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CONSTRUCTION OF A SOLAR POWERED PORTABLE REFRIGERATOR

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Abstract- *Refrigeration is the process of maintaining temperature of a given system (space or substance) lower than that of atmosphere. Most of the time, electrical energy used to run these refrigerators. Nevertheless, where there is scarcity of electricity, alternate source of energy can use. Solar energy can play a vital role for this purpose. The objectives of this paper are to design and construct a solar powered refrigerator; test the performance by varying perforated area and annular space between two cylinders to obtain optimum cooling time and cost analysis of the solar powered refrigerator. The solar powered portable refrigerator consists of two cylinders of different diameter. Space between the inner and outer chamber filled with wet sand. In hot weather, the water content in the sand receive some latent heat from inner cylinder wall and gets evaporated through the hole of outer cylinder. Inner cylinder wall receives some heat from the inner chamber. This process may reduce temperature to approximately 6°C depending on the time, weather condition etc. The maximum temperature drop is with 25% perforation area of the outer cylinder. The cooling time for 25% perforation area is 9.6 hours. Since this refrigerator works on the basis of evaporative cooling, obviously it depends on humidity. When humidity is less, then it works more efficiently. In this project, a portable solar powered refrigerator designed and constructed using locally available materials so it is cost effective and for the larger perforated area, cooling time will be less.*

Keywords: Portable refrigerator, Perforation area, Annular space, Evaporation Rate.

1. INTRODUCTION

Refrigeration is the process of maintaining temperature of a given system (space or substance) lower than that of atmosphere. Refrigerators are used to preserve perishable food. In the present world, not only the food but also several materials such as medicine, vaccine, chemicals etc. are needed to be stored below the atmospheric temperature. There are many available techniques such as drying, making jelly, storing in vacuum pot etc. for the preservation of food. Nevertheless, with the change of time, human demand has been changed and different types of refrigeration systems are developed. These refrigerators are used in different sectors in different places. Most of the time electrical energy is used to run these refrigerators. But where there is scarcity of electricity or where sufficient electricity is not available, alternate source of energy can be used. Solar energy plays a vital role for this purpose. Solar energy is the only one source of energy that is free and available in all places. Solar energy is widely used all over the world in several applications to decrease the use of conventional energy and to reduce energy crisis in many developing countries. If solar energy can be applied perfectly in refrigeration sector to store perishable goods, it would be a new dimension in case of the use of solar energy. Solar powered refrigerator is the concept to use solar energy to maintain a space cooler than the surroundings and to store any perishable goods in any remote places as the alternatives of the conventional types. A portable solar powered refrigerator was constructed in the previous year. In that refrigerator perforated area was 14% of the outside cylinder area, annular space was 1.7cm and cooling time required was 16.68 hours. This cooling time was too long. So in this project, the design of the portable solar powered refrigerator was modified to obtain an optimum design. Then the performance of the constructed refrigerator was tested for various exposed area and space between two cylinders to obtain the optimum cooling time.

2. Portable Solar Powered Refrigerator

A Portable solar powered refrigerator has been produced for use in the developing world. The basic design uses the principle of evaporative cooling. The refrigerator is solar powered, but does not require solar panels, and can be made from basic household material lowering the cost and making access to the developing world easier. Without using any power, the refrigerator can keep perishable goods at a temperature of 6-8°C for days together [1].

3. Working Principle

The solar powered refrigerator employs a combination of heat conduction and convection, no electricity is required and can be made from commonly available material such as cardboard, sand, recycled metal and cork sheet as insulator. The working principle of this type of refrigerator can be described as follows:

i. This consists of two cylinders of different diameter. The inner cylinder is of small diameter and made of metal. This small cylinder is inserted inside the cylinder of higher diameter. This cylinder needs not to be drilled to provide holes.
ii. Another cylinder is to be of higher diameter than the inner cylinder. Materials of low conductivity such as wood or plastic may be used to make this. Holes of small radius are drilled on the outside cylinder.
iii. Space between the inner and outer chamber is filled with organic material, which includes sand, wool or soil that is then saturated with water.
iv. In hot weather, the sun's rays heats up this wet material and the water is evaporated. During the evaporation of water, it takes some heat from the inner cylinder wall. As a result, cylinder wall losses heat and take more heat from the inner chamber. This process may reduce temperature to approximately 6oC depending on the time, weather condition etc.
v. Re-soaking material with fresh water will keep the refrigerator working [2].

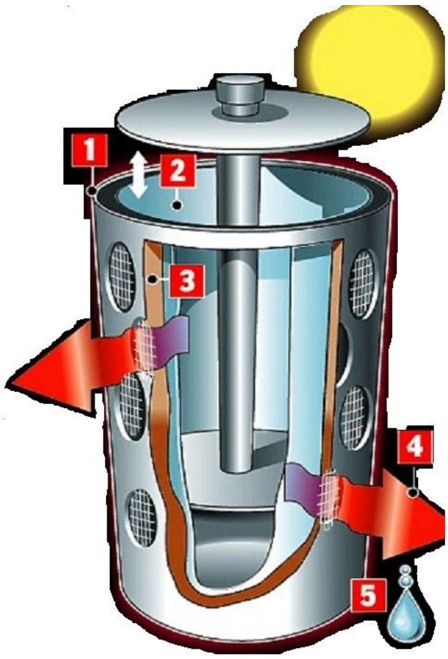

Fig.1: The working principle of solar powered refrigerator.

3.1 Assumptions for a Device to be Portable

The following assumptions were made to make the device portable:

- It should be low in weight.
- It should be small in length and diameter.
- It should be easy to handle and convenient to carry from one place to another.

3.2 Component Parts of the Refrigerator

The solar powered refrigerator should have the following components:

i. One cylinder of metal (as inner chamber)
ii. Lid
iii. One cylinder of plastic (as outer cylinder)
iv. Handle
v. Sand or any water absorbing material
vi. Wire net / synthetic net
vii. Thermal insulator at the top and bottom of the inner cylinder

3.3 General Consideration for Cylinders

The size of the cylinders depends on the mass to be preserved in the cylinder. Generally, the inner cylinder should have a volume of 20% or 30% greater than the volume of mass to be stored in the refrigerator. In this project, potato was supposed to be used for experimental purpose, which is needed to be preserved. The diameter of the inside cylinder was estimated by providing annular space 1.4cm, 2.0cm, 2.7cm respectively. The height of the cylinder is determined keeping in mind that it would be a portable device.

3.4 Construction of Solar Powered Refrigerator

As mentioned earlier that the refrigerator consists of two cylinders. The outer cylinder is made from plastic. The inner cylinder is made of galvanized iron sheet. The inner cylinder is inserted into the plastic cylinder. The gap between the cylinders is filled by sand of different grain sizes. This sand is wetted by water just before allowing it to be used. For making available the direct sun light to the wetted sand, holes of the diameter 1.90 cm is made on the wall of the plastic cylinder.

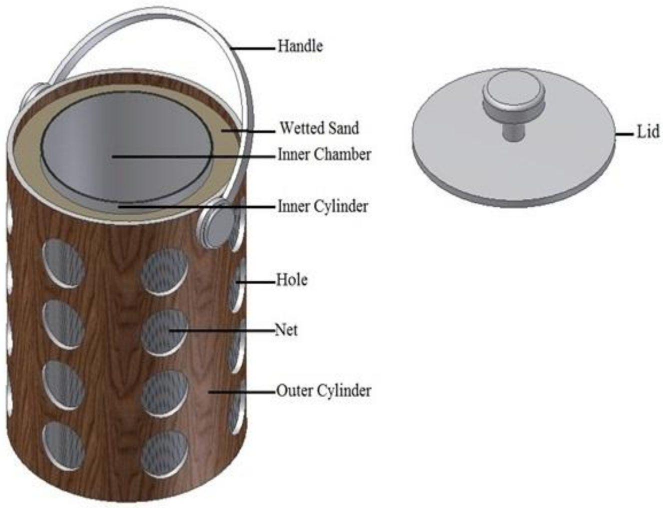

Fig.2: Construction of solar powered refrigerator

Two layers of the wire net or mosquito net was provided inside the plastic cylinder to prevent the sand from coming out through the perforation on the outer cylinder. Mosquito net was attached inside the plastic cylinder wall by glue and another net of metallic wire was attached with the help of metallic wire. This is done due to increase the strength of the net to overcome the pressure developed by the sand in the cylinder gap. A lid and a handle were provided. To increase the thermal resistance, insulator of the circular shape was provided at the top and bottom of the inner cylinder. Some sealing agent was used to make the inside cylinder leak proof.

4. Theory

The amount of heat to be removed,

$$Q = mc_p \, \Delta t$$

Where,
m = Mass of potato that can be preserved
C_P = The specific heat of potato
Δt = Temperature difference
Total mass of water to be evaporated,

$$M_W = (Q \times F_S)/L_V$$

Where,
F_S = Factor of safety
L_V = the latent heat of vaporization of water
From Stefan's law [3],
evaporation rate,

$$m_w = DPMA/RT(X_2 - X_1)\ln((P - P_{w2})/(P - P_{w2}))$$

Where,
D = Diffusion co-efficient
P = Atmospheric pressure
M = Molecular weight of water
T = Ambient temperature
A = Perforation area
$(x_2 - x_1)$ = 1 cm = 0.01 m
P_{w1} = 3.41 kPa, P_{w2} = 0
Cooling time = M_w / m_w

5. Result

The experimental data were taken from 01.08.2012 to 16.08.2012. During this period daily temperature data were recorded. From these data following graphs were obtained.

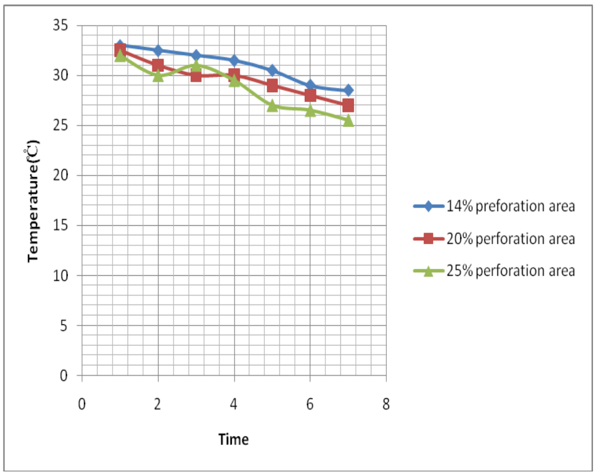

Fig.3: Variation of temperature with time (for annular space 2.7cm)

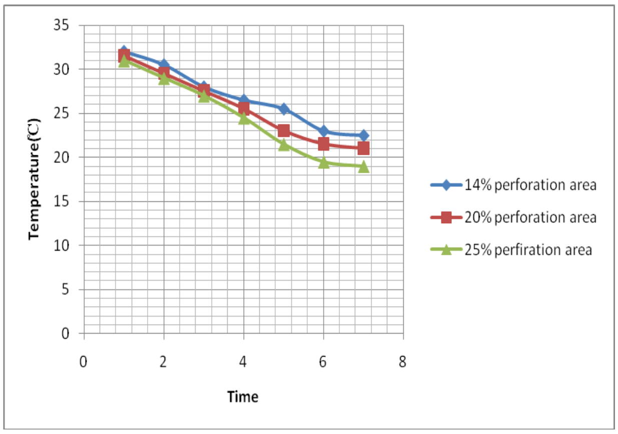

Fig.4: Variation of temperature with time (for annular space 2.0cm)

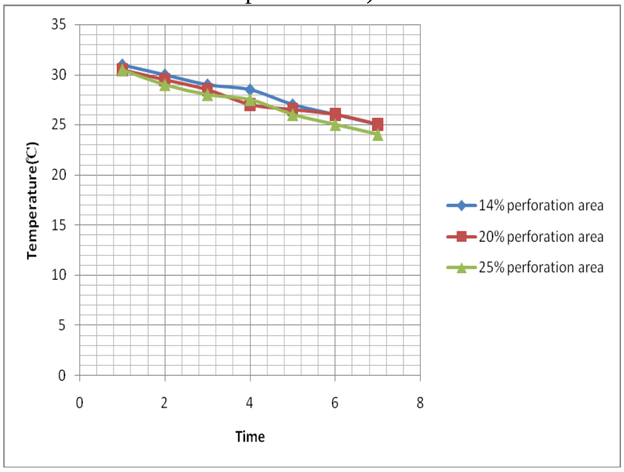

Fig.5: Variation of temperature with time (for annular space 1.4cm)

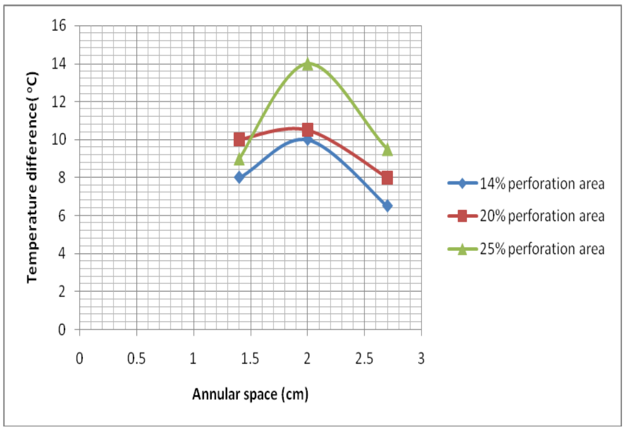

Fig.6: Variation of temperature difference with annular space.

6. Discussion

In all cases shown in Fig.3, 4 and 5, the temperature decreases with time with sand size 300-600 μm. From these graphs it is also obvious that, in each case the temperature drop is maximum with 25% perforation area of the outer cylinder. Fig.6 shows the variation of temperature difference between ambient temperature and inside of the inner chamber for 14%, 20% and 25% perforation area of the outer cylinder. From this graph it is obvious that highest temperature difference is obtained for 25% perforation area and 2.0cm annular space.

The cooling time for 14%, 20% and 25% perforation area are 16.86 hrs, 12 hrs and 9.6 hrs respectively. A significant reduction in cooling time is achieved with 25% perforation area of the outer cylinder.

During data collection, for three annular spaces perforation area was varied and annular space was same for each time. But it was not possible to collect data by this way in a single day. Since temperature and humidity varies from day to day so, for each perforation area, the variation of temperature drop with annular space, shown in Fig. 6 was at different temperature and humidity.

Since this refrigerator works on the basis of evaporative cooling, obviously it depends on humidity. When humidity is less then it would work more efficiently because evaporation rate will be more. When humidity is high evaporation rate decreases and it works less efficiently.

Normally solar intensity increases with day time. For higher performance of the refrigerator, it is essential to obtain a large value of solar intensity in that particular time. So, as time passes, the intensity increases and hence, the performance of the refrigerator also increases with respect to time.

7. Conclusion

In this project cooling time 9.6 hrs is obtained with 25% perforation area while previously constructed refrigerator, it was 16.86 hrs. About 7 hrs cooling time has been reduced in this project.

Temperature drop increases with annular space up to 2.0cm and then it decreases (Fig. 6). The temperature drop is maximum for 25% perforation area and 2.0cm annular space.

Since a significant cooling time is reduced with 25% perforation area and maximum temperature drop is obtained for 25% perforation area and 2.0cm annular space so, it can be concluded that 25% perforation area of the outer cylinder and 2.0cm annular space is the optimum design for portable refrigerator.

8. References

[1] http://en.wikipedia.org/wiki/Solar_powered_refrigerator (Date of access: 13/7/2013)

[2] http://www.dailymail.co.uk/sciencetech/article-1108343/Amazing-solar-powered-fridge-invented-British-student-potting-shed-helps-poverty-stricken-Africans.html (Date of access: 13/7/2013)

[3] Heat Transfer, J P Holman, Tata Mcgraw-Hill Book Company Limited, Ninth Edition, 2008

9. NOMENCLATURE

Symbol	Meaning	Unit
Q	Heat	(KJ)
m	mass	(kg)
c_p	The specific heat	(J/K)
Δt	Delta t	(K)
M_W	Total mass of water to be evaporated	(kg)
F_S	Factor of safety	Dimensionless
L_V	the latent heat of vaporization of water	(kJ-kg$_m^{-1}$)
m_w	evaporation rate	per *unit* of time
D	Diffusion co-efficient	(m^2/s)
P	Atmospheric pressure	(Pa)
M	Molecular weight of water	(kg)
A	Perforation area	(m^2)
R	Gas Constant	(m^2 kg s^{-2} K^{-1} mol^{-1})
T	Ambient temperature	(^{K})
X_2-X_1	Annular space	(m)