Theoretical Analysis of Air-Cooling by Using Concept of Zeer Pot Refrigeration

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Abstract: In this project, we are using the concept of "Zeer Pot Refrigeration" Technique for Air cooling. Air cooling is a method of dissipating heat from the system. It works by making the air to flow over the surface area of the cooled object. This cooling effect can be increased by having an increased flow of air over its surface. In all the cases air has to be flown over the object or surface from which is cooler than the air flown. The air has been cooled by chilled water and the heat transferred to that medium is transported outside where, often, fan driven water-to-air heat exchanging is again affected to reject the heat into atmosphere. Ambient temperature simply means " The temperature of surrounding" and will be same as room temperature indoors. Refrigeration is the process of removal of heat from space where it is unwanted and transferring the same to the surrounding environment where it makes little or no difference. Zeer Pot is an evaporating cooling refrigeration device which does not use temperature. The rate of cooling depends upon outside temperature and relative humidity.

In this project, we are combining the concept of Zeer Pot refrigeration and the air cooler. By using secondary liquid in the Zeer Pot and circulating in a copper pipe over the fan by which it absorbs heat from the closed system. Cooling depends upon the difference in the ambient temperature and the secondary liquid temperature. Then the Zeer pot full of water is used to cool the water flowing through it back to fan and it blow cool air. Various parameters that affect the cooling rate are ambient.

IndexTerms - Air Cooling, Zeer Pot Refrigeration, Porous Evaporation, Refrigeration, Lower Power consumption

INTRODUCTION

A. NEED FOR AIR-COOLING

The heat of the summer is simmering and the air conditioners around the country are going full swing. Approximately 20% of the country's commercial and 30% of the residential buildings use room air conditioners (RACs) as their current cooling method. This does not even include the thousands of packaged terminal air conditioners (PTACs) in use in hospitals, apartments, and hotels around the country. During the hottest part of the summer air conditioners can put a severe strain on the country's power plants. During peak air conditioning use in the summer, electrical facilities need to produce greater amounts of electricity and therefore emit increased amounts of pollutants. Coal is the most common fossil fuel burned for production of electricity and is known to release dangerous particulate pollutants. The most common pollutants are carbon monoxide, carbon dioxide, nitrogen oxides, hydrocarbons and various heavy metals. For this reason, manufacturers, the electrical production industry and the environmental community are all encouraging the procurement of high efficient and natural means of air cooling. Not only do these cut down on wasted energy and pollution, but they also reduce usage costs by consumers.

B. AIR COOLING:

An air cooler is any device for cooling the air inside a building, room, or vehicle. Air coolers are used in thermally insulated casings to form refrigerators and are also used in buildings to cool rooms. In buildings they are only required when the building itself is not constructed so that it is able to dissipate enough heat.

Several devices exist, these include:

- Wet air coolers
- Dry air coolers
- Absorption air coolers

Coolers outfitted with extras as heating, and dehumidifying are called Air conditioners. Wet air coolers, otherwise known as evaporative or swamp coolers, are devices that use the evaporation of water to cool an environment. When the air blows past water, some particles on the surface of the water are carried away. Those particles take some heat with them, cooling the air. That is how sweating works: the water particles on the surface of the skin carry off heat with them as they evaporate, cooling the skin.

C. EVAPORATION PROCESS:

Evaporation is an endothermic process. Evaporation means changing of water into water vapor at temperature below its melting point. Evaporation causes cooling as water particles gain energy in the form of heat and then change to gas and get mixed with air. For molecules of a liquid to evaporate, they must be located near the surface, be moving in the proper direction, and have sufficient kinetic energy to overcome liquid-phase intermolecular forces. When only a small proportion of the molecules meet these criteria, the rate of evaporation is low. Since the kinetic energy of a molecule is proportional to its temperature, evaporation proceeds more quickly at higher temperatures. As the faster-moving molecules escape, the remaining molecules have lower average kinetic energy, and the temperature of the liquid decreases. This phenomenon is also called evaporative cooling. Clay pot has small holes visible at microscopic level through which water seeps out and gains energy to become a gas and get evaporated causing cooling. Evaporative cooling works by removing the high-velocity tail of the kinetic energy distribution. That is, only the fastest molecules escape the liquid, leaving the rest to thermalize at a lower temperature. If there is capillary action taking water to the outside of the pot and that is evaporating, then the pot cools down as it is losing heat to the leaving molecules' kinetic energy. This then cools down the water inside by conduction. For evaporative cooling to work, the air needs to be dry so that more molecules leave the water than condense into it. In a closed environment, though, evaporation will raise the air's humidity until both processes are equally likely and everything thermalizes.

ZEER POT REFRIGERATION

A Zeer pot refrigerator or a pot-in-pot refrigerator is an evaporative cooling refrigeration device which does not use electricity. It uses a porous outer earth ware pot, lined with wet sand, contains an inner pot which can be glazed to prevent penetration by the liquid within which the food is placed.

Figure 1: Sand in between the larger pot and the smaller pot

The evaporation of the outer liquid draws heat from the inner pot. The device can be used to cool any substance. In the case of the Zeer refrigerator, water evaporates out of the sand through the surface of the outer clay pot and from the whole top surface of the moist sand exposed to the solar radiation, removing energy from the system.

CONSTRUCTION:

The zeer pot is a simple method for cooling items that are placed in the pot. It consists of two pots that are clay or terracotta. One pot is larger than the other. The small pot is placed in the larger with a layer of sand poured between them. The sand is then watered. Once the water in the sand starts to evaporate, the inner pot cools while the outer pot draws heat away from itself. Items placed inside will become cooled as the water evaporates. Let's have a look at the construction of a zeer pot to clarify the conceptFirst, you need two pots. They need to be non-glazed so the water can absorb into the pot. A glazed pot doesn't work so well with evaporation cooling. One pot will be larger than the other so that sand can be poured under and around the smaller pot. Next, you need some sand. Any type will do. A couple of corks are also a good idea to plug the holes in the pots. You don't want the sand and water to poor out of the bottom of the pots. A Zeer pot is constructed by placing a clay pot within a larger clay pot with wet sand in between the pots and a wet cloth on top. The device cools as the water evaporates, allowing refrigeration in hot, dry climate. It must be placed in a dry, ventilated space for the water to evaporate effectively towards the outside. Evaporative coolers tend to perform poorly or not at all in climates with high ambient humidity, since the water is not able to evaporate well under these conditions. Obtain two large clay or terracotta pots. One pot must be smaller than the other pot. Check that the smaller pot fits inside the larger and that there is a space around it of at least one centimeter, up to three centimeters. Fill in any holes at the base of the pots. Use clay, large pebbles, cork, and a homemade paste - anything suitable to hand to fill the hole. If you leave the holes open, the water will enter the inner pot and will also run out of the larger pot, making the fridge ineffective.

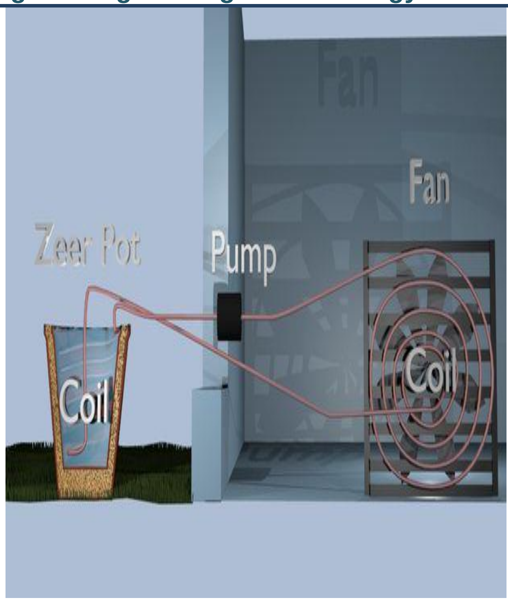


Figure 2: Schematic representation of air cooling using zeer pot refrigeration technique

Fill the base of the larger pot with coarse sand. Fill about 2.5cm/1 inch deep, and only fill to a height that will ensure the smaller pot sits even in height with the larger pot. Now, pour some sand into the larger pot and coat the bottom of the pot. You should place enough sand in the bottom so that the small pot, once placed inside the larger pot, is level with the rim. Basically, shore up the pots so that the tops are level. Next, Place the small clay pot into the large pot and fill the space between them with sand. Fill it to the top and give the pots a little tap on the ground to settle the sand. Add more sand as needed Arrange its base flat on top of the lower layer of sand. Once the two pots and the sand are all leveled out, add water. Slowly pour water into the sand. Be sure to water all around the pot and not just into one area. Again, pour the water slowly. You don't want to flush out the sand by pouring it too fast. Let the sand absorb the water. Also, this is very important, do not overfill the pot with water. If you have ever heard of the term " soil liquefaction" you will experience it at first if you add too much water. The sand will turn into soup and the inner pot will start to float. We don't want that .After your pot is filled up, place your items inside to be cooled. Lastly, you can take a pot lid or plate and cover the top. Be sure not to cover the sand or the evaporation will not take place. Cover the pot just enough to close the top of the inner pot to keep the cold air in.

Next, place a wet towel over the top of the unit. This will keep the top cool from evaporation and the wet sand can still *evaporate* through the towel. I am trying a new technique for the lid where I place some wet sand in the dish cover and see if that increases cooling and efficiency. Place the pot in direct sun and keep an eye on the moisture level, adding water as needed .If there is an impermeable separation layer between the food and the porous pots, undrinkable water such as sea water can be used to drive the cooling process, without contaminating the food. This is useful in arid locations near the ocean where drinkable water is a limited commodity, and can be accomplished by using a pot that has waterproof glaze applied to the inner wall where the food is stored. Extended operation is possible if the pots are able to draw water from a storage container, such as an inverted airtight jar, or if the pots are placed in a shallow pool of water. A strap can be used to tie the inner pot down instead of using sand to prevent it from floating. No matter where you live or how well the pot works does not change the fact that it does work. When the power goes out and the fridge has warmed and the ice has melted, the zeer pot might be your last resort. Having a cold drink is a luxury but having your limited food last longer because it is cool is critical. Even more important is keeping vital medications cool in order to retain their effectiveness. Besides, building one for fewer than twenty bucks is pretty cool (pun intended) and a lot less expensive than keeping an emergency generator around. Heck, you really don't need to pay for it as the materials needed are usually around the house. A couple of old terracotta pots and some sand are not hard to come by.

Figure 4: Representation of air cooling using zeer pot refrigeration technique

OPERATION PRINCIPLE:

The figure shows the graphical representation of the water and energy flow within a Zeer refrigerator.

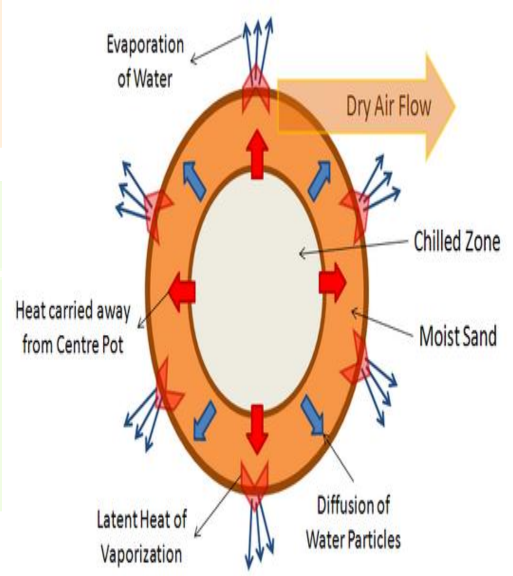
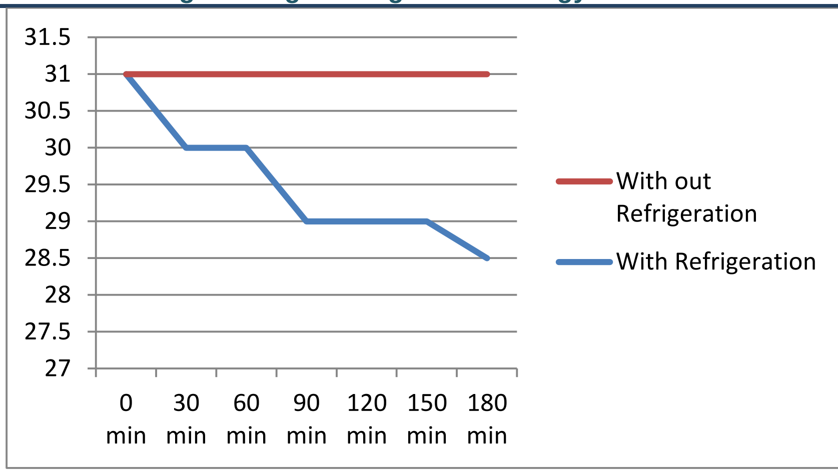


Figure 3: Flow of heat transfer in Zeer pot

When evaporation occurs from a surface, there is an energy associated with the phase change known as the latent heat of vaporization. In a given system, as a gas species flows over the wet surface, evaporation and condensation continuously occur to maintain steady-state conditions.In order to sustain evaporation, there must be a draw of internal energy in the liquid, which would result in a temperature reduction. This cooling effect is known as evaporative cooling and is most effective in dry climates due to the lack of moisture content (relative humidity) in the air.In the case of the Zeer refrigerator, water evaporates out of the sand through the surface of the outer clay pot and from the whole top surface of the moist sand exposed to the solar radiation, removing energy from the system

A. **VARIATION OF TEMPERATURE:**

The equipment is established in a closed room with Zeer pot outside the room. The secondary liquid is made to flow through the copper pipe over the table fan. By taking into consideration that the heat generated in the fan is negligible observations have been taken in the tabular form. The variation of the room temperature with respect to the time when the equipment is made to run is observed and a graph is plotted using the readings. The readings are also calculated without operating the system and the readings are plotted in the graph.



Plot 1: Variation of room temperature with time

The above graph gives a clear picture of the decrement in the ambient room temperature with the refrigeration effect.

B. LIMITATIONS:

Beyond the limitations of the required climatic conditions for the pot-in-pot refrigerator to be successful, there is also a need for a continuous supply of water. For many regions, water may be prioritized for other purposes making it difficult for communities to adopt the technology. The device also has no proper seal for the storage chamber, reducing its overall effectiveness since warm ambient air can seep into this chamber and increase the temperature of chilled zone. (However warm air will rise and chilled air is heavier and drops, so the temperature will always be coldest on the bottom).

C. ADVANTAGES

- Power consumption is limited to the fan and water pump vs. compressors, pumps and blowers in mechanical refrigeration. Coolers are economical to operate, using one-third the energy of refrigerated air-conditioning.
- Most of the cooler maintenance and repairs can be accomplished by the homeowner.
- Most of the cooler replacement parts are nominal in cost when compared to air-conditioning system replacement parts.
- Evaporative coolers can improve the indoor air quality inside a home by drawing a large supply of fresh outdoor air through the home

CONCLUSION

A. ZEER POT

A parametric analysis concerning the performance of a Zeer pot-in-pot refrigeration device has been performed. As expected, the device performs well only in climates possessing a low relative humidity. The velocity of the wind and the area available for evaporation to occur on/through are two primary factors that can be addressed to improve the performance of the pot-in-pot refrigerator. It has been shown that increasing the radius of the outer pot from 0.25m to 0.45m, almost doubles the total cooling effect. The adaptation of this however, is restricted by the increase in cost associated with using more materials. It is suggested that the strategy to make larger pot-in-pot refrigerators be employed only if community members are willing and able to pool their resources to share a device with superior performance. It is unrealistic to assume that electricity is available to ensure that there is a constant and adequate source of air flow. The device is dependent solely on naturally occurring winds. To maximize air flow, it is recommended that Zeer refrigerator be placed as high above the ground as possible. This can be accomplished by building a simple frame to support the device, and placing them on high ground or on top of buildings. There remains the potential for future analysis of this device. The development of a detailed conduction model to analyze heat transfer and mass diffusion mechanisms within the various layers would aid in identifying factors limiting performance and how they can be addressed.

B. ECONOMY:

Evaporative coolers do not use compressors, condenser, chiller coils, and cooling towers of heavily insulated piping. Thus the cost of acquisition and operation is a fraction of conventional air conditioning and mechanical refrigeration systems.Initial cost is less than 1/2 the cost of refrigerated air conditioning and the operating costs is 1/3 the cost of refrigerated air conditioning to run. Maintenance costs are minimal requiring simpler procedures and lower skilled maintenance people.

C. **EFFECTIVE:**

It lowers effective temperature- the temperature you feel – by at least an additional 4^o to 6^o. In some cases, the temperature will be lowered more, depending on relative humidity. The rapid motion of cool air increases skin surface evaporation resulting in heat loss.It reduces radiated heat – The constant flow of cool air absorbs heat from all exposed surfaces and results in a reduction of the heat radiated to the human body.

CONCLUSION:

Summarizing, the evaporative coolers have a low first cost, use a lot less electricity than conventional air conditioners, and do not use refrigerants, such as chlorofluorocarbons (CFC' s) and hydro fluorocarbons (HFC' s) that can harm the ozone layer. It is economical, effective and it provides much needed alternative to conventional mechanical refrigeration.

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