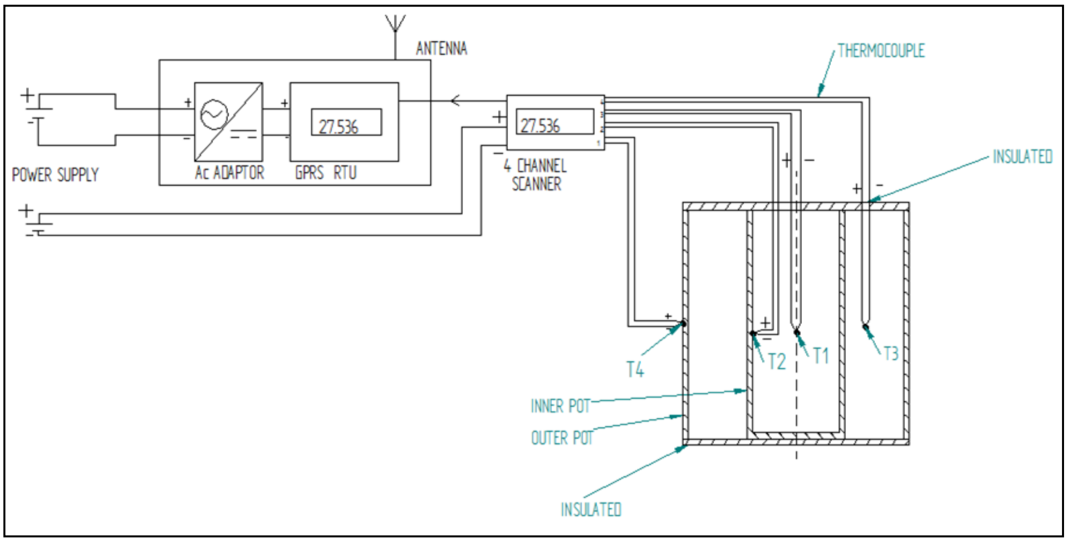

Fig 3: Experimental setup of clay pot in pot for natural convection

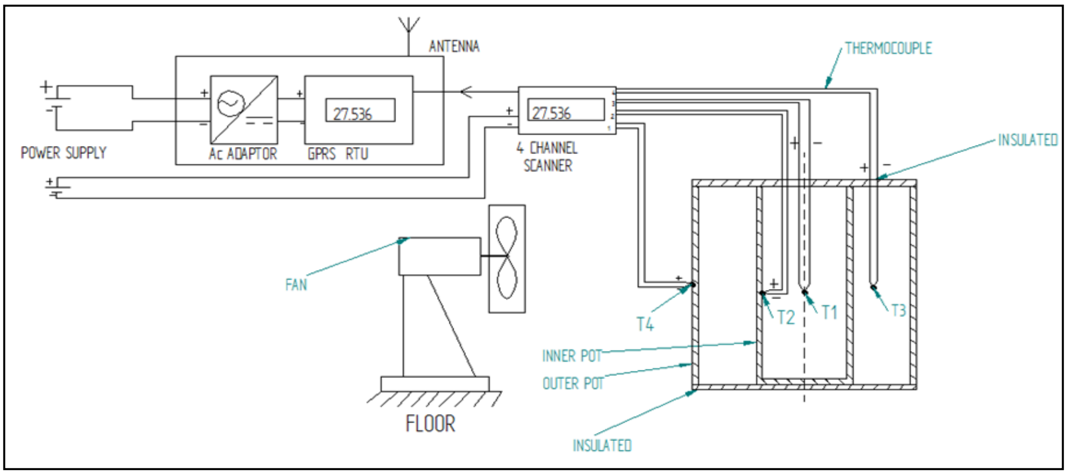

Fig 4: Experimental setup of clay pot in pot for forced convection

IV. Results And Discussion

By using the same pots in all cases, the size of the pores in the clay, as well as thickness of their walls are held constant.

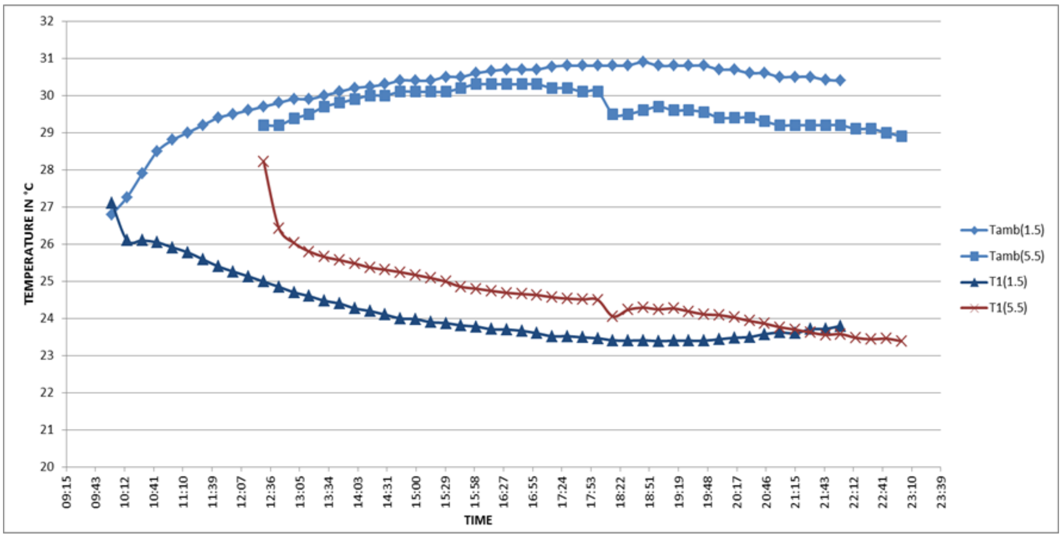

Fig 5: Variation of Temperature T1 with height

Investigation is carried out by varying height of the water in the inner pot by 1.5, 3.0, 4.5 and 5.5 liters of water. Ratio of sand to water in the annulus of the two pots is 15:2.5 and it is constant for all cases. In all cases pot in pot refrigerator is kept for natural convection. Where T1 is the temperature at the center of inner pot and T_{amb} is the ambient temperature.

FIG 5 shows the variation of temperature T1 when pot in pot refrigerator is filled with 1.5 and 5.5 liters of water. Rate of cooling is highest when the water quantity is 1.5 liters and lowest when the water quantity is 5.5liters. This is because area available for evaporation is same for both the cases but when load in the inner pot is maximum then more amount of heat has to be removed to produce maximum cooling effect. From the graph it can also be observed that plots for 1.5 and 5.5 liters coincide at the end of the experiment.

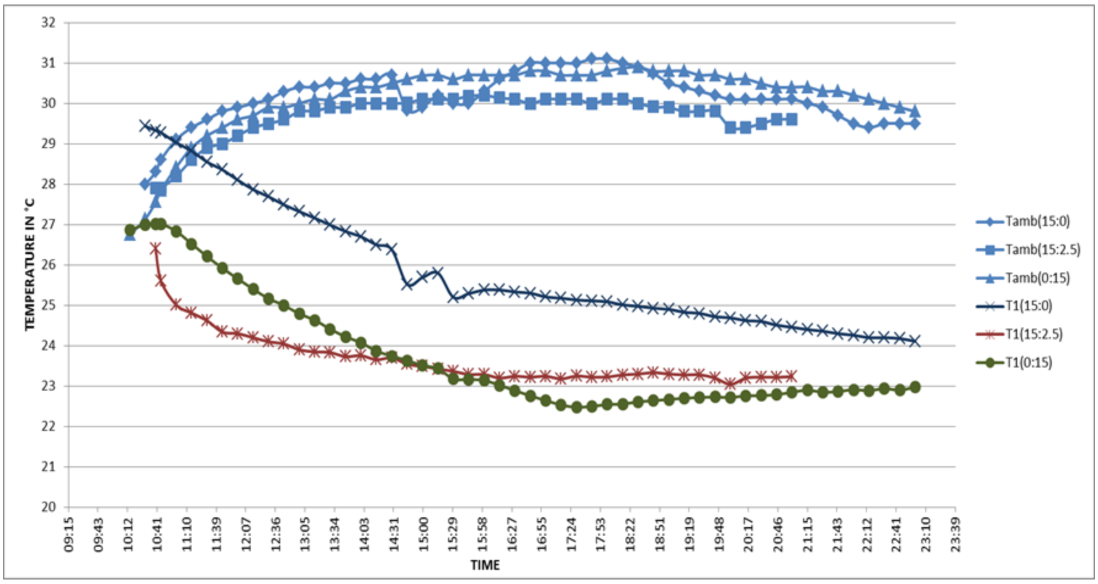

Fig 6: Variation of Temperature T1 with ratio of sand to water

Experimental analysis is carried out by varying ratio of sand to water in the annulus of the two pots by 15:0, 15:0.5, 15:1.5, 15:2.5 and 0:15. Water in the inner pot is 1.5litres and it is constant for all cases. In all cases pot in pot refrigerator is kept for natural convection.

FIG 6 shows the variation of temperature T1 when the ratio of sand to water is 15:0, 15:2.5 and 0:15. It shows that temperature T1 decreases by increasing the water level in the annulus of the two pots. Temperature T1 is higher throughout the experiment when the ratio of sand to water is 15:0 (no water in the annulus of two pots) this is because when water level in the annulus of the two pot is less, large area is not available for evaporation as a result evaporation rate is low. From the graph it can also be further observed that reduction of T1 is maximum when ratio of sand to water is 0: 15(annulus of the two pots is filled with water with no sand). At the end of the experiment it can be observed that temperature T1 increases when the ratio of sand to water is 0:15 but the temperature T1 remains constant when the ratio of sand to water is 15:2.5 this is because sand acts as a thermal insulator for the entry of heat from atmosphere into the inner pot.

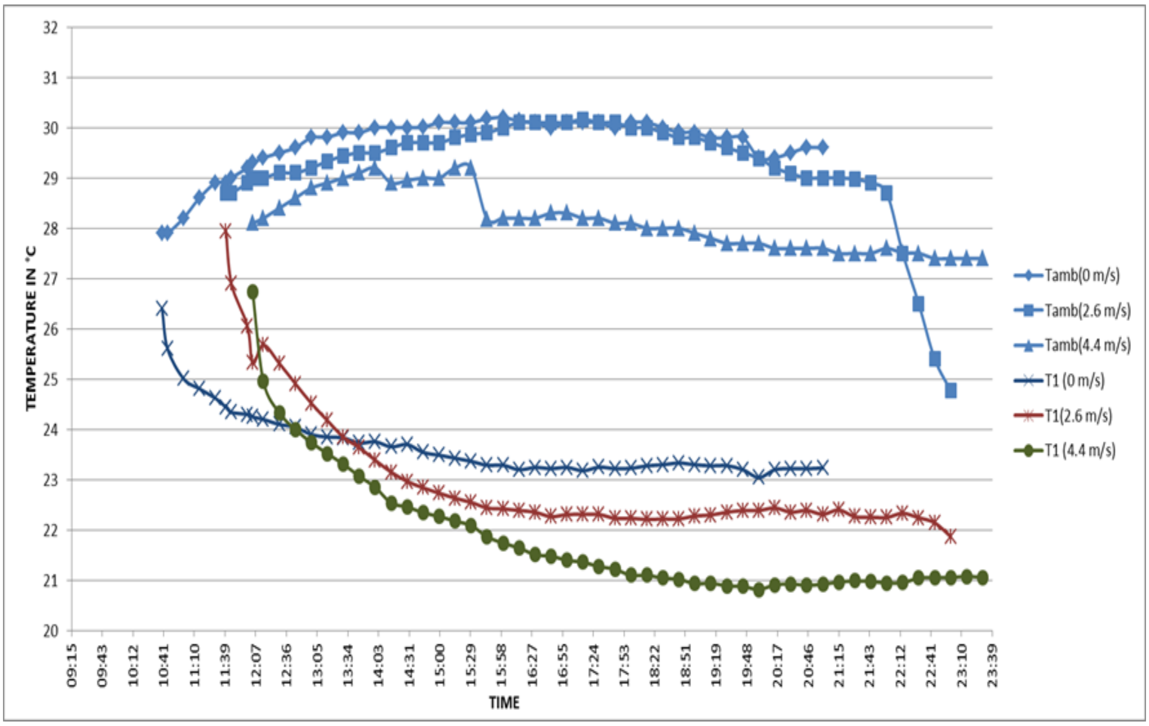

Fig 7: Variation of temperature T1 with wind speed

Experimental investigation is carried out by varying wind speed by 0, 2.6, 3.4 and 4.4 m/s. Ratio of sand to water in the annulus of the two pots and water in the inner pot is 15:2.5 and 1.5litres respectively and they are constant for all cases. Fig 7 shows the variation of T1 with the wind speed. From the graph it can be observed that rate of cooling is higher when the wind speed is 0 m/s and lower when wind speed is 4.4 m/s this is because of low rate of evaporation during natural convection and high rate of evaporation during forced convection. As a result temperature T1 is highest when wind speed is 0 m/s and lowest when wind speed is 4.4 m/s.

V. Conclusions

Experimental analysis of a clay pot in pot is carried out by varying height of water in the inner pot, by varying water level in the annulus of two pots and by subjecting the pot in pot refrigerator for free and forced convection. The following conclusions have been drawn

1.) Temperature T1 is higher throughout the experiment when the ratio of sand to water is 15:0 (no water in the annulus of two pots) in a pot in pot refrigerator.
2.) Reduction of temperature T1 is maximum when ratio of sand to water is 0: 15(annulus of the two pots is filled with water with no sand) in a pot in pot refrigerator.
3.) When a pot in pot refrigerator is considered temperature T1 reduces to a minimum value when ratio of sand to water is 0:15 and increases at the end of the experiment but the temperature T1 reduces and remains constant when the ratio of sand to water is 15:2.5 indicating effect of sand which acts as insulator for the flow of heat from inner pot to atmosphere.
4.) Rate of cooling is highest when the water quantity is 1.5 liters and lowest when the water quantity is 5.5liters for a pot in pot refrigerator indicating the effect of load.
5.) Temperature T1 is highest when the wind speed is 0 m/s and lowest when wind speed is 4.4 m/s for a pot in pot refrigerator which indicated the effect of speed on rate of cooling.

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